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Designing a didactical situation with mobile and web technologies

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We have designed, implemented and evaluated a didactical situation where 27 students in grade 4 created large triangular constructions in an outdoor environment by involving a customised GPS-based mobile application. The students' strategies for construction were reflected upon during a teacher-led discussion involving web technologies and aiming at the formulation of principles for construction. The effective communication of underpinning theories and possible learning objectives, in combination with user-friendly mobile and web technologies, served to scaffold the teacher's successful orchestration of a logos-oriented mathematical discourse.

Keywords: Didactical situation, mobile technologies, web technologies, design.

INTRODUCTION

Many tasks in mathematics textbooks relate to contexts in the real world that are beyond the student's reach and sight in the classroom. Such tasks are commonly treated in micro-space (Brousseau, 1986) on the student's desk. Students seldom get the opportunity to experience mathematics in large, full-sized space, which is crucial for considering spatial ideas and not only visual ideas as represented in models and in drawings on paper (Bishop, 1980). However, doing mathematics in meso-space, outside the classroom, calls for the teacher to provide and orchestrate meaningful teaching activities. Further didactical challenges include how to connect such activities with mathematically meaningful follow-up activities in the classroom.

Recent developments in the field of technology-enhanced learning show promising attempts to design outdoor teaching activities involving the use of mobile and web technologies (e.g., Sollervall & Milrad,

2012). While mobile technologies can support the design and orchestration of outdoor teaching activities, they pose technological challenges regarding stability (Gil, Andersson, Milrad, & Sollervall, 2012) and pedagogical challenges regarding usability and instrumental genesis (Verillon & Rabardel, 1995).

Beyond these pedagogical and technological challenges, we have to consider how to connect the activities with the regular mathematics curriculum and how to implement complete didactical situations (Brousseau, 1997) in specific schools with specific groups of children, preferably with limited resources for the purpose of scaling up.

For these reasons, we have adopted a co-design methodology (Penuel, Roschelle, & Shechtman, 2007) where researchers in mathematics education and media technology work together with schoolteachers to design and implement didactical situations with innovative technologies such as augmented reality (Nilsson, Sollervall, & Spikol, 2010) and customised mobile applications (Sollervall & Milrad, 2012).

The inherent complexity of the designed activities has on several occasions led to the researchers controlling the implementation of the outdoor activities and neglecting the follow-up indoor activities. Although our ambition is to design didactical situations where the teacher has full agency of the implementation, our conclusion – based on the outcomes of several similar projects – is that a first design cycle should prioritize the functionality of the technologies and the didactical flow of the situation. During the first cycle, we are satisfied if the technologies perform acceptably and the students experience a sequence of meaningful and enjoyable mathematical activities. To support the achievement of such outcomes, the researchers have

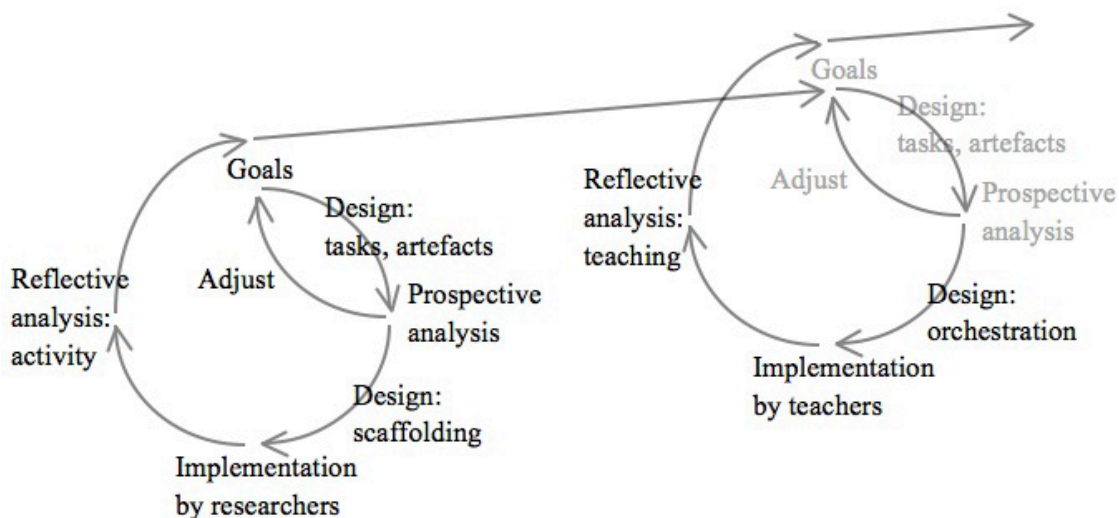


Figure 1: First and second design cycle, as implemented in the current project

been actively involved in implementing the activities (Figure 1).

During the second design cycle, the researchers provide support for new teachers to orchestrate and adapt the didactical situation by enhancing the customised technologies, communicating learning objectives, and indicating how these objectives may be achieved by unfolding didactical affordances of the situation. The teacher is fully responsible for pedagogical design and implementation (Figure 1), but is not involved in the initial phase where the activity, including its tasks and artefacts, is modified by the researchers who also prepare guidelines for orchestration. These guidelines are communicated to the teacher during a short preparatory session, directed at enabling the teacher to interpret and unfold the learning opportunities that are embedded in the didactical situation.

In this paper, we report on the second cycle implementation of a complete didactical situation and characterize the possible learning opportunities in terms of dimensions within a mathematical praxeology (Rodríguez, Bosch, & Gascón, 2008).

Our research question addresses the evaluation of an implemented didactical situation, specifically designed to promote a logos-oriented mathematical discourse:

How do the scaffolds provided support logos-orientation in a teacher’s orchestration of a didactical situation that is specifically designed with mobile and web technologies to provide opportunities for a logos-oriented discourse?

THEORETICAL AND METHODOLOGICAL CONSIDERATIONS

A teacher’s design cycle includes the analysis of a teaching activity both before and after it is implemented with students. Such prospective and reflective analyses are central features of design-based research (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). In our prospective analyses, we put focus on students’ hypothetical action trajectories, analysed from a socio-cultural perspective. In the reflective analyses, and particularly when advanced technologies are involved, we shift our focus of attention between the cycles. In the first cycle, we simply evaluate the activity flow. In the second cycle we evaluate the teaching outcomes, and in the third cycle we analyse the learning effects. The current paper reports on a second cycle and will put focus on evaluating teaching outcomes, for the purpose of informing future implementations of the activity by modifying and improving the guidelines for orchestration. This approach is underpinned by an ambition to find a reasonable distribution of ownership between researchers and teachers.

In the process of designing teaching activities with advanced technologies, we have noticed that fundamental didactical principles may become neglected when the research efforts favour enhancing the performance of the technologies themselves. For example, involving technologies that provide extensive feedback may remove didactical challenges that are actually needed to promote students’ learning processes. For this reason, we have adopted the theory of didactical situations (Brousseau, 1997) as a design model. The fundamental structure of a didactical situ-

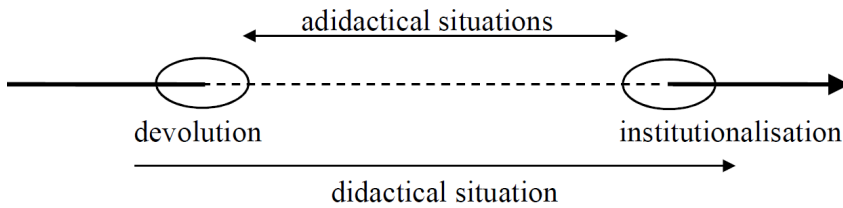


Figure 2: Structure of a didactical situation

ation – devolution, adidactical situations, institutionalisation (Figure 2; adapted from Balacheff, 2013) – fits particularly well when designing with mobile technologies across physical contexts.

The three phases within a didactical situation become naturally separated if adidacticity is promoted by giving the students full responsibility for the technology-supported exploration of mathematical tasks by retroacting only with the milieu and not the teacher, as indicated in Figure 3 (left pane, adapted from Bessot, 2003, p. 7).

While the theory of didactical situations provides a structure for a teaching activity, with focus on achieving mathematical learning objectives, we utilize the notion of praxeologies to capture qualitative differences of the learning opportunities that are offered to the students during a didactical situation. In our analysis, we will characterise such teaching outcomes in terms of praxeological elements (Figure 3, right pane).

While praxis, that is, tasks and techniques, naturally dominates within the adidactical situations, the logos dimension may emerge in the phase of institutionalisation where the students are invited to reflect on their experiences by engaging in technological and theoretical discussions about how and why the tech-

niques work. A technology-oriented discourse may include describing techniques, explaining how they work and when they work, while a theory-oriented discourse aims at justifying the techniques and the technological claims (Rodríguez et al., 2008).

In previous projects (e.g., Perez, 2014) we have observed situations dominated by praxis-oriented activities where the teacher has not unfolded the logos-oriented affordances that were embedded in the situations. In the current study, we chose to make explicit the notion of praxeologies for the teacher and discussed a variety of affordances for a logos-oriented discourse during the institutionalisation phase, based on the students’ experiences from exploring tasks in the outdoor environment.

DESIGN CONSIDERATIONS

In the first cycle, a teaching activity in an outdoor environment was designed for the purpose of investigating spatial orientation ability (Peng & Sollervall, 2014). The teaching activity involved ten similar tasks that each called for the coordination of two given distances with respect to two given reference points. Each such task can be interpreted as the construction of a triangle with three given sides, a construction that is treated in Euclid’s Elements (Heath, 1908, p. 292; Figure 4).

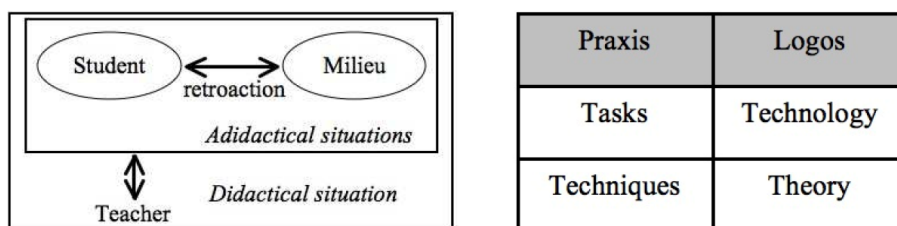


Figure 3: A didactical situation (left pane) and elements of a praxeology (right pane)

Book I Proposition 22

Out of three straight lines, which are equal to three given straight lines, to construct a triangle: thus it is necessary that two of the straight lines taken together in any manner should be greater than the remaining one.

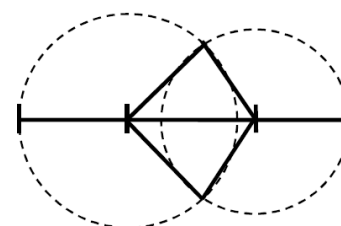


Figure 4: Euclidean construction of a triangle with three given sides

During the second cycle, the purpose was to stimulate a logos-oriented discourse during the phase of institutionalisation, involving technology as well as theory:

- technology: identifying and comparing strategies for construction, distinguishing between possible and impossible constructions;
- theory: justifying the strategies particularly the circle strategy, formulating criteria and arguing why some constructions are possible and others are not.

Based on their experiences from the first design cycle, the researchers designed a complete didactical situation encompassing devolution, an outdoor activity, and institutionalisation. The outdoor activity involved ten tasks, that each called for the coordination of two given distances with respect to two given reference points. Seven of the tasks involved possible constructions while three were impossible, such as “10 15” when the distance between the reference points was 35 meters. The impossible constructions were included for the purpose of stimulating a technology-oriented discourse during the institutionalisation phase.

The researchers’ ambition was that the students should work with their ten tasks in small groups, simultaneously and independently, in the schoolyard. To achieve variation of tasks between the groups, it was decided to place six different reference points in the schoolyard (Figure 5) and to vary the order of the tasks. For example, Group 7 had their first task “20 30” against the house and the tree (Figure 6, right pane) while Group 5 had “20 30” as their eighth task against the bicycle and the car.

The didactical situation was designed for up to 14 groups and targeting students in grades 4–6. The 14 sets of tasks were deployed on mobile phones (androids) supporting a customised technological application (Figure 6, left pane).

Although Euclidean constructions are not in the grade 4 mathematics curriculum in Sweden, the presented didactical situation connects well with mathematical content such as distances, measurements, and circles. Moreover, the institutionalisation phase involved mathematical communication and reasoning, as competencies that are strongly emphasised in the steering documents for mathematics education in Sweden.

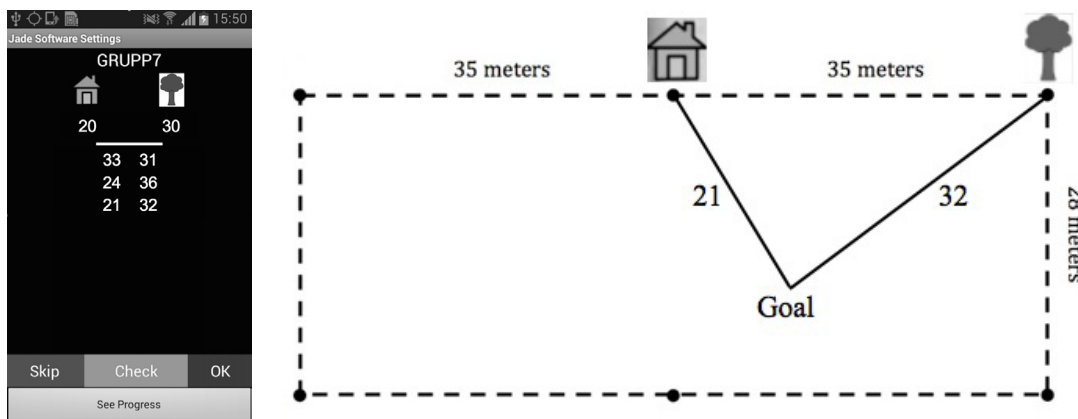


Figure 5: The presented Google Map (left pane) and the actual field (right pane)



Figure 6: The display (left pane) and an illustration of the solved task (right pane)

SCENARIO FOR THE DIDACTICAL SITUATION

Two days before the activity was implemented, with 27 students in grade 4, the researchers met the teacher at her school. After a short outdoor session where the mobile technologies were tested hands-on, she was informed about the researchers' desire to promote a logos-oriented discourse. The schematic structures of a didactical situation and a praxeology (Figure 2 and 3), the Euclidean circle strategy (Figure 4), together with possible logos-oriented learning objectives, were presented on a single sheet of paper and was briefly discussed. A sample set of 10 tasks was also presented and discussed. Furthermore, the teacher was informed about the possibility to show the students' results on a Google Map. It was made clear that these ideas should serve only to inspire her and that she was completely free to orchestrate the activity according to what she believed would be best for her students, not for the researchers.

The entire activity including devolution, the outdoor activity, and institutionalisation, was video-taped and lasted 1 hour 45 minutes (8.00–9.45 on a Friday morning).

Scenario for devolution

The 27 students arrived to the regular classroom at 8 o'clock in the morning. They had been told in advance that they would engage in an outdoor activity and use mobile phones. Before the students arrived, the teacher had divided them into 12 groups that were displayed with on the whiteboard. The three visiting researchers introduced themselves and the teacher informed the students that they were going to work with mobile phones to solve mathematical tasks outdoors on a field where the researchers had placed six coloured markers (cat, house, tree, bicycle, car, horse).

The field and the markers were displayed on a Google Map (Figure 5, left pane). When the teacher asked the students if they recognised the field in the picture they immediately answered yes. The teacher informed the students that they were going to look for "magic points" that were located specific distances from two of the markers, and that they were going to use the mobile phones to check the distances. The teacher asked the students what they would do if they were not satisfied with the measurements and they readily answered that they would try again. Each group re-

ceived a phone from the teacher and got them started after a few instructions.

When all students had opened their first tasks that were all different (an example is shown in Figure 6, left pane) the teacher told them to go to the field (Figure 5, right pane) and try to solve the tasks. The time was now 8.15. The researchers noticed that the teacher had not informed the students about the inherent inaccuracy in the GPS values that may cause a measurement error of a few meters.

Scenario for the outdoor activity

As mentioned earlier, the researchers had prepared 14 sets of 10 tasks. The 10 tasks were identical with respect to distances but were presented to the groups in different order and with respect to different markers. Each task referred to distances to two of the six markers. For example, for Group 7 the distances "20 30" were shown on the display of their mobile phone directly under pictures of "house" and "tree" (Figure 6, left pane). The objective was to find the point on the field that was located 20 meters and 30 meters from the markers, respectively (Figure 6, right pane). The response "21 32" could be considered as acceptable. On a few occasions, the teacher negotiated this issue of non-exact measurements with the students directly on the field.

The students showed no signs of confusion either regarding how to handle the mobile phones, how to interpret the tasks, and even accepted the somewhat inaccurate measurements. They were enthusiastic and engaged fully in the tasks, although some phones did not give correct measurements due to thick clouds that caused large errors in some of the GPS-values. After half an hour some students complained that it was cold outside and the teacher decided at 8.50 to ask them to go back to the classroom.

Scenario for institutionalisation

At 8.56, everyone was back in the classroom. After a short discussion about some incorrect values and asking if the students liked the activity (which they did) the teacher asked the groups to present their strategies for finding the "magic points". Most of the groups were eager to present and the teacher promised that they would all get to do it. The first group gave their mobile phone to one of the researchers who downloaded its log file to a computer that was connected to the classroom projector. Their tasks and their attempts



Figure 7: One group presenting (left pane) and the whole class contributing (right pane)

became visible (numerically) on the board (a regular whiteboard, not interactive) to the left of the Google Earth (Figure 7, left pane). They chose the task they wanted to present and what attempts they wanted to be shown with “pins” on the Google map visualisation.

For several of the groups, the teacher had to tell the students to describe the task before they started talking about how they worked with it. During the presentations, she repeatedly asked technology-oriented questions like “How did you think when you did that?”, “Why did you do walk like that?”, and “How did you get those values?”. Several of our previously identified strategies were confirmed (Peng and Sollervall, 2014) but the targeted circle strategy did not appear in the presentations.

However, when all the groups had presented, the teacher continued the discussion, focusing on the last group’s presentation. They had marked a point located 20 meters away from the bicycle marker (upper right corner in Figure 7, right pane) and had drawn a line segment from the point to the marker. The teacher asked the class if somebody could mark another point that was also located 20 meters away from the bicycle. Several students tried, but failed. They seemed confused about what to do but were eager to contribute. The teacher commented on their attempts, for example “Oh that is more than 20 meters”, “That point is too close”, “That is too far away”. She tried to guide the students by asking questions: “If you stand there and it is 20 meters, how can you walk to keep 20 meters?”, “Where else can you find 20 meters?”. Finally, one student managed to mark a point that seemed to be the same distance from the marker. The teacher confirmed the attempt by saying: “Yes! You found it!” and then “How did you know how

to do it?”. The student responded: “I just thought it out”. The teacher continued with “Now I want each of you to mark a new point, that is also located 20 meters away from the bicycle”, and “Don’t worry, there are infinitely many such points and each of you will get a chance to mark one”. Most of the students caught on to the idea about keeping the distance 20 meters but changing directions, and occasional mistakes were quickly corrected. When about ten points had been marked, all located on the field, the teacher commented: “Oh, nobody is being brave today”. One student understood what she referred to and readily marked a point in the bushy area behind the field (Figure 7, right pane). A few more points were marked outside the field. A crucial scaffolding question was asked.

Teacher: Do you begin to see a pattern? You can walk in any direction.

Student 1: Oh it is a circle!

Student 2: A spider web!

Teacher: Yes! A circle! Can you all see that?

The teacher drew a circle through the points.

Teacher: Now I have 20 here and how can I find 30 down there?

The students were invited to mark points that were initially not connected with the first circle. These points were corrected after comments from the teacher, who wrapped up the discussion at 9.45 by saying “If you can find the point where the two circles meet then you have found the magic point”. Although enforced by the teacher, the concluding theory-oriented comment completed a didactical situation addressing all the four dimensions of an emerging point praxeology.

CONCLUDING DISCUSSION

The institutionalising discourse may be characterised as teacher-driven but student-centred. The teacher was informed about the researchers' desire to promote logos-oriented discussions and was prepared for orchestrating the session towards issues relating to technology and theory. Knowing about possible strategies for construction guided her to ask logos-oriented questions aiming particularly at the circle strategy. She patiently awaited the students to catch on to the mathematical ideas that were embedded in the didactical situation. She amplified the students' presentations by adding interpretations that led them to unfold ideas that were shared among all the students by involving them in making new constructions.

The teacher's orchestration was influenced by the preparatory session two days before the trial, particularly regarding the logos-orientation and the circle strategy. The customised mobile applications inspired the students to engage in the outdoor activity, while the web technologies served to underpin the presentations and connect their obtained measurements with their field experiences. All students could readily relate to what the presenting students were referring to on the Google map application. These technical design features scaffold effective communication in the classroom and enabled the teacher to put focus on asking logos-oriented questions.

A few incidents occurred during the implemented outdoor activity. The inaccurate and sometimes failing GPS-values (due to cloudy weather) caused confusion among some of the students. However, the teacher swiftly handled all such incidents.

It may be noted that the teacher did not address the issue of possible and impossible constructions. This may be considered as a natural decision due to the fact that the students were quite young (grade 4) and possibly not yet ready to engage in conditional reasoning. Instead, the teacher engaged the students in interpreting their triangular constructions in terms of circles, as one of several suggested discourses.

The mobile-assisted outdoor activity offered opportunities for the participating 27 students to simultaneously engage in similar coordination tasks, involving the same pairs of distances but with respect to different markers. Being informed about possible

logos-oriented discourses and having observed the students acting in the outdoor environment, the teacher cleverly managed to institutionalise their common experience with respect to the circle strategy. The customised mobile and web technologies inspired the students to engage in the activities and supported transitions between outdoor and indoor contexts. These supporting technologies enabled the teacher to put focus on pursuing mathematically meaningful institutionalising activities, thus successfully finalizing a complete and complex didactical situation.

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