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Trade-offs between pedagogical and technological design requirements affecting the robustness of a mobile learning activity

Håkan SOLLERVALL*, Didac GIL DE LA IGLESIA, Marcelo MILRAD, Aihui PENG, Oskar PETTERSSON, Sadaf SALAVATI, Jane YAU
School of Computer Science, Physics and Mathematics, Linnaeus University, Sweden
*hakan.sollervall@lnu.se

Abstract: We develop an innovative mathematical mobile learning activity for 12 year old students, who are asked to coordinate themselves physically in terms of given distances with respect to two given points in an outdoor setting. The development of the outdoor activity poses pedagogical as well as technological design challenges. In this paper, we elaborate on two critical incidents that occurred during the implementation of the activity. Such incidents call for increasing attention to the negotiation of pedagogical and technological requirements during the design process. We argue that the efficient development of innovative mobile learning activities aiming at supporting learning in outdoors and indoors settings requires effective negotiation and coordination of pedagogical and technological strategies and requirements during the entire design process.

Keywords: Design research, learning activity, mobile technologies

1. Introduction

This paper reports on the design and validation of a technology-enhanced learning activity developed in collaboration between researchers in mathematics education and media technology, who previously have collaborated in projects involving outdoor mathematics supported by mobile technologies and interactive visualization techniques [8,9,10].

A central feature within the current activity is the use of a customized mobile application for supporting the measuring of distances. Guided by the methodology of design research [3,5] the research team has designed an activity providing opportunities for students to experience mathematics in full-sized space. The activity was tried out by twelve students in grade 6 (13-14 years old) at a school located in a rural area in southern Sweden. They worked with three separate tasks during a number of sessions in the period December 2010 - April 2011. Two of these tasks are reported in this paper. The process of pedagogical design, technical implementation, and validating the initial task with students, required a time frame of less than three months.

The research objective for the current study is to explore how high pedagogical ambitions, regarding the learning objectives for the tasks within the activity, require that special attention is directed towards the issue of carefully negotiating and coordinating pedagogical and technological design requirements during the preliminary design phase. In this paper, we account for and discuss unexpected critical incidents that occurred during the implementation of the activity, and argue that such incidents emerge as a consequence of the design trade-offs between pedagogical requirements and technological affordances.

2. Design for learning guided by ancient mathematics and modern psychology

The learning activity, which will be described in the next section, may be interpreted as a construction of triangles with three given sides. Such a construction was considered by Euclid over 2000 years ago [6] and may be regarded as a traditional school task related to geometry, problem solving, and visualization, which students can solve on a piece of paper by using a compass and a ruler. In that case, they make use of a spatial ability which is sometimes referred to as *object manipulation*. This ability includes the skills required for supporting spatial visualization and spatial relations and concerns manipulation of spatial forms from a fixed perspective, involving an object-to-object representational system [7]. Within the psychometric research tradition, spatial visualization and spatial relations are contrasted with a third spatial ability, namely spatial *orientation*, which involves "movement of the egocentric frame of reference" [7, p. 745] and a self-to-object representational system. The self-to-object system activates another part of the brain than does the object-to-object system ([7, p. 745-746], which implies that object manipulation and spatial orientation should be considered as separate spatial abilities. This observation agrees with Bishop's standpoint that "insofar as we are concerned with spatial ideas in mathematics as opposed to just visual ideas, we must attend to large, full-sized space, as well as to space as it is represented in models, and in drawings on paper" [1, p. 260]. Furthermore, activities taking place in full-sized space may be related to Bruner's enactive mode of action and corresponding mode of thinking, as one out of three modes – enactive, iconic, symbolic – characterizing an individual's interaction with the world [2].

The current learning activity stimulates students' enactive mode of action by supporting spatial orientation and avoiding features of visualization. We argue that this singular activity may serve as a general frame of reference regarding students' geometric constructions on paper, where the current activity may provide a connection between iconic constructions on paper and constructions imagined to be enacted in an outdoor setting.

3. Description of the mobile learning activity

The current learning activity, comprised of a combination of different tasks, draws on the use of GPS technology available in a mobile device, allowing the user to measure distances between her own and other devices.

3.1 The first task within the learning activity

In the first task, the students worked in pairs. They were asked to use one mobile device to coordinate themselves outdoors with respect to two given distances measured against two fixed reference points, which were marked by a triangle and a square (Fig. 1 & Fig. 2).

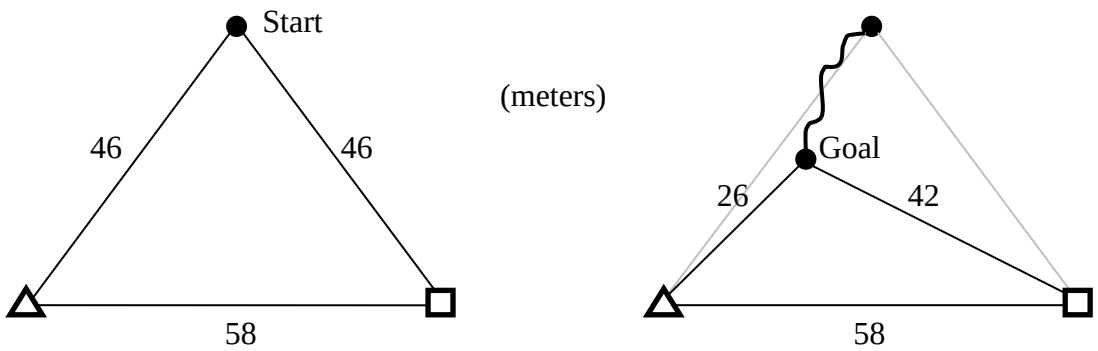

Figure 1: Visual representation of the first task.

The standing markers for the reference points were placed 58 meters apart and could be readily identified from a large distance (Fig. 2, left pane). A suggested starting point was marked with a pole and located 46 meters from each of the markers (Fig. 1, left pane). A total of ten goal points, corresponding to ten different subtasks, were chosen to provide variation between longer and shorter distances. The first goal point required the students to coordinate themselves with respect to the distances 26 m and 42 m (Fig. 1 & Fig. 2).

Figure 2: Children in the outdoor activity and the display of the mobile device.

The large distances in the subtasks, 22-86 meters, were chosen for two reasons. Firstly, we wanted the students to move substantial distances within the chosen field. Secondly, inaccuracy of the GPS values resulted in an error for the computed distances. Testing showed that a tolerance of two meters was enough to compensate for the inherent inaccuracies of the used GPS technology. At the final stage of the implementation (December 2010), students were randomly organized into six groups (pairs). They worked simultaneously with the activity on the same field, which was covered with 20 cm snow. To avoid having the groups following each other (in order to complete their ten tasks) six variations of the initial sequence of points were constructed based on symmetry (interchanging distances to the reference points) and taking the goal points in individual order. Between the reference points, we provided distance markers for 5 and 10 meters which the students could use as references either before or during the activity. In order to put focus on the spatial orientation ability, we decided not to provide visual references on the mobile device although this was technically possible (such as maps with marked attempts). To promote students' reflections during the activity, their new distances were shown on the display of the mobile device only when so prompted by the students (Fig. 2, right pane). They were explicitly challenged to try to minimize the number of prompts/tries for each task. The activity took less than one hour to complete by the six groups.

3.2 The second task within the learning activity

The first part of the activity was implemented in December 2010 and was followed by a more complex exercise in early February 2011, involving a task including multiple coordination of distances. The new requirement for the mobile application was that distances had to be measured with respect to moving targets as the initial reference points A and B (triangle and square) were replaced by the other students as new reference points for the measuring of distances. Each group consisted of either three or four students who were equipped with three GPS enabled mobile phones, which were programmed so that relative distances between the students were measured.

The groups prepared for the outdoor activity in the classroom. They were presented with maps (size A4) of a construction presented on a neutral white background and with marked distances on each edge (Fig. 3, left pane). They were asked to find the goal point,

indicated with a circle in Fig. 3. Before attempting the constructions outdoors, they were asked to discuss possible strategies for approximately 15 minutes and to decide on a strategy for reaching the goal point before engaging in the outdoor activity.

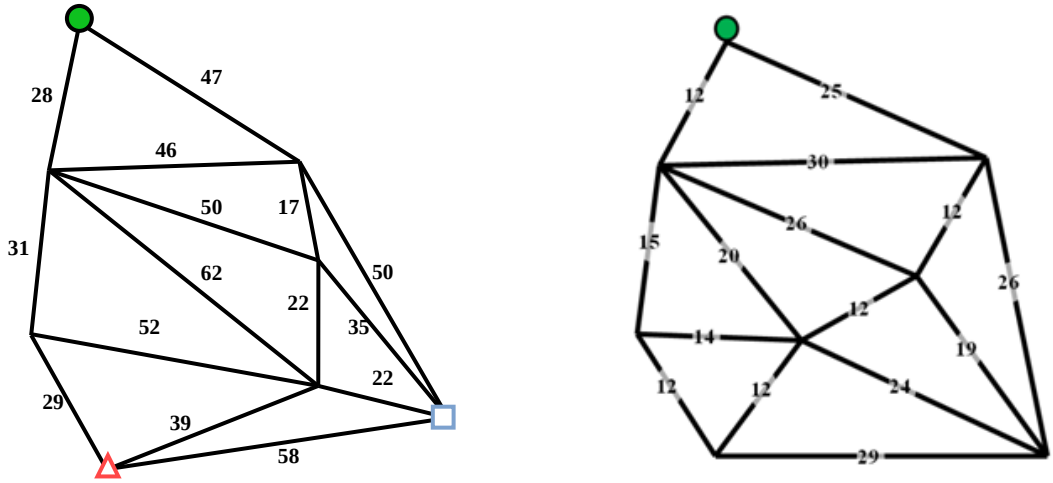

Figure 3: Maps used in February 2011 (left pane) and in April 2011 (right pane).

In the section below, we elaborate on two critical incidents that appeared during the implementation of this activity. These incidents led us to implement a re-designed version of the activity at the end of April 2011 (Fig. 3, right pane). The change in design involved halving the distances in the construction, making it less sensitive to measuring errors, and providing technological scaffolding for the students' indoor preparations of strategies.

3. Critical incidents during the implementation of the activity

The first critical incident concerns the reliability of the GPS-enabled mobile phones. During the implementation of the first task in December a group of students was using a mobile phone where the GPS suddenly stopped working, continuing to give the GPS location from the moment before it stopped updating. The device had to be restarted twice by a member of the research team. As already mentioned, an important aspect of the pedagogical design was to exclude visual external resources so the students would have to rely on their orientation ability during the activity. The negative impact of the critical incident was amplified through the activity being totally dependent on the functionality of the GPS.

For future iterations of the design, we will take measures (for example, by providing spare devices allowing the replacement of non-functioning devices) to secure the functionality of the GPS devices without having to rely on hands-on technical support.

The second critical incident appeared during the second task in February 2011 and addresses issues related to (lack of) communication and collaboration in one of the groups. There were bad weather conditions on the day of the activity. The field was covered with 20 cm deep snow, which impeded the students' physical movements. Furthermore, strong winds hampered the oral communication across the field. Both these exterior factors caused disturbances and delay in the students' collaboration regarding the implementation of common strategies and specifically, the positioning and coordination of the individual students on the field. But the shortcomings regarding their work on the field were also due to the fact that they did not engage sufficiently in the indoor planning of the outdoor activity.

As the outdoor construction proceeded, the students could not readily agree on what they should do. At one occasion, *two* students started moving simultaneously while the third stayed at a correct point. Finally, they managed to construct a triangle which fitted the measurements on the map. However, this constructed triangle ended up to be incorrect with

regard to the intended construction, as there are (infinitely) many possible triangles with three specified side measures if *only one* corner remains fixed. The group proceeded to build their construction on this incorrect triangle and finally ended up at an incorrect goal point located outside the field.

The critical cases discussed above show the need for careful negotiations and coordination of pedagogical and technological requirements in the design of this type of activities. Trade-offs regarding design requirements are always an issue in design research, but the negative impact in terms of critical incidents during the implementation phase is often amplified if the activity has technological restrictions due to high pedagogical ambitions.

5. Lessons learned and future efforts

Although the participating researchers have been collaborating for several years in similar projects, there still remains a need for developing a more detailed understanding of both the pedagogical intentions of the activity and the functionality of the supporting technological applications in order to improve the design and realize the learning objectives for the students. Design research supported by mobile technologies involves the control of many aspects ranging from pedagogical issues to technological specifications, but also the control of momentary decisions during the implementation and testing of the learning activity. During future iterations of the design process, we will include a prospective analysis of pedagogical actions and anticipated decisions that may have to be taken by the teacher, thus reducing the momentary decisions which are an inherent feature in all social interaction.

The outcomes of this current research effort have also taught us to spend more time doing requirements gathering in our future projects. Reworking code to fix errors originating from faulty or vague requirements have been reported to account for 40% of all errors in projects [4]. It is thus important to pay special attention to the detailed specification of requirements in the design process.

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