Eliciting the potentials of mathematical mobile learning through scaffolding learning processes across contexts

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Abstract: Little is understood in terms of scaffolding learning processes in more dynamical contexts than the classroom environment. The scope of mobile learning research has so far been limited to the scaffolding functions of the mobile technology. Thus, in this paper, a larger grip was taken, focusing on all available means, such as teachers, mobile technology, pre- and post-activities as supportive structures. In doing that a sequence of learning activities were designed within the domain of mathematics education. We asked what scaffolding role the available resources can play in supporting the students learning processes, and further, how we are to orchestrate these resources across contexts in a pedagogical manner. The findings demonstrates how students’ learning processes are to be scaffolded and how learning in an outdoor context can be meaningfully supported through the sequencing of activities and the utilisation of pre- and post-activities in indoor contexts.

Keywords: mobile learning; scaffolding; orchestration.


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1 Introduction

It is claimed that by taking advantage of mobile technology new learning opportunities emerges that may remove the barriers of traditional instruction and enable us to bring learners to otherwise remote and authentic contexts for student-centred and situated learning activities (Sharples et al, 2007). Promising examples have indeed been presented amongst the growing body of conducted studies within the field of mobile learning.
Nevertheless, despite the promising examples, a large portion of the conducted studies has been strongly technology-driven lacking explicit educational foundations (Traxler and Kukulska-Hulme, 2005; Kukulska-Hulme et al., 2011).

Despite this, there is still a huge mountain of challenges that needs to be dealt with before we can meaningfully realise the actual potentials of mobile learning. Those potentials can be realised and fairly evaluated only when the techno-centric conceptualisations of mobile learning are abandoned, and when researchers determinately approach the designs of mobile learning studies with the firm pedagogical intent to create the conditions for learning to happen.

In a concept mapping study of 20 international acknowledged domain experts, Börner et al. (2010) has for instance identified orchestration of learning across contexts as one of the six most important challenges of mobile learning. Unfortunately, even though mobile learning has recently been viewed to support boundary- and context-crossing (Pachler et al., 2010), this has mostly been studied in terms of the role mobile technology can play in one context, usually in an outdoor environment, rather than studying the pedagogical value of crossing contexts as such. Still little is understood about how we can pedagogically orchestrate the utilisation of different contexts to support learning.

In fact, little is understood in general of how we support learning in more dynamical contexts than the classroom environment, in terms of scaffolding learning processes. We know from a socio-cultural point of view that appropriate assistance, i.e. scaffolding, needs to be provided in order to create the conditions for students to develop higher levels of understanding within the Zone of Proximal Development (ZPD) (Wood et al., 1976; Vygotsky, 1986). A large body of productive research work has certainly been conducted on the importance and notion of scaffolding in educational settings, for instance as conceptualised within situated learning (Lave and Wenger, 1991). These approaches have nevertheless, to large extent, either emphasised teachers scaffolding functions in face-to-face conventional classrooms with their physical and social constraints, or more recently focused on computer-based environments where teachers are not present (McLoughlin, 1999).

The lessons and principles obtained from research in classroom contexts are consequently not directly transferable to mobile learning contexts. Scaffolding students learning processes in outdoor mobile learning activities brings other challenges than learning in the classroom. The step out of the classroom into more dynamical environments, combined with the increased mobility of the students and the utilisation of technology, radically changes the conditions for providing scaffolding support. In such environments, teachers may not be as accessible due to the mobility of the students, and the dynamical contexts can constrain the possibilities for social interactions (Winters and Price, 2005). Simultaneously, although the mobile technology can be utilised to provide scaffolding to some extent, for example demonstrated by Chen et al. (2003), it is nevertheless a design challenge to determine what scaffolds to incorporate given the dynamical needs of learners and the constrains of mobile phones (Luchini et al., 2004). The scope of mobile learning research has been limited to the scaffolding functions of the mobile technology, such as in the work of Chen et al. (2003).

If we are to meaningfully realise situated, inquiry- and problem-based mobile learning approaches, the question of how the students are to be pedagogically supported cannot remain as inadequately answered. Thus, in the empirical study reported on in this paper, we explore how students learning processes are to be scaffolded through the orchestration of activities and scaffolding support across contexts.
In doing that a sequence of learning activities were designed within the domain of mathematics education. The designed learning activities were aimed at a group of primary school students using mobile technology with the objective to collaboratively practice the area concept in outdoor settings. A systemic activity design perspective is adopted through which the focus is directed towards all available scaffolding resources, including teachers, mobile technology, indoor- and outdoor-contexts, i.e. pre- and post-activity and the sequence of activities as a supportive structure. We asked what scaffolding role the available resources can play in supporting the students learning processes, and further, how we are to orchestrate and coordinate these resources across context in a pedagogical supportive manner. Findings along with the associated challenges, demonstrates how students’ learning processes are to be scaffolded by teachers and mobile technology, and how learning in an outdoor context can be meaningfully supported through the sequencing of activities and the utilisation of pre- and post-activity in indoor contexts.

2 Scaffolding

Scaffolding has been traditionally defined as the process by which a teacher or a more knowledgeable peer provides assistance that enables learners to solve problems and carry out tasks, which are beyond their unassisted efforts (Wood et al., 1976). The notion of scaffolding is thus strongly linked to the work of Lev Vygotsky, and in particular to the concept of ZPD. The theory behind the concept of ZPD is that the highest potential development level of an individual only can be reached through the assistance of a more capable peer or adult (Vygotsky, 1986, p.86). Hence, enabling a learner to bridge the gap between the actual and potential development level depends on the kinds of support provided.

In defining the nature of the guidance that promotes development, Wood et al. (1976) suggested six types of support that an adult can provide: recruiting the child’s interest, reducing the degrees of freedom by simplifying tasks, maintaining direction towards task-relevant goals, highlighting critical features of the task that the child might overlook, controlling frustration and demonstrating ideal solution paths. Another categorisation of scaffolding support put forward is the one of Hill and Hannifin (2001). They identified four types of scaffolds: conceptual, metacognitive, procedural and strategic scaffolds. Masters and Yelland (2002) included two more: affective and technical scaffolds.

From the perspective of Wood et al. (1976), three elements are central to scaffolding. Firstly, a shared understanding of the goal of the activity, which is attained when the adult and the child collaboratively invest in and take ownership of the task. Secondly, that the adult provide appropriate support based on an ongoing diagnosis of the child’s current level of performance and understanding. Wood et al. (1976) stated:

“The effective tutor must have at least two theoretical models to which he must attend. One is a theory of the task or problem and how it may be completed. The other is a theory of performance characteristics of the tutee. Without both of these, he can neither generate feedback nor devise situations in which his feedback will be more appropriate for this tutee, in this task at this point in task mastering. The actual pattern of effective instruction then, will be both task and tutee dependent, the requirements of the tutorial being generated by the interaction of the tutor’s two theories.” (p. 97).
The final key feature of scaffolding is fading the support provided to the learner as the learner gain in proficiency. This feature has relations to Vygotsky’s notion of internalisation. From a Vygotskian perspective, psychological development progresses from a social (interpsychological) to an individual (intrapsychological) plane through the process of internalisation. With this terminology, fading thus entails motivating and supporting the learner to internalise learning processes and to allow the learners to take control and responsibility for their learning.

Since the inception, the scaffolding metaphor has been described and represented in a number of ways. As a result of a considerable range of research unfolding the nature of guidance that promote learning, the scaffolding metaphor has been extended and applied more broadly to include various types of support. Scaffolding is consequently no longer restricted to interactions between individuals as artefacts, resources, curricula as well as environments are also being used as scaffolds (Puntambekar and Hübsher, 2005).

In terms of research on mathematics education, the importance of sequencing and decomposing the tasks in a supportive manner is particularly stressed (Anghileri, 2006; Selander, 2008). In line with this, pre- and post-activities are highlighted as effective supportive scaffolds if designed appropriately. The pre- or introduction-activities can offer an opportunity for the learners and teachers to create a shared understanding of the main activity and its curriculum goals, set expectations, provide motivation and also provide the necessary skills that students may not be familiar with (Puntambekar and Hübsher, 2005, Selander, 2008). Post-activity or follow up activity on the other hand, can offer an opportunity for re-representing, emphasising and clarifying key points and concepts, and an opportunity for the teacher to assess the students and provide feedback (Yelland and Masters; 2007, Selander, 2008).

During the last two decades a lot of research has also been conducted around the educational application of scaffolding through technology. The results have been promising indicating that technology, including computers and handheld technology may be able to scaffold learners – for instance with prompts that trigger reflection, hints that highlight critical features, simple feedback and task structuring (McLoughlin, 1999; Wood; 2001; Reiser, 2004; Roschelle et al., 2010). However, the research conducted so far has clearly demarcated the current limitations of technology. Ultimately, the technology fails at delivering that which is in the very core of scaffolding; namely individual, adaptive and calibrated support, including the fading of it, based on the learner’s current understanding (Pea, 2004; Puntambekar and Hübsher, 2005). By all indications, currently and probably for a time to come, the teacher will still have an important – if not a central – role in providing the scaffolding required for effective learning to happen.

However, with that said, we do adopt the view that all of the aforementioned resources, such as pre- and post-activity, peers, teachers and technology, have affordances that may support learning of mathematics and science in naturalistic outdoor settings. Rather than investigating how each of these resources isolated can support mobile learning, we believe that there is a need to take a larger grip and face the challenge of orchestrating the available resources so that the affordance of each are taken advantage of. This is especially important when students are expected to learn in more dynamical and complex outdoor environments that can both limit teacher availability and increase stimulus complexity for the learners.
3 Research methodology

3.1 Study setup

The study that was part of The Math edUcation and pLayful LEarning (MULLE) research project was held in Sweden in the autumn of 2009 and aimed at fifth-grade primary school students (age 12). The objective was to design an activity in which the students could practice the area concept, playfully, across indoors and outdoors contexts, with concrete content and physical manipulative. The goals of the design team were thus to get the students away from the desk, to make mathematics more tangible and to provide opportunities for the students to collaborate, discuss and solve mathematics problems in meaningful contexts. In doing this, we mainly draw on socio-cultural and situated perspectives of learning (Vygotsky, 1986; Lave and Wenger, 1991).

3.1.1 The design process

In approaching the research questions we designed and implemented the learning activities, by adopting design practices from design-based research (Design-Based Research Collective, 2003). In particular, we relied on co-design (Penuel et al., 2007) for the design iterations.

With the objective to design a learning activity in mathematics, we held two co-design workshops together with teachers in the months before the field activities. The first workshop was conducted in order to design tasks based on what mathematical concepts the students were currently working with. The outcome of the workshop led to a design of both the activities and the mobile devices.

The objectives of the second design workshop were to complete the design of the tasks for the outdoors and indoor activities. We also tested and evaluated the developed mobile system with the students. The design team consisted of three researchers from human computer interaction and learning, two researchers from computer science and two practicing natural sciences and mathematics teachers from one local school.

3.1.2 The introduction activities

As a total, four sub-activities were designed and performed: two indoors introductory activities, an outdoor field activity, and an indoor post activity (see Table 1). The students worked in two groups of three students each. Two teachers participated in the learning activities.

The second introduction activity in the study was the familiarisation with the outdoor field activity. It took place five days before the outdoor activity. The aim was to let students come prepared to the outdoor activity with experience of how the devices operated in the field and with a representation of the tasks and the learning goals. First a short film from the pilot trial was presented to show the students what the field studies look like. Then we introduced the scenario.

3.1.3 The outdoor field activity

The scenario for the outdoor activity consisted of an imaginary, almost extinct and species needed to be relocated from the local wild animal park. The task for the students was to see to that the new enclosures for the animals had the right measurements.
Figure 1 Two areas on the small field and one area on the big field (see online version for colours)

The two student groups of three students in each group received the mobile devices to be used outside the school. After a short introduction they were told to follow the instructions on the primary device. The primary device told them to go to a meadow on the other side of the woods. On entering the small field (see Figure 1), the primary device signalled that they were in the right location.

In the big field, the students were asked first to guess and then to measure the area of a large rectangle. The large rectangle was approximately 4000 m² and had cones to mark the corners. The students measured the rectangle by measuring each side of it using the mobile devices and the implemented GPS-measurement functionality. The third and last task was to go to another field nearby and to create their own rectangle of 4000 m². The outdoor activity ended with the children showing their constructed area to one of the teachers.

The aim of the activities was for the students to practice the area concept on a both procedural level and conceptual level. On a procedural level, the focus of the practice was on familiarising the students with different area calculation and construction methods, in terms of both formulas and approximation techniques. On a conceptual level, the aim was to provide tasks that encourage the students to reflect upon how areas are constituted and how they can be decomposed, that different shapes can have the same area, and in general, that the relation between the lengths of the sides of a shape determine the area of that shape.

3.1.4 The indoor post-activity

The scenario for the indoor post-activity was that the children were to design the plan of an amusement park. The area of the park was known in advance, the children had to calculate appropriate length and width, and to draw the plan using pen and paper. Similarly, they were to place attractions and service facilities, each with a certain area, in the amusement park they had created. The objective of the post-activity was to let the children repeat and re-represent the tasks performed outdoors, but this time in more abstract terms, expectantly aided with the concrete experiences gained outdoors. The post-activity also aimed at creating an opportunity for the teacher to clarify concepts, assess the students and provide feedback.
3.1.5 The mobile devices

Measuring large enclosures required the students to use the mobile software application prototyped by our team. The application measures the distance between two mobile devices using GPS. Apart from measuring, the primary device presented students with tasks based on where they were located and where they were in the task structure. The primary device was also used for submitting answers and providing feedback, while the secondary device displayed clues.

3.2 Data collection

The empirical data analysed and presented in the paper were collected through audio and video recordings focusing on the students and teachers verbal and non-verbal interactions.

To record the student’s conversations, a small microphone was attached to each student. Four researchers recorded the video material with close-up and wide-angle cameras. Thus, each of the two groups of three students, was followed by two researchers recording their activities; one with a close-up camera for collecting group interaction data, and the other with a wide-angle camera for capturing complementary angles out of view from the close-up camera.

The total amount of video and audio data was of approximately six hours.

3.3 Analytical framework – a formal learning design sequence

In order to conceptualise and describe the activities, the Learning Design Sequence model (LDS) provided by Selander (2008) was used in a slightly modified form (see Figure 2). The LDS originates from the view of learning as a socio-cultural meaning-making process, and can be seen as a conceptualisation of a number of fundamental elements in formal learning sequences. The LDS model describes the learning process as a sequence of three units, an introduction unit/activity (‘setting’ in the model) followed by two transformation units, namely the primary and the secondary transformation unit.

Figure 2 The formal learning sequence model

Source: Selander (2008)
Selander (2007) argue that the introduction unit is a central element of the learning sequence aiming at making the learning tasks and their goals clear for the students. In the primary transformation unit, the students collaboratively make meaning by transforming and forming knowledge out of the available information using different resources and artefacts. Here an opportunity is presented to analyse what kind of media is used and how information is represented in different modes. During this phase the teacher also make formative assessments of the learning processes and intervene when necessarily to scaffold the students.

In the secondary transformation unit the focus is on how the students create representations based on their gained understandings, and how they present these representations. This cycle includes the student’s discussions and meta-reflections over their learning processes and results, and the opportunity for the teacher to perform summative assessments.

In performing the analysis the three different learning activities of this study were conceptualised according to the LDS model. As such, the introduction activities were mapped to the unit setting in the model, but reframed and highlighted as the first transformation unit. Accordingly, the outdoors activity was mapped to the primary transformation unit (second transformation unit), and the post-activity to the secondary transformation unit (the third transformation unit). Within this conceptualisation we asked: (a) how the students could be scaffolded within each unit, by means of teachers and the technology and (b) on a general level, how the units as isolated entities and the sequence of units as a whole, could support the students learning processes. The reasons to why the LDS model was used are three, namely it views a sequence of activities as a coherent whole, explicitly highlights different relations between units in a sequence, and describe a sequence of activities that resemble the designed activities of this study.

The collected data was then divided into three parts, introduction data, outdoor activity data and post-activity data. For each part, episodes were identified and transcribed in which the interactions between the students and the teachers or the students and the mobile technology, could be categorised according to the six types of scaffolding support presented by Hill and Hannafin (2001) and Masters’s and Yelland (2002), i.e. conceptual, metacognitive, procedural, strategic, affective and technical. One example of such an interaction is a teacher helping out with a technical problem, i.e. providing technical scaffolding. A selection of representative episodes has been presented in the result section.

4 Results

The analysis resulted in a detailed picture of the scaffolding support provided to the students in the three units through teachers, the mobile technology and the task and activity sequence, in terms of the six types of scaffolding support presented by Hill and Hannafin (2001) and Masters’s and Yelland (2002) (see Table 1). The analysis also highlighted the relations of the different units in the sequence, how they enforced and nurtured each other, and acted as a supportive sequence as a total (see Figure 3). In the result section a set of represented episodes are presented and elaborated upon. Names of the students are replaced with the codes L1, L2, etc., and teachers with T1 and T2.
Table 1: An overview of the scaffolding provided in the three transformation units

<table>
<thead>
<tr>
<th>First transformation unit (Introduction)</th>
<th>Second transformation unit (Outdoor activity)</th>
<th>Third transformation unit (Post-activity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual scaffolding: Through creating a shared task understanding</td>
<td>Strategic scaffolding: Through formative feedback from teachers and summative feedback from the mobile devices</td>
<td>Strategic scaffolding: Through formative feedback and the possibility to reflect back on the strategies used in the second transformation unit.</td>
</tr>
<tr>
<td>Procedural scaffolding: Through creating a shared task understanding</td>
<td>Metacognitive scaffolding: Through summative feedback</td>
<td>Metacognitive scaffolding: Through summative feedback and the possibility to reflect back on the learning processes in the second transformation unit.</td>
</tr>
<tr>
<td>Affective scaffolding: Through creating a shared task understanding</td>
<td>Procedural scaffolding: Through summative feedback from teachers and mobile devices, along with the possibility to reflect back on the procedural information provided in the first transformation unit</td>
<td>Procedural scaffolding: Through summative feedback and the possibility to reflect back on the procedural used in the second transformation unit.</td>
</tr>
<tr>
<td>Technical scaffolding: Through appropriating the technology</td>
<td>Conceptual scaffolding: Through encouraging reflection</td>
<td>Conceptual scaffolding: Through encouraging abstract thinking</td>
</tr>
<tr>
<td></td>
<td>Affective scaffolding: Through supporting collaboration</td>
<td>Affective scaffolding: Through supporting collaboration and engagement</td>
</tr>
<tr>
<td></td>
<td>Technical scaffolding: Through support with technical problems and the possibility to lean on the technological knowledge gained in the first transformation unit</td>
<td>Technical scaffolding: Through support with technical problems</td>
</tr>
<tr>
<td></td>
<td>Fading of scaffolding: Through increasing student agency</td>
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</tbody>
</table>

Figure 3: The relations between the different units in the activity sequence of the learning activities and the provided scaffolding support
4.1 The first transformation unit

4.1.1 Shared task understanding – procedural, conceptual and affective scaffolding

In the first introduction activity the teacher introduced the scenario, the task structure and the task goals of the outdoor field activity. In terms of the types of scaffolding, the presentation of task structure can be translated into the provision of procedural scaffolding facilitating the students understanding of the tasks, their decomposition and what procedural actions is expected from them. Analogously, the presentation of the task scenario and the task goals can be translated into conceptual and affective scaffolding; conceptual scaffolding due to the provision of answers to why the tasks goals are relevant on a conceptual level, and simultaneously affective scaffolding as it aimed to increase the student’s motivation.

During the introduction activity the students also asked questions and were provided with answers and clarifications. At the time of the outdoor field activity, we could observe that the students had gained an understanding of the tasks and their goals in a way that evidently supported their problem-solving processes, confirming Wood et al. (1976) and Puntambekar and Hübsher (2005). The students referred back to what had presented in the introduction activity at several occasions and were able to resolve arising information needs in this manner without having to rely on a teacher. For instance, in the following episode one of the groups had just completed one of the tasks on the smaller field and received a task instruction from the primary device that directed them to the bigger field.

L1: Which big field?

L3: You know the big one, on the computer you know. (A map was shown on a computer during the introduction activity)

L3: It must be that one! (Points in the correct direction)

One of the learners (L1), noticeable a student that did not participate in the introduction activity, did not know where the big field was located. At this point student L3 supported her by referring to the introduction in which a map of the fields was presented on a computer.

4.1.2 Technical scaffolding

The purpose of the second introduction activity was to allow the students to familiarise themselves with the technology scaffolded by the teachers (and researchers). Even though many technical problems arose during the outdoor activity, the majority of these problems were due to failures of the system and not a result of the student’s lack of competence. On the contrary, our impression is that the students were sufficiently familiar with the technology and knew how to navigate the system. One example of many is the following episode. Student L5 is looking on the mobile device and is waiting for the first task instruction. Just before L5 attempts to contact a teacher in order to retrieve the task instruction, L4 remembers how to retrieve it from the device.

L5: Then we have to ask someone.

L4: She told us last week that we were supposed to calculate the area.
As a result of the technical scaffolding and the construction of a shared understanding of the tasks, less learning unrelated obstacles was faced; the need for teacher support decreased, and the learning flow was maintained. This result also confirms Puntambekar and Hübsher’s (2005) advice to let students familiarise themselves with the necessary skills in pre-activities. To put it the terminology of Laurillard (2007) and Eisenhart et al. (1993), the introduction activities constituted an opportunity to familiarise the students with the prerequisite discursive/conceptual and practical/procedural tools.

4.2 The second transformation unit – the role of the teachers

4.2.1 Formative feedback – strategic scaffolding

In the following episode the students could not figure out what was expected of them and how they should understand the task instruction that was provided to them from the mobile device. At first they consulted the clues but no such clues were available that could represent the task goal in an understandable way. This resulted in that one of the learners formed the misconception that the task should be calculated using the measuring capabilities of the mobile devices. The available teacher could however, contrary to the capacity of the mobile devices, identify and correct the misconception by providing a comment.

L4: I will check the clues.
L5: Yes check the clues.
L5: (no clues found) We should calculate the area with the phone.
T2: You are not supposed to use the phone for that.

This was followed by that the students re-reflected upon the task instruction and its goals and that they later consulted the teachers for further clarifications. In this particular case the students may have accomplished the task by changing strategy eventually without the intervention of the teacher. It is nevertheless a simple illustrative example of how a teacher’s adaptive analysis of a situation and demonstration of ideal solutions/strategies can lead to a progression of the activity and maintain the student’s direction towards task goals (Wood et al, 1976). This kind of formative assessment and provided strategic scaffolding proved to be supportive in many situations, especially considering the limited time frame of the activity.

4.2.2 Summative feedback – metacognitive and procedural scaffolding

In addition to the aforementioned role of the teachers we could also observe that they could provide summative feedback and maintain the direction towards task-related goals in situations where there were obvious needs for it. In the following episode, one of the groups was working on the last task and had measured two of the rectangles sides and completed the calculation of the area. The instruction given was to provide the answer
representing the area to the teachers to complete the outdoor activity. Despite the fact that the task instruction was fulfilled, by providing an answer that was in a marginal tolerated previously in the activity, the teacher had the conception that the performance could be improved and decided to give the instruction that the group should repeat parts of the task. The decision was made in situ and was not anticipated for before the activities.

T1: **What was the answer?**

L1: 5050.

L3: *But that is correct, it differs with only 1000.*

T1: No, you should have 4000. But you don’t have to redo everything.

As such, by stating that the result achieved by the student was not correct, and informing that all parts does not have to be redone, the teacher provided both procedural and metacognitive scaffolding encouraging the students to reflect upon why they got the answer wrong and what they should do better.

### 4.2.3 Reflection encouragement – conceptual scaffolding

Besides providing feedback and providing technical scaffolding when technical problems arose, the teachers also played a role of initiating learner reflections by engaging in conceptual dialogues with the students, by highlighting critical features of the tasks (Wood et al., 1976) and by generating questions to them. In the following episode the students in one of the groups had great difficulties with the final task. Two of the three students were passive and did not participate in the problem-solving process the active student was engaged in. The more active student tried repeatedly, without success, to obtain help from the group by explaining what she had done so far and what she was unsure about. At this point the teacher got involved.

T2: *Where is the rectangle then? I can’t see the rectangle.*

L5: *We didn’t have a cone. And then I wanted to measure... ehm*

T2: *What distance did you want to have between the cones?*

L5: 100 and 40.

L5: *I tried to find out how far it was. It said that it was 65 first, then 265.*

L5: *But now it says that we should measure another side.*

T2: *That will not be required until you have sent an answer.*

L5: *Yes that’s right. Okay, L4, go 100 m in that direction.*

The ongoing diagnosis (Wood et al., 1976) and the help from a more knowledgeable was an influential factor that resulted in the continuation of the learning process, and decrease of frustration, not only for the student the teacher had a dialog with but also for the other group members that became more involved by knowing which next step to take. An adapted analysis and dialogical conversation of this kind is currently beyond the capacity of the technology.
4.2.4 Collaboration support – affective scaffolding

The active student in the previous episode was the active during the whole activity while the two other group members became passive at several occasions. One possible reason for that, which we support based on the observations, is that the active student relied on the inputs from the other group members to a minor extent and did not always include them in the problem-solving process. In the following episode we could notice that the teachers shared that analysis and made an attempt to improve the weak collaboration. In the episode, the active student had used the mobile device for a long time and did not involve the group member next to her, which got less and less motivated as the activity progressed.

T1: Are you not going to share the phone?
L5: Wait, it’s about 24000 or something like that.
T2: You are three in the group. Don’t you want to do this together?
L5: L4, I have measured it, come.
L4: Finally!
L5: L4, this was 80 and that 30, so we can calculate 80 multiplied by 30.

The attempted social regulation of the collaboration, the control of frustration and the maintenance of direction towards task-related goals for all students, was based on the teacher’s ongoing analysis of the situation and the learners need at hand. This crucial ability is also beyond the reach of today’s technology.

4.3 The second transformation unit – the role of mobile technology

4.3.1 Summative feedback – procedural and strategic scaffolding

While completing the area calculations on one of the sub-tasks the students were observed to be confused and reflect on the feasibility of both the approach they had taken and the answer they had reached. They were supposed to provide an answer on the mobile device, which they at last did but without conviction. This action was immediately followed by feedback from the mobile phone and reacted to with satisfaction.

L1: I send 12.
L2: I don’t know.
L1: I don’t know either. Let’s take a chance.

Mobile text: Well measured! 12 is the correct answer.
L1: It was correct!

After this episode the mobile device directed them to the next task, which was similar in its structure to the previous one but different in respect to geometrical figure. While the first task was based on an area calculation on a rectangle the second concerned a square. The summative feedback and confirmation of the first task strategy, i.e. procedural and strategic scaffolding, resulted in that the students successfully took a similar approach at
the new task being confident of its validity and hence able to do adjustments and improve it. In regard to less successful attempts the mobile system was designed to provide feedback and allow repetition of the task, which the following is an example of:

Interface text: The answer is not correct. Try again.

Although the information provided in this feedback is confirming that the taken approach should be adjusted, and is valuable in that sense, it does not provide information on how the adjustments should be made and if the first approach was completely wrong from its starting point or not. In other words, adaptive formative assessment, and adaptive strategic and procedural scaffolding, is beyond the capacity of mobile technology.

4.3.2 Maintenance of direction towards task-related goals, simplification of tasks, and highlighting of critical features – procedural and strategic scaffolding

In the following episode the mobile device introduced a new task. The students were however not sure of which actions to take and how to accomplish the task goal. In this particular situation a mobile clue provided successful procedural and strategic scaffolding resulting in the accomplishment of the goal without the involvement of teachers.

L1: No, press clues. (L3 is holding the device)
L1: Calculate the area, press there.
L1: There, length. You are supposed to measure the length.
L3: Okay, I will go over there
L1: Wait. (Continues to read from the mobile device)
L2: Aha, okay. Come! I and L1 will go there, and you L3 go over there.

This example illustrates how the mobile device can support the maintenance of direction towards task related goals by providing task instructions and controlling the task sequence. The clues on the other hand, although predetermined and not generated as a result of an ongoing analysis of learner’s needs, could successfully simplify the task and highlight critical features.

4.4 The third transformation unit – all six scaffolding types

While the dynamic context of the outdoors activity limited the possibilities for deeper reflections and more elaborated discussions, we could observe that the post-activity or the secondary transformation unit, supported these processes to a much higher extent. The limited classroom context, implicated that teacher had access to all students, and made it possible for the teachers to engage to a much higher extent in giving feedback, re-representing concepts, clarifying key points, and also in assessing the students, confirming (Yelland and Masters, 2007). Basically, compared to the outdoor activity, we could observe more elaborated dialogues both between the students themselves and between the teacher and the students. In fact, the post-activity supported all of the six types of scaffolding, and consequently, to a certain degree, compensated for pedagogical needs that potentially were not met in the previous activities.
For instance, the support of the teachers in the outdoor activity mostly regarded practical and procedural issues, such as arising technological problems, collaboration problems within the groups, calculation problems, task clarifications and so fourth. In a sense, if generalised, during the outdoor activity the support of the teacher could be characterised as a scaffolding of practical/procedural learning processes (Eisenhart et al., 1993; Laurillard, 2007). In the post-activity, however, the emphasis of the teacher was to higher extent put on scaffolding student’s conceptual processes. As such, the post-activity made it possible for the teacher to compensate the lack of scaffolding of conceptual learning processes in the outdoor activity. Simultaneously, if considered necessarily, the post-activity also made it possible for the teacher to fade the scaffolding of already appropriated procedural learning processes.

Furthermore, the task of the post-activity was constructed to be more abstract but analogous to the task in the outdoor task. In other words, the two tasks had the same underlying mathematical structure and were objects of practice for the same mathematical concepts. While the outdoor activity task facilitated physical manipulation on concrete objects, and concrete experiences, the post-activity task involved the abstract versions of these learning objects, thus providing conceptual scaffolding motivating transfer and abstract thinking. Essentially, the post-activity not only offered an opportunity for repetition, but more interesting, potential opportunities for utilising the concrete experience gained in the outdoor activity, i.e. the everyday concepts, in order to understand the abstract scientific concepts (Vygotsky, 1986). Also, as the tasks in the second and third transformation unit had similar mathematical structure, the procedural and strategic experiences gained in the first could act as scaffolding resources in the latter.

In addition, the post-activity was also less controlled than the outdoor activity. In the outdoor activity the student’s degree of freedom was markedly limited in the sense that the procedures, the tool use and the task sequence were predetermined, and that the tasks contained few open-ended problems. This can be motivated by one of the six types of scaffolding Wood et al. (1976) suggests teachers to provide, i.e. reducing the degrees of freedom by simplifying tasks. The post-activity on the other hand contained more open-ended problems, more elements of construction and a radically less controlled task sequence structure – thus increasing the student’s degree of freedom and fading the scaffolding support.

The post-activity also constituted an opportunity for the students to present their work, which brings along two advantages. Firstly, meta-reflection on the whole learning process is encouraged (Selander, 2008). Secondly, when students are to create representations configured in a form that reflects their understanding of the task, what they perceive as central or peripheral, the teacher retrieve an opportunity to perform both formative and summative assessments (Selander, 2008).

5 Conclusions

We attempted to gain an understanding of how we can orchestrate the support and scaffolding of mobile learners across contexts by adopting a systemic learning activity design perspective. In this regard, mobile technology, with its affordances and restrictions, was only conceived as one mediating and supporting resource amongst others as, for instance, teachers and pre- and post-activities. On a specific level, the
findings obtained indicate that pre-activities constitutes a opportunity for the students to appropriate the technology used outdoors and create a shared task understanding; a conceptual and affective scaffolding that supported the learning flow in the outdoor activity. We could also conclude that mobile technology, although able to provide summative feedback in form of strategic and procedural scaffolding, compensating the lack of available teacher scaffolding, has quite limited capacity for providing the required scaffolding in general. The teachers on the other hand were shown to be a quite central scaffolding resource in the outdoors activity, being able to perform adaptive assessments and provide adaptive scaffolding as opposed to the mobile technology.

In addition we could conclude that post-activities, if designed meaningfully, can compensate for pedagogical needs that potentially are not met in prior activities. For instance, by offering opportunities for the teacher to assess the students, fade scaffolding support when evaluated necessarily, and provide types of scaffolding support restricted in the outdoor context. The post-activity also constituted an opportunity to put the focus of the learning on higher abstraction level, allowing the students to utilise the gained concrete experiences in the outdoor context, to familiarise themselves with the associated formal and abstract scientific concepts. On a general level, we could thus conclude that the pedagogical potential of mobile learning is to high extent dependent on how activities are sequenced in terms of pre- and post-activities.

From this, we argue that it should be avoided taking as starting point to design outdoors mobile learning activities supportive on their own accord. Instead we ought to recognise that the optimal approach rather may be in investigating how different learning processes can be distributed, sequenced and orchestrated across contexts. Essentially, it is a matter of acknowledging the limitations and utilising the affordances of different contexts and resources. This brings us to the general conclusion of this paper.

We found it very beneficial to conceptualise the orchestration of the scaffolding support and the activities in terms of a learning sequence. From a methodological perspective, the LDS model offers two beneficial possibilities by making different relations between units in a sequence explicit. Firstly, it may be used as a conceptual design tool used in the design process to encourage us to explicitly consider each designed unit in a learning sequence as a meaningful and dependent pedagogical part of the whole. That can hopefully facilitate the orchestration of mobile learning activities. Secondly, for the same reasons, the LDS model may be used as a tool a posterior in the design-based research process; either to evaluate whether a learning activity design is pedagogically sound and meaningful, or in order to analyse the reasons behind eventual shortcomings informing future design iterations.

As final remarks, a limitation of this study ought to be mentioned. We studied quite extraordinary learning activities in which two teachers were available for only six students. This seldom reflects the reality of how learning is conducted in formal educational systems. As such, in one sense, a best-case scenario was studied. We would however argue that the limitation in it self reinforce the validation of the conclusions. We do that based on the argument that it is not unreasonable to infer that less teachers and more students would increase the relevance of sequencing and orchestrating activities in terms of pre- and post-activities and in terms of optimising the utilisation of the affordances of different resources and contexts.
References


