T. Hirashima et al. (Eds.) (2011). Proceedings of the 19th International Conference on Computers in Education. Chiang Mai, Thailand: Asia-Pacific Society for Computers in Education

Identifying the potential needs to provide mobile context-aware hints to support students' learning

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Abstract: In recent years, mobile and context-aware technologies have been used in an attempt to enhance students' formal and informal learning experiences both in the classroom and outdoor settings. Such technologies have supported teaching and learning in a variety of subjects. In this paper, we present the ongoing research efforts in our Geometry Mobile (GeM) project, where we conducted a number of trials in the last two years with primary and secondary school students in Sweden. The current trial of our GeM project (April 2011) is discussed together with the data collection method we have used for exploring how Context-Aware learning hints (CA hints) can be utilized to support the different stages of the learning activity. Insights and preliminary results from this trial are described. We also present the motivation of our proposed CA hints, the definition of the requirements of those, and the formulation of a classification thereof.

Keywords: Context-aware mobile learning hints, collaborative learning trajectories, Geometry Mobile

1. Introduction

In recent years, numerous indoor and outdoor mobile learning (m-learning) activities have been developed in different subjects including activities appropriate for school mathematics. An example is the MobileMath [1], a location-aware game. Its objective is to motivate teams of students to compete against each other to construct squares, rectangles, parallelograms and cover as much of these areas as possible. Students do this by physically walking to and clicking on each vertex of the shapes using a mobile application with GPS.

Our project named GeM [2] has been designed in collaboration between researchers in mathematics education and m-learning. Several members of the current design team have previously collaborated in projects involving outdoor mathematics and mobile technology. The activities involved in this project are related to inquiry-based geometric learning tasks carried out outdoors. GPS-enabled mobile phones together with an in-house mobile application and a web-based visualization tool have been the tools used for the activities. Previous results from our trials have indicated that some students required and/or appreciated additional help, support, and/or guidance in solving their learning tasks, which were carried out in the absence of teachers during the outdoors activity. Hence, we are currently exploring how the use of mobile CA hints can support teachers in order to provide a good learning environment for the students during their unsupervised activities.

GeM Triangulation is the name of the current learning activity discussed in this paper. The activity emerged as an idea during a design team meeting where a selection of available mobile technologies and their pedagogical potential for the learning of mathematics were discussed. The objective of this GeM Triangulation outdoors activity is to, in groups of 3 and 4 students; construct a series of triangles in the right order to reach the final given point. The students were provided with GPS-enabled mobile phones, and a map with two reference points and the distances between those two points to a third one. This activity was carried out in three days and conducted in April 2011 and it is discussed in section 3.1.

This paper is divided as follows – in section 2, we present a literature review on learning hints and CA hints. In section 3, we present our current project trial conducted in April 2011. Section 4 presents our definition of the requirements of CA hints and a classification of those. Finally, conclusions and future work are presented in section 5. Moreover, this paper focuses mainly on the design of CA hints. The aspects relating to the learning goals of this project are further described in Sollvervall *et al*., [3].

2. Literature Review on Learning Hints and CA hints

We explore and propose a definition of the concept learning hints (2.1) and describe the advantages and limitations of learning hints (2.2) in order to increase our understanding regarding these notions, so that we can potentially incorporate them into our project to further support the students' learning. In 2.3, we present related works on CA hints.

2.1 Definition of learning hints

A search on 'learning hints' in the literature reveals different types of learning hints, currently being deployed in traditional classroom teaching/learning, e-learning, m-learning, and context-aware m-learning settings, in different domains including Mathematics, Natural Science, and other inquiry-based subjects. Learning hints can be given in the classroom context by teachers to students, in a verbal manner, where the teacher guides the student to solve some given exercises. The level and depth of information to be 'hinted' to students is important as the aim is to allow them to achieve the end results by themselves, and not to give them too much information, so as to strike an effective balance between support and intrusion [4]. In e-learning settings, learning hints can be given to students on their desktop application, in the form of additional tabs, pop-ups, or links to other websites. Similarly, in m-learning and context-aware m-learning settings, learning hints can be given to students on their mobile application at required times. Specifically, in context-aware m-learning settings, learning hints can be given to students when certain user contexts are fulfilled as informed by automatic contexts retrieval, indicating to the application that the student requires additional help, at the right time, and right location [5].

It has been noted by Abu-Mostafa [6] that the use of such learning hints is appearing in many research fields involving learning and adaptive systems. However, different researchers and practitioners have used this term to mean different things and 'learning hints' have been deployed but under different names. For example, RLO-CETL [7] considered 'learning hints' as reminders for seminars, course-work deadlines and pointers to online resources that were sent to students via their mobile phones in the form of text messages, as part of their BA Marketing course. On the other hand, Dias *et al*., [8] interpreted them as 'information' based on managing the diversity of cognitive styles so that groups of students can cooperate effectively together to finish a learning task (such as completing a jigsaw). Since there are differences in the definition of hints, for the purposes of this paper we have defined and interpreted learning hints as follows: ***aids/clues that can help learners to solve their learning task/problem at hand in order to achieve their learning goals***.

2.2 Advantages and limitations of learning hints

Within e-/m-learning applications, learning hints can be used for learner profile modeling and/or user contexts modeling in order to enhance the users' learning effectiveness and experiences. In learner profile modeling, the aims are i) to automatically personalize/adapt learning content to users based on their learner profile, or ii) to suggest only those learning contents that are appropriate to users based on their learner profile. For example, the following can be adapted to enhance students' learning – a) the format and selection of information to be presented, b) the content of the learning tasks and problems to be solved, and/or c) the content of learning hints and feedback and when they should be given to learners [9]. It has been argued by some researchers that it is more effective for students to learn content suited to their learning styles/learner profile i.e. known as adaptive hints [10], which can be seen as an advantage of the use of learning hints. Non-adaptive CA hints seem currently to be an appropriate match for our project needs since our current research is concentrated on short focused activities due to their short implementation time.

Additional advantages of using learning hints include a) effectively engaging students in their learning tasks, b) helping students with challenging materials using scaffold hints, c) training users with hints for incorporating their prior knowledge can be an effective method for learning/teaching, and d) accommodating the needs of individual learners such as when they are using a context-aware m-learning application. This is done similarly by having "*a model of the learner's understanding (e.g. knowledge, skills, difficulties, misconceptions), inferred from their actions in the environment (such as responses to questions, tasks of various forms, browsing, or requests for* ***hints*** *or help)*" [11]. Using context-aware techniques in the field of m-learning is a recent development; so CA hints are relatively a new concept. The nature of CA hints is discussed in 2.3 and the motivation of them being deployed by other researchers differs significantly to how we propose to deploy ours.

The above mentioned advantages of using CA hints can be rather application-specific. For example, in our GeM Triangulation trial, providing CA hints to students could give them the following advantages – a) automatic help based on the location (e.g. if they are lost or they are in a location which they should not be in; this is known via the GPS), b) similar advantages to those offered by learner modeling, except that these can also take into user contexts for detecting - i) the amount of time that a student has been attempting to solve a part of the activity, and consequently offer some help if a long time has elapsed and the user has taken no appropriate action, and ii) the location that a student is in. For example, where the application infers that the learner is having problems trying to calculate distances, e.g. (known via the user profile), then help could be offered to them when they are in that context and the user has taken no action for a long period of time.

Some limitations of learning hints include that they cannot easily be integrated into learning as they are heterogeneous and different hints may be required for different scenarios [6]. They are also application-specific which means that a significant amount of time is necessary for designing and implementing CA hints into each application that requires them. As mentioned, the novelty of CA hints implies that there are not enough empirical results to indicate their real advantages and limitations.

2.3 Related works on CA hints

A broad literature review on context-aware m-learning applications is described in [12]. We have identified two different types of CA hints in the literature review of CA m-learning applications – namely static and dynamic and examples of those are given below. The main difference between these is that a static hint is pre-determined and triggered when clicking a button, for example. To be precise, a static hint is not a CA hint, but the application is context-aware, and therefore, researchers have interpreted them in some way to be a static CA hint. We do not agree with this definition and do not consider this to be a CA hint. On the other hand, a dynamic CA hint is provoked on-the-fly, when certain values of context(s) are met.

In the work of Ogata and Yano [5], static (i.e. not dependent on any context changes) hints could be accessed by students on their English-learning application TANGO. For example, a screen snapshot of TANGO shows a question in English such as "Where is the fabric chair?" Students could listen to this repeatedly as well as see more text relating to the task in order to help them answer the question. If they are still unsure, a static hint can be accessed which explains what 'fabric' is. This is so that the students who could not answer this question before because they did not understand the word 'fabric' might understand the question better. The next two related efforts illustrate the use of dynamic hints. In their bird-watching m-learning system, Chen *et al.*, [13] have interpreted hints and guidance for the identification of particular birds. The hints are used for scaffolding the learner's comprehension in the learning of birds and for learners to become aware of the bird's key features in order to identify them successfully. These hints are dependent on the particular bird, and what the learner knows about the bird already. In the Explore treasure hunt application of Costabile *et al*., [14], students are required to discover meaningful locations in a designated area (i.e. a park in their scenario) by following instructions and marking the positions of the locations on the map. A 'game master' supervises this game, whose main tasks are a) to check that the students observe the rules, b) to encourage the group if they struggle to reach the next location, and *"push them in the right direction by giving suitable hints*" (Ibid). These hints are considered as navigational hints, where appropriate indications are given to students based on their current mission, user position (via the GPS), and task-related knowledge (e.g. whether the location to be reached is similar to any other places). Sound hints are also provided to students.

3. Design and evaluation of the GeM Triangulation trial conducted in April 2011

We have currently designed, implemented and carried out the project trial in April 2011, concerning the GeM Triangulation activity, excluding the use of CA hints. Twelve students of fourth-grade (8 boys, 4 girls) in a local school in Sweden participated in this trial. From the students' perspectives, the objective was for them to explore their own strategies to construct the steps in order to complete the map without any additional guidance from the teachers or learning hints from the mobile application during the activity. Students were given instructions at the beginning of the task and any of their queries were resolved before the activity took place. More information on the didactical and technological design of this activity can be found in [15]. Here, we present 1) the GeM Triangulation task to be solved by participants, 2) motivation of deploying CA hints to support students' learning, and 3) data collection method used concerning any potential CA hints and the preliminary findings.

3.1 GeM Triangulation trial consisting of Days 1-3

The Day 1 included an indoor activity for students to use Algodoo, a 2D simulation software, on laptop computers in the classroom (pane b) in fig 1). The idea was for them to develop some strategies in order to construct a sequence of steps to reach the final given point on the predesigned map (pane a) in fig 1). Based on two reference points, the participants (three groups of four students) were required to build the map using appropriate strategies. After this hands-on exercise, each group of participants presented their strategies to the other groups (pane c) in fig 1). The aim of these trials was to ensure that each participant in every group understood and had a clear strategy to complete the same task on the next day in the outdoor setting. The Day 2 activity shared the content with the activity done on Day 1 but students were required to construct the map and the series of steps leading to the final point (A in pane e) in fig 1) on the field outdoors with real measurements (pane a) in fig 1), in opposition to the computer in indoors settings. Two reference points (Ref A and B in pane e) using cones were placed on the field and each of the three groups had different areas on the field to work on (in order to prevent them from copying or following one another to reach the points). Their hand-drawn strategies from the previous day were given to them as reference for the outdoor activities (pane d and f) in fig 1).

The Day 3 activity was a more complex task based on the strategy and construction completed from the previous day. First, each of the three groups completed a similar map as the day before, though the map was either mirrored or rotated (pane g) in fig 1). Each of the three groups reached a final point from their constructions and they were asked to place cones (pane i) in fig 1) on these three final points as reference (points A, B, C in pane h) in fig 1). These final points made the starting points of a new shared map where collaboration between the three groups was required to reach the ultimate point, which is the midpoint of the triangle formed by these three final points (pane g and h) in fig 1).

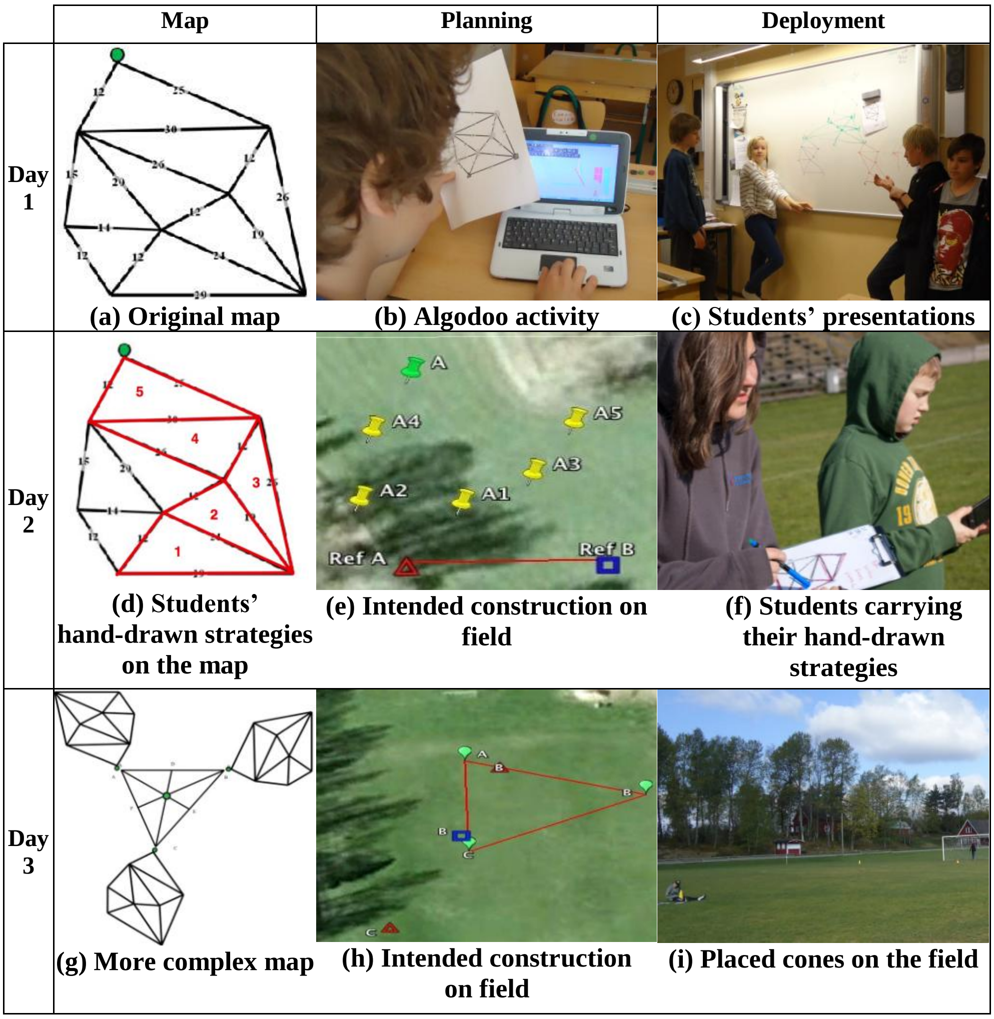

Fig 1. An illustration of the different learning activities in the GeM Triangulation trial

3.2 Motivation of deploying CA hints to support students' learning

In our observations from previous GeM trials [3, 15] where participants had attempted to solve some set geometric tasks, we observed that students had difficulties to complete these tasks. This motivates us to deploy CA hints for our future project trials in order to help students to complete their tasks. The observations made from these last two trials inform us that a number of students experienced difficulties at various stages in solving the tasks (for example, students went in the wrong direction, attempted to obtain points without having first obtained the prerequisite points, or they did not understand some instructions).

Particularly, we wanted to provide such 'materials' to only those students who require it, at the right time and location, so that each participant could solve and complete the tasks successfully and correctly. Since our learning application currently makes use of location-aware technologies (i.e. GPS), we are exploring the use of learning hints based on the students' location (and other necessary users' contexts) for providing appropriate guidance. For this reason, we consider that the use of CA hints would be appropriate.

At the end of our last trial in Feb 2011, we interviewed groups of students to obtain their insights into any learning hints that they felt would have been useful for them at the different stages of completing the learning task. Only one group (out of 3) of students had successfully finished the task (though incorrectly) [15]. This group of students had commented that they did not require any additional learning hints for the guidance in the completion of the task. However, it was clear to our research team that all three groups would require additional help, at one stage or another, in order to complete the task. This is because none of them had deployed any of the correct strategies in order to complete the task and they were not actually aware that they were using wrong strategies, which it is an even more undesired pedagogical scenario [15]. These results suggest that there is a potential need of providing CA hints to students, (at least to some, who require them).

3.3 Preliminary findings and data collection method concerning any CA hints

As mentioned, we had avoided the use of CA hints to instruct students to perform certain steps or correct their steps based on wrong performances in this trial. Participants were not informed whether the points (intermediate, final or ultimate) were correct. Our mobile application allows the user to measure distances between his/her own device and other (user-defined) mobile devices, and logs the user's attempts to allow researchers to check whether their chosen locations are correct (via the GPS). The log results recorded showed that all three groups had completed the Day 3 activity with an inaccuracy of around 5 meters for obtaining the three final given points where they had placed the cones. The ultimate point was 6 meters inaccurate compared with the set point. This data suggests that the participants had performed fairly well, although not entirely accurate. It is important to note that the activity generated a large amount of information (i.e. around 25 attempts for the given points by participants) for data analysis. The data that was logged is reliable although the GPS data was not entirely accurate which is beyond any researcher's control. Therefore we had to interpret these data in a sensible manner and also with the help of the video recordings that we had made of all the groups during the entire session.

We used a short questionnaire where participants were required to complete immediately after each of the outdoor activities on day 2 and 3. We collected quantitative data as presented below and in section 4, we discuss how we have used these for proposing the CA hints for our next trial, as well as the guidance in constructing CA hints in general. On average, each of the questionnaires was completed in around 5-10 minutes.

Questionnaire for the day 2 activity – students were asked if they needed help with (i) calculating correctly the given distances, (ii) orientating themselves to obtain the given distances, and also if they (iii) tried to obtain a point which required obtaining other points first, (iv) sometimes assumed that they obtained a point correctly when it was in fact incorrect, and (v) required some further instructions during the activity.

Questionnaire for the day 3 activity – students were asked whether they needed help/instructions (vi) with focusing on their own group's construction, (vii) on how to cooperate with the other two groups to get the final points, and (viii) on how to cooperate with the other two groups to get the ultimate point?

The 12 participants (8 boys, 4 girls) had completed the questionnaires immediately after the respective activities. Table 1 shows the results for Day 2 (i-v) and Day 3 (vi-viii).

Table 1. Results for Day 2 (i-v) and 3 (vi-viii)

Question	*YES*	*NO*	*Maybe*	*N/A*
(i) Did they need help with calculating correctly the distances on the map?	*3*	*8*	*1*	*-*
(ii) Did they need help with orientating themselves to obtain the distances?	*1*	*10*	*-*	*1*
(iii) Did they try to obtain a point which required obtaining other points first?	*8*	*3*	*-*	*1*
(iv) Did they assume that they obtained a point correctly that was incorrect?	*4*	*6*	*2*	*-*
(v) Did they require some further instructions during the activity?	*1*	*9*	*1*	*1*
(vi) Did they need help with focusing on their own group's construction?	*2*	*10*	*-*	*-*
(vii) Did they need help on collaborating with others to get the final points?	*5*	*7*	*-*	*-*
(viii) Did they need help on collaborating with others to get ultimate point?	*1*	*9*	*2*	*-*

4. Current and future investigative work on CA hints

Based on the above findings, we propose three types of CA hints that could potentially help participants with not only completing the mathematical task but to help themselves to fully understand each step that they are taking and the reasoning behind it. These three types are: 1) to inform students when they attempt to reach some points in the mathematical structure that should be acquired after they have obtained the prerequisite ones, 2) to inform students instantly when they found a point incorrectly, and 3) in the day 3 collaborative activity, to inform students when they are outside the areas in which they should be constructing the geometrical structure i.e. completing the task. The proposed requirements (4.1) originate from the understanding of CA hints that we have based on our GeM project; however, these can be generalized for CA m-learning applications requiring the aid of such or similar CA hints. From our proposed requirements, we suggest a classification (4.2) which can be used to categorize the different types of CA hints that can be designed and developed as an integrated component of m-learning applications.

4.1 Proposed requirements of CA hints

1. CA hints are used within context-aware m-learning applications where particular learning content/materials are recommended/given to students based on the changes in the values of those contexts that are deployed in that application (where the contexts values are usually continuously sensed or can be sent by the learner or retrieved at intervals by the application). The learner's current learning situation is therefore up-to-date in order for any hints to be prompted at the appropriate location and time, and/or when certain contexts values are fulfilled.
2. CA hints are triggered when there is a change of contexts values i.e. they are dynamic and not static (e.g. if a user is walking in the opposite direction to their desired destination, known via the GPS, and the application will 'hint' to the user).
3. CA hints can either be shown to the learners directly on the user interface of the application, or be prompted to the learners in which they have a choice in deciding whether they would like to view the hint or not.
4. CA hints are used in situations where the learners may require additional help to complete their m-learning activity/assessment, as informed by their user contexts/profile. The situations in which the CA hints are used a) should have been scrutinized by subject experts, and are deemed appropriate; b) would aid the learners to achieve their final learning goals without providing them too much information and that they can still achieve their end results on their own, and c) without intruding on the learner and their learning task.

4.2 Classification of CA learning hints

Based on these requirements, the preliminary results findings from our trial and the dimensions of the problems that we mentioned students faced in 3.2, we have classified different categories of CA hints, as follows:

1. Type of flexibility - dynamic vs. static

2. Type of interactivity - interactive vs. non-interactive
3. Type of automation– based on user-input vs. based on automatic contexts changes
4. Type of adaptivity – adaptive vs. non-adaptive
5. Type of user profile such as based on learner's preference/styles, knowledge level, proficiency languages
6. Type of contexts – location vs. time vs. other contexts such as learner's preferences
7. Status of activity – wrong/incomplete answers vs. wrong/incomplete flow vs. unsuccessful/incomplete attempts, based on time duration of non-interactivity

From the students' perspectives, it would be ideal to have personalized, dynamic and interactive hints in order to accommodate their different individual needs.

5. Conclusions

We identified the potential need of using CA hints for supporting students' learning. The requirements of these CA hints and a classification were presented. We are planning to implement CA hints in the coming version of our mobile application. The reasoning behind this is so that we could compare the participants' results in both of these trials in order to determine if and how the CA hints have helped students in completing the tasks. Also, the effectiveness of the proposed approach will be evaluated by comparing the learning performances and attitudes of GeM learners and those who learn with conventional approach.

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