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LEARNING WITH OR WITHOUT MOBILE DEVICES? A COMPARISON OF TRADITIONAL SCHOOLFIELD TRIPS AND INQUIRY-BASED MOBILE LEARNING ACTIVITIES

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A central proclamation of the mobile learning field is that decontextualized traditional classroom education can be replaced, or at least complemented, with for instance inquiry-based learning in authentic contexts supported by mobile technology. This paper examines such a proclamation asking the following question: *How do children's learning processes and outcomes develop in the context of traditional inquiry-based field trips without technology and in the context of inquiry-based field trips with technological support?* A quasi-experimental study was designed to examine the research question. The treatment group in the study consisted of one group of 15 students performing a mobile supported natural science inquiry-based learning activity while the control group also comprised of 15 students performing a so-called traditional natural science field-activity without mobile support. To study potential learning advantages and disadvantages of respective groups, a qualitative analysis of the learning processes studied was conducted, along with a quantitative analysis of students' performance. Among the results we found there was no statistically significant difference between the two teaching methods but that mobile technology could support actions relevant to inquiry-based learning.

Keywords: Mobile learning; evaluation; analysis; methodology; Activity Theory.

1. Introduction

The study presented in this paper is grounded in the conception that mobile learning may be able to, and most likely can, support and enhance inquiry-based learner-centered, and situated learning practices. However, we believe that a critical and thorough evaluation is needed in order to better understand both the potential and the drawbacks emerging from inquiry-based mobile learning activities. More specifically, we argue that such an evaluation requires: 1) comparisons between learning activities practiced outdoors with mobile technologies (mobile situation) and without them (traditional field trip situation); and 2) ecological investigations of mobile learning activities in relation to the actual conditions, the requirements, and the needs that characterize a specific educational system.

We believe this type of evaluation is necessary to carry out as according to Cuban (1986) and Oppenheimer (2007), there is a repetitive cycle of technology in education, characterized by hype, investment, poor integration, and lack of educational outcomes. Likewise, when reviewing the existing literature on mobile learning, it seems that the field is going through similar phases, and that mobile learning and its pedagogical opportunities are sometimes glorified, indicating a possible hype phase. For instance, claims are made that mobile learning has the potential to transform the very nature of learning (Traxler, 2007) but it is, however, unclear how such transformations are possible. To an extreme, it seems that mobile learning is viewed as the ultimate solution for a declining educational system and as the replacement for existing educational practices.

This is, maybe, not surprising if we consider that most studies attempting to empirically show the potential of mobile learning have, to a large extent been conducted through evaluations. These are conducted in the form of attitude surveys and interviews, putting emphasis on either learners' motivation or teachers' acceptance of the new learning innovation (Sharples, 2009; Wingkvist & Ericsson, 2009). While drawing attention to some of the learning outcomes, these studies lack a critical analysis and evaluation of the learning processes (Sharples, 2009; Vavoula & Sharples, 2008). More importantly, it is also how they are transformed by the introduction of mobile technology, which is verified after a review of some of the most salient European research projects. For example, "HandLeR", (Sharples, Corlett, & Westmancott, 2002), "CAERUS" (Naismith, Ting, & Sharples, 2005), "MOBILearn" (Lonsdale et al., 2004), "Myartspace" (Vavoula, Sharples, Rudman, Meek, & Lonsdale, 2009), "Mystery at the museum" (Cabrera et al., 2005), "Savannah" (Benford et al., 2004), "The Treasure Hunt" (Spikol & Milrad, 2008), and "MULLE" (Nouri, Cerratto-Pargman, Eliasson, & Ramberg, 2011).

Research studies examining mobile learning practices have also shown that a large body of the pilot studies and trials conducted has been technology-driven with no explicit educational foundations (Hulme, Sharples, Milrad, Arnedillo-Sánchez, & Vavoula, 2011). A few studies compared learning in traditional inquiry-based field trips without technology with inquiry-based field trips with technological support. For all these reasons, it may not be too farfetched to believe that mobile learning seems to be part of a repetitive cycle of technology in education as suggested by Cuban (1986) and Oppenheimer (2007).

Although we acknowledge the conception that mobile learning may support and enhance learner-centered inquiry-based learning practices, we believe that current research in the mobile learning field calls for a more critical approach that more thoroughly and extensively evaluate mobile learning studies.

The present study examined the following question: What are the differences between traditional and inquiry-based natural science field trips with mobile devices in terms of children's learning processes and outcomes?

The empirical material collected came from a quasi-experimental study comparing a traditional field-activity part of a natural science curriculum for primary school with an inquiry-based mobile learning activity. The evaluation focused on: (i) differences observed in children's learning processes and learning outcomes, and (ii) mediation of mobile devices of learning processes in the inquiry-based mobile learning activity. Results of the analysis and evaluation were discussed in terms of teachers' costs of orchestrating inquiry-based mobile learning activities, time spent, required competence, available resources, constraints and requirements of educational systems.

2. Methodology

The mVisible II study used a quasi-experimental design to compare a technologically unsupported field-activity as a part of a natural science curriculum for primary school, with an inquiry-based learning activity with mobile support. The evaluation of the mVisible II study focused on differences in learning processes manifested due to transformations introduced by the mediation of technology. Quantitative and qualitative methods were used for collecting and analyzing data.

2.1. *Participants*

Participants of the research project consisted of 30 primary school students from two classes of a primary school in Stockholm, Sweden. The students were typical of students in Sweden, attended the fifth class and were between 10 and 11 years old.

The participants in this study were equally divided into two groups performing the two different learning activities, namely, an inquiry-based learning activity supported by mobile technology (mobile group, n=15) and a traditional learning activity without technological support (traditional group, n=15). The students in the mobile learning group were further divided into five groups of three students. The teachers used a group selection criterion that focused on high heterogeneity in the groups with respect to subject knowledge based on principles for collaborative learning (Johnson & Johnson, 1985).

Both learning activities were carried out outside the classroom, in the woods, to explore characteristics of species of plants and trees and their biotopes in the north of the Stockholm area, Sweden.

2.2. *Design process for the inquiry-based learning activities with mobile support*

The design team consisted of three researchers, one with expertise in pedagogy and learning design, the other in interaction design, and the third in computer science. These three areas informed the design process of the mobile learning activity.

The design input from the learning design perspective was based on: (i) a literature review summarizing known problems and previous learning challenges in mobile learning studies, with a particular focus on findings presented in Nouri (2012) and Nouri et al. (2011); for instance, concentrating on the sequencing of learning activities, the provision of scaffolding, and issues of orchestrating collaboration among the students, (ii) utilization of the pedagogical framework of inquiry-based learning, and (iii) theories on scaffolding and collaborative learning (Johnson & Johnson, 1985; Wood, Bruner, & Ross, 1976).

Inquiry-based learning, prototypically, involves learner-centered and non-structured investigations that are based on students' own choice of questions, hypothesis, and observations of phenomena (Edelson, Gordin, & Pea, 1999). However, it is argued that more structured and guided inquiry activities are preferable if the intended students are young and lack experience of inquiry (Edelson et al., 1999). As this was the case of our study, we chose to apply a high degree of structure in the students' tasks in order to guide the students through the inquiry-based learning activity.

The design process was also informed by the end-users comprising of students and teachers. A participatory interaction design methodology consisting of future workshops was conducted with two teachers and six students in order to discuss, test prototypes, evaluate, redesign, and implement the learning design. The design input from the students and teachers drew attention to desired practices in inquiry learning activities and issues with current ones.

The teachers were actively involved in the design of the traditional learning activity, and they were instructed to design it according to how they would usually plan, organize and run field-activities in the subject. Our role in the design of the traditional learning activity was to align the teachers' design to our research requirements.

2.3. *The inquiry-based learning activity with mobile support*

The mobile learning activity could be divided into three main activities, namely, an indoor introduction, an outdoor field activity, and an indoor post-activity. The *introduction activity* provided the students with an opportunity to familiarize themselves with the technology used in the outdoor activity, and to understand the tasks they needed to perform – guided by the researchers and teachers who facilitated the learning process and provided instructions. The technology used consisted of a smartphone and a tablet.

The *field activity* started with a group of students arriving at one of four different nature squares in the forest behind the school. Each student had a smartphone and there was one common device, a tablet, located at each nature square. The squares were designed for the purpose of the study and contained the relevant flora to be investigated by the students.

The field activity was designed as a sequence of four tasks (see Figure 1) below. In the *first task* all three students in the group used their mobile devices to *scan the QR code for the nature square* they arrived at. The code initialized the mobile devices to show a list of species available in the current nature square. The common device also provided students with further task instructions. The *second task* required students to individually use the mobile devices to scan QR codes attached to each species and identify them. The *third task* involved reading information about the scanned species, and followed by the *fourth task* which required students to use the phone camera to capture what they believed characterized the species. Task 2 to Task 4 were performed for each of the listed species in the nature square.

The mobile device provided the students in-situ descriptions of species and their biotopes and allowed for multimodal data collection in the forms of pictures and videos. The tablet, on the other hand, constituted a common tool that scripted the collaboration between the students. It "forced" the students to provide individual codes each time a task instruction was needed from the tablet. This discouraged individual students to progress through the activities on their own. As such, the use of the tablet was intended to encourage the students to create a joint task understanding and to deliver equal task information so as to not empower the students asymmetrically (Nouri et al., 2011). Besides these functions, the common device also provided affordances to collaboratively create dynamical pie charts that were used to visualize the tree distribution in a particular zone of the field studied. The role of the teacher in this particular activity was to intervene and support the students only when they actively asked for his help through a phone call. The teacher intervened and provided scaffolding both through phone calls and face to face in situ.

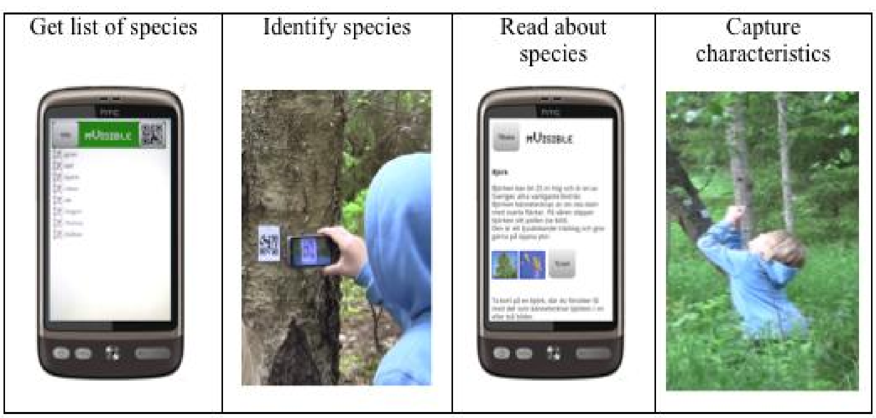

Figure 1. The four tasks in the outdoors mobile learning activity.

The *indoor post-activity* was planned to let the students analyze the collected multimodal data from the outdoor activity. The students collaboratively had to interpret, transform the data collected, and summarize it into conclusions and new representations. The activity ended with the students displaying multimodal presentations that were discussed together with the whole class. Two available teachers scaffolded the students' work during this post-activity. All communication between students and teachers in the post-activity was performed face-to-face.

2.4. *The traditional learning activity without technological support*

Similar to the mobile learning activity, the traditional learning activity was divided into three activities: an introduction activity, a field activity, and a post-activity. The aim of the introduction activity was to let the students understand the objectives of the traditional learning activity, and what was to be done in the field- and post-activity.

The field-activity for this group of 15 students was quite different from the field-activity for the group of students from the mobile learning group. In this particular field-activity, the teacher guided the students to the same nature squares as in the mobile learning activity. While being in the nature squares with the students, the teacher provided information about the different species and their biotopes, asked students questions and gave them opportunities to ask their own questions. The field-activity ended with the teacher taking pictures of the species and collecting branches, leaves, and needles.

In the post-activity, the collected materials were put on a table. Then the teacher started a discussion about the characteristics of the different species in the nature squares experienced by the students. Finally, the teacher invited the students to examine the collected material.

2.5. *Data collection and data analysis*

The qualitative data collected was video, using handheld video camera, taken of each group in the mobile learning activity, and the traditional learning group. The camera followed each group of students while conducting the activity and seven hours of outdoor activity videoed data were collected, approximately one hour per group, over the time-span of one day. The first author did the video analysis that was conducted in the following manner. The data analysis was recursive, informed by Activity System model presented in the following section, and the system aimed at identifying the significant instances in which the different triangle components mediated the learning activities being carried out. This type of analysis was performed for the two compared groups, and it ended when no more relevant examples of component mediation (i.e. rules, division of labor) could be found. For instance, we examined the activities in all of the mobile learning groups looking for rules that mediated these activities. By so doing, we for example identified rules that affected whether the activities were learner-centered or teacher-centered. In the next level of analysis, focus was put on selecting rules that emerged and were common to all the mobile learning groups, and the rules that were most salient in the traditional learning group. This way of analysis was repeated for each of the components in the Activity System model.

Quantitative data was collected through pre- and post-tests. These were constructed to examine the students' appropriation of the subject with respect to their ability to identify the name, characteristics, and the biotopes of the different species. We conducted a two-way mixed design Anova (analysis of variance) for a more detailed analysis of the two groups, treating the pre-test as the covariant variable and the post-test as the dependent.

Framework of analysis: Activity Theory

Activity Theory was used for the analysis of the collected data. Activity Theory is a descriptive tool as well as a theoretical framework that aims to understand human beings through an analysis of the genesis, structure, and processes of their activities (Kaptelinin & Nardi, 2006). The framework uses the concept of activity, which is understood as the subject's purposeful interaction with the world, as the fundamental unit of analysis, and offers a set of concepts that can be used in order to conceptualize a model of activity systems.

Activity Theory has its origins in Vygotsky's (1976) concept of tool mediation and Leontiev's (1978) elaborated notion of activity. Vygotsky (1976) proposed the idea that human beings seldom interact with the environment directly without using cultural artifacts such as technical and semiotic tools as mediators of external activities.

Vygotsky's ideas about cultural tools as mediators of activities, and in particular the concept of activity itself, were further developed by Leontiev (1978) into the fundamental principles of Activity Theory (Kaptelinin & Nardi, 2006). In addition, Leontiev introduced the concept of the object of the activity and the notion of a hierarchical activity structure. The proposed claims were that all human activities are directed toward objects that motivate actions; activities are seen as mediators of interactions between subjects and objects (Kaptelinin & Nardi, 2006), and that activities can be analyzed at three hierarchical levels - activity, actions and operations. Actions are conscious and goal-directed undertaken to fulfill the object of the activity, whereas operations are routinized, unconscious and automatic components of actions.

Inspired by Vygotsky's and Leontiev's approach, Engeström (1987) proposed an extended activity system model (see Figure 2), including the subject-tool-object relation of Vygotsky, but with a description of activity as a collective phenomenon, as opposed to Leontiev, who almost exclusively focused on individual activities (Kaptelinin & Nardi, 2006). In order to account for the social structure of activities, Engeström (1987) included three additional components: (i) rules that regulate the subject's actions; (ii) the community of people who share a common object; and (iii) the division of labor – how tasks are divided between the community members.

Engeström's activity system model, thus, depicts the constitutive components of tool-mediated and collaborative activities, such as, the mobile learning activity investigated in the present study. For instance, the notion of division of labor stresses the collaborative aspect and provides the means for making a distinction between cooperative and

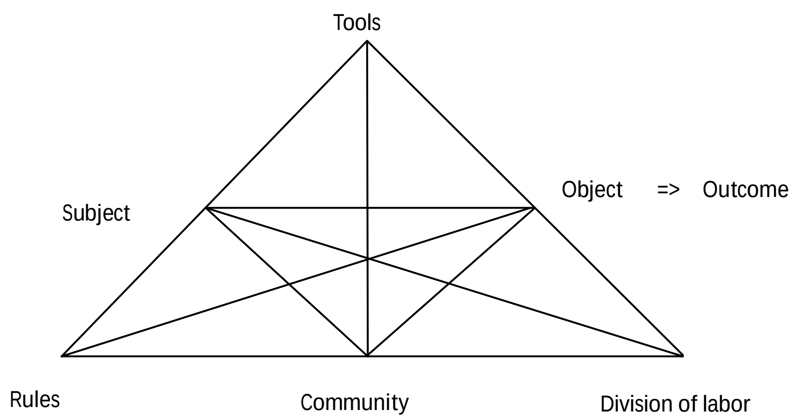

Figure 2. The activity system model (Engeström, 1987).

collaborative processes (Nezamirad, Higgins, & Dunstall, 2005). Rules, on the other hand, regulate the relationship between a person and the community he or she is a member of, as well as the relationship between a person/community and the technology. Rules also emerge with the introduction of technology. Thus, the notion of rules and community allows the analysis of how the learning activities studied are regulated, facilitated, and constrained.

Finally, the notions of hierarchical structure and of dynamic transformation between activities, actions and operations facilitate an in-depth analysis of the transformations introduced by mobile technology. Analyzing data at the level of granularity provided by Activity Theory allows for comparing in detail the two different learning activities, and, thus, to *evaluate* the transformation of learning activities emerging from the use of mobile technologies in school settings. After all, tools transform the activities that they mediate, making it impossible to understand activities independent of those tools.

3. Results

3.1. *Overview of the results obtained*

Examination of the traditional learning group and the mobile learning group showed that the activities developed in both learning conditions differed notably. Although both groups pursued the same learning outcomes in the two types of learning activities, namely, to investigate species in the nature squares in order to learn to identify and characterize species in the nature, the strategies developed as well as the operations involved in their actions differ greatly (see Table 1).

Table 1. Activities for the mobile learning group and the traditional learning group.

Activity levels	Mobile learning	Traditional learning
Activities	Investigate species in the nature squares	Investigate species in the nature squares
	Collect data (students)	Collect data (teacher)
Actions	Documenting and examining characteristics of the tree species through taking pictures	Find and identify species (teacher)
	Receiving tasks instruction timely and sequentially through the mobile device	Describe species (teacher)
	Getting multimodal information about the species in situ	Ask and answer questions (teacher and students)
	Interacting with the teacher through the mobile device	Collect data (teacher take pictures)
Operations	Scan QR codes	Take pictures (teacher)
	Take pictures	
	Navigate the UI	
	Make phone calls	

The following sections present in more detail how the different learning activities observed were supported by different actions and operations, starting with an examination of the tool component in the Activity System model (Engeström, 1987).

3.2. *Differences of both learning groups in terms of tool mediation*

Mobile learning groups - technology mediation

Supported by the use of the mobile device, the children in the mobile learning groups performed the following four main actions: (i) documenting and examining characteristics of the tree species through taking pictures, (ii) receiving tasks instruction timely and sequentially through the mobile device, (iii) getting multimodal information about the species in situ, and (iv) interacting with the teacher through the mobile device.

(i) Documenting and examining the characteristics of the tree species through taking pictures

One of the technology-mediated actions performed in the mobile learning group was collecting data and experiences as a part of the inquiry-based learning process. This was operationalized through taking pictures with the mobile phones, which the students did quite successfully in terms of engagement, reflection and discussion. We observed that the students became really engaged during this particular phase where pictures were

Figure 3. Students engaged in taking pictures.

taken. That was reflected in the amount of pictures taken (on average 2.5 more pictures than required per individual) and the time spent on discussions about them. Taking or retaking pictures become an activity per se for the students requiring the following actions: a) a thorough observation of the characteristics caught in the picture, b) a reflective activity in relation to the information about the species, and c) discussion between group members. Furthermore, we noticed students wanted their pictures to become aesthetically appealing, too, which can be understood as a sign of motivation and engagement. While digital cameras certainly could support the particular action of taking pictures, and the specific goal of capturing information in a visual modality, the advantage of mobile technology here is the ubiquitous availability of the technology, and that the process of taking pictures can be scaffolded. For this group, the mobile application guided the students toward the characteristics of the species.

(ii) Receiving tasks instruction timely and sequentially through the mobile device

In this group the students got task instructions through the mobile device. One could of course argue that getting task instructions could have been supported through traditional means, such as using paper, for instance. However, in this case the instructions available on the mobile device were given timely and sequentially, thus reducing the risks for confusion and providing a clear guidance. Of course, few occurrences of problems and breakdowns were observed. For instance, a couple of students had difficulties understanding the task instructions, which cannot be attributed to the mobile technology.

The task instructions were also provided to the students symmetrically in time meaning that they were provided to all of them only when all group members had completed a task. To provide instructions with the mobile device was, indeed, a conscious design choice. From our observation in previous mobile learning projects, asymmetrical distribution of task information leads to asymmetrical division of labor and, consequently, to collaboration difficulties (Nouri, Zetali, & Cerratto-Pargman, 2013). As such, this design choice makes the task instructions an element that in practice become a collaboration script for the students and a regulator of their activities as students. Individually, the students could not advance too quickly in the activity and leaving group members behind as this would affect the dynamics of the group collaboration. Thus, the script worked as a tool that balanced the distribution between individual work (within a cooperation) and collaborative work.

(iii) Getting multimodal information about the species in situ

Another action the children performed with the mobile device was receiving and reading descriptions of the species in situ by augmenting contextual information in QR codes. We observed that scanned QR codes provided information about the species the QR code was attached to. The code had two different functionalities and supported two different actions. Firstly, we observed that the physical existence of the QR codes attached to the different tree species examined scaffolded students' attention. The QR codes directed them toward the relevant learning objects, in this case the specific species to investigate. By identifying the QR code in the woods, the students also identified the targeted species to investigate. However, we also observed there was a disadvantage with students using QR codes as an instrument for identification of species. Students were seeking QR codes in the nature instead of thinking how to identify specific species in the wild.

In a natural dynamic and complex environment with rich information such as the woods, QR codes may nevertheless reduce complexity and direct students toward the relevant learning objects they have to examine. Furthermore, previous project experiences clearly showed that students who utilized the QR codes to access contextual information about the species, outperformed students that did not use them. In fact, we found a significant correlation between these variables (Nouri et al., 2013).

(iv) Interacting with the teacher through the mobile device

Support and feedback from the teacher was received through a phone call. While this was incorporated into the learning design, in practice it was not utilized to the extent anticipated. This was despite the need for scaffolding, that is, the need for teacher support, as explicitly expressed by the groups. An explanation for this behavior could be that students made the decision to solve the problems on their own.

Traditional learning group – tool mediation

Besides a digital camera that the teacher used to take picture of the focused species, the children in the traditional learning activity used neither specific tools nor technology. Only the teacher took pictures of the species of trees studied at the end of the field trip. All other actions were mediated by language and gestures.

For instance, children in the traditional learning groups did not document and examine characteristics of the tree species through taking pictures; they were rather looking at and eventually asking the teacher about their observations. We observed that the teacher had control over the talk and the camera and, thus, s/he was taking the active role in the outdoor classroom.

Viewing the learning activities from an operation level, not much can be reported concerning the traditional learning activity. Besides automatized operations such as being able to walk in the woods, or use of the language in order to formulate questions, few actions, and even fewer operations were executed by the students.

3.3. *Differences for the two learning groups in terms of division of labor, rules, and community*

In the previous section the analysis focused on the tool component of Engeström's Activity System Model (Engeström, 1987). This section presents an analysis of the *activity systems* observed through the lens of the other components, namely, division of labor, rules, and community. Table 2 presents a summative overview of the characterization of the two learning activity systems.

Division of labor – social vs. individual learning processes

One major difference between both learning groups was how the workload and efforts were divided among different group members in the learning activities. The division of labor in the traditional learning activity manifested itself in that the teacher lectured the students in the natural context by providing rich explanations of the species and their biotopes. The responsibility of the students on the other hand, who did not work in groups or collaboratively, consisted of paying attention, receiving the provided information, and asking questions. The teacher noticeably mediated this activity.

In the *traditional learning group*, students became increasingly passive and some even detached from the learning activity as time progressed – possibly because of the lack of responsibility for and ownership of actions.

In the *mobile learning group*, the learning processes and the actions executed in this activity were individual and collaborative, that is, individual in terms of students being able to perform actions individually, and collaborative in terms of students performing and discussing actions jointly. The configuration of the mobile technology contained almost all functionalities needed to support each student to reach the learning objectives

Table 2. The main characteristics of the two different activities.

Components	Mobile learning activity	Traditional learning activity
Division of labor	Collaborative exploration/discussion	Teacher providing rich information
	Individual exploration within the groups	Passive students receivers of information
Rules	Learner-centered activity	Teacher-centered activity
Community	Collaborative scaffolding	Teacher scaffolding
Tools	Technology scaffolding	-
Object	Personalized motives Engaged students	Non-personalized motives Less engaged students

through individual actions. However, the design of the collaboration script (three individual codes required to receive task instructions) encouraged collaborative actions, and the recommendation (implicit rule) to collaborate. The role of the teacher in the activity was limited to providing support to the students when required although this did not happen more than four times in total. As such, the students were the active actors in this learning activity, collaboratively and individually exploring the natural phenomena, mediated by the mobile technology.

Rules affecting agency, control and power

Some distinctive differences between the two activities were reflected by the formal and informal rules that governed the behaviors of the students and teachers in both learning groups. A set of those rules, or more precisely a set of reciprocal expectations and obligations, could be captured by the notion of didactical contract between the teachers and the students (Brousseau, 1984).

In the *traditional learning group,* the didactical contract which evolved from previous interactions, comprised of expectations on the students to, for instance, listen to the teacher, to assume that the teacher had something important to say, to not interrupt, and to not individually or collaboratively explore the learning phenomenon.

In the *mobile learning group,* the didactical contract comprised of expectations to collaboratively explore and discuss the learning phenomenon, to adhere to the task instructions provided by the mobile technology, to utilize the functionalities offered by the mobile technology, and to contact the teacher when support was needed.

Accordingly, the character of the learning activities was partly influenced by the rules in the activity systems, an influence that mainly can be reflected in terms of student agency, control and power.

In the *traditional learning group,* we observed a pronounced teacher control and a limited student agency, that is, a teacher-centered activity. The teacher provided task-instructions, explanations, and regulation of the activity. The students, on the other hand, acted as passive listeners with limited actions offered by the teacher and with limited power within the activity system to construct or personalize actions.

In the *mobile learning group*, the students were responsible for executing actions depicted by the task instructions, and had the power and freedom to construct own actions within the activity system. For instance, one group of students chose to examine the soil and, thus, the biotope of an investigated species. Also, explanations and information were accessed through the mobile device when needed and through the students' proactive decisions (*agency*), instead of being provided by the teacher in an order decided by him. This particular rule had both constraining and enabling effects in the mobile learning activity – besides determining the division of labor between student-teacher and student-student. Furthermore, we observed that actions, at some instances, could be mechanical and instrumental in the sense that the students attempted to complete the actions as soon as possible with minimum effort and reflection. Also, the same rule enabled an increased student agency in the mobile learning activity that gave the students more control and power of how they collected experiences and how they constructed knowledge. More specifically, the students in the mobile learning activity could explore in an embodied way using more perceptual senses than the students in the traditional activity when engaging with the environment.

The rules and the didactical contracts had influence on all of the components in the activity system. They determined what tools to use in the mediation of actions; they delineated the community in the two different activities, that is, small groups in the mobile learning activity and one big group in the traditional learning activity; and a horizontal division of actions between the members of the communities and a vertical division of power, agency and control. In the next section, we present a more detailed description of the division of labor followed by an account of the community component.

The community as a support structure

The two-activity systems comprised of two different communities, namely, the small group of three students plus a teacher in the mobile learning activity, and a group of 15 students plus the teacher in the traditional activity. An analysis of the data collected demonstrated that the constitution of the communities also determined a strong conversational division of labor between the two communities in the two activities, as indicated quantitatively.

In the traditional learning group, the students expressed in total 36 task-related utterances, all between students and the teacher, compared to 129 utterances per group in average in the mobile learning activity. Zooming in on the different types of utterances, coded in simple and elaborated utterances, qualitative differences become apparent as well. Three out of the 36 utterances in the traditional learning activity were elaborated utterances, in comparison with 13 elaborated utterances in average per group in the mobile learning groups. Table 3 below shows the frequency of simple and elaborated utterances by the mobile learning group and the traditional learning group.

Examining the elaborated utterances thoroughly, what also becomes evident is the different quality of the elaborated utterances. The following excerpt illustrates the most elaborate conversation between a student and the teacher in the traditional learning activity.

Excerpt 1:

Teacher: *How do we know that this is a birch tree?*

Table 3. Frequency table of expressed utterances in the two different activities.

Utterances	Mobile learning activity	Traditional learning activity
Simple utterances	89 per group in average	33
Elaborated utterances	13 per group in average	3
Total utterances	129 per group in average	36

Student: *It has hanging branches and don't they have lighter leaves?*
Teacher: *Correct. They only have lighter leaves in the spring.*

The following excerpt illustrates the most elaborate conversation between a student and the teacher in one of the mobile learning groups.

Excerpt 2:

S1: *What should I take picture of, what is characteristics of a pine tree?*
S2: *It has a branch free stem.*
S1: *What is a branch free stem? All of these have branches on their stem.*
S2: *But that is because they are still small and growing.*
S1: *How can you then tell that they are pine trees?*
S2: *Check the needles, they should be bunched 3 and 3 and their cones are smaller than cones of fir trees.*
S1: *Okay, then that one is definitely a pine tree (points).*
S2: *Yes, that should be a pine tree. Let's take a picture of that one.*

The difference between the two excerpts is due to the fact that the students in the second excerpt initiated the discussion based on their own agency, curiosity and conceptual needs, whereas in the first excerpt, the teacher initiated the discussion. Notably, the second excerpt, unlike the first, also showed that the students engaged in a joint exploration of the species, inferring, deducing and arriving to conclusions and understandings together. In contrast, in the traditional learning groups, the conversational activity was characterized by the provision of rich, elaborated, adapted, and correct explanations given by the teacher to the students. Explanations of this kind from teachers is certainly of value, especially bearing in mind that young students collaborating in a context and a community with limited teacher presence could sometimes be misled by their construction of knowledge. This could be due to the spread of misunderstandings, as demonstrated in Nouri et al. (2013). Thus, despite utterances and explanations in the traditional learning groups were fewer, such utterances and explanations were fully correct as they were provided by the teacher to all students.

We observed that students in the mobile learning groups relied on the community of the activity system, and utilized it as a supportive tool, which resulted in elaborated and interesting conversations. In contrast, the community in the traditional learning groups did not seem to constitute as support for the individual students but rather as a tool for the teacher to convey his messages to as many as possible.

3.4. *Learning performances and outcomes for both learning groups*

This section will present an analysis of the outcomes of the two learning activities, represented by performance, multimodal products and acquaintance with the inquiry process.

Performance

The performance results of the pre- and post-tests are presented in Table 4 below. The pre- and post-tests were constructed to examine the students' appropriation of the subject with respect to their ability to identify the name, characteristics and biotopes of the different species. Thus, the tests consisted of 10 main questions targeting 10 species. Each of these questions was divided into three sub-questions, the first asking about the name of the species (each of the species was represented by a picture in the tests), the second asked about the characteristics of the species, and the third asked about the biotope of the species. Noticeably, it can be concluded that the mobile learning group in general demonstrated higher mean score gains (M=44.3%, SD=35.3%) in comparison with the traditional learning group (M=39.5 %, SD=20.2 %).

We conducted a two-way mixed design Anova (analysis of variance) for a more detailed analysis of the two groups, treating the pre-test as the covariate and the post-test as the dependent variable. First of all, a main effect of post-tests was found ($F(28, 1)=4.196$, $p < 0.05$) confirming that the students in both groups actually performed better after the learning activities (M=13.6, SD=3.3). However, a test for between-subject effects revealed no significant difference in performance between the groups ($F(28, 1)=4.196$, $p=0.107$). Looking at the mean scores of the pre-tests for the mobile learning group (M=10.47, SD=3.42) and the traditional learning group (M=8.73,

Table 4. Performance of the two different groups.

Student	Mobile learning activity			Student	Traditional learning activity		
	Pre	Post	*Δ*		Pre	Post	*Δ*
S1	12	15	25.0%	**S1**	13	16	23.1%
S2	12	18	50.0%	**S2**	9	12	33.3%
S3	8	15	87.5%	**S3**	7	12	71.4%
S4	14	17	21.4%	**S4**	7	11	57.1%
S5	16	22	37.5%	**S5**	5	9	80.0%
S6	12	14	16.7%	**S6**	10	14	40.0%
S7	8	13	62.5%	**S7**	9	14	55.6%
S8	10	13	30.0%	**S8**	11	16	45.5%
S9	15	16	6.7%	**S9**	11	13	18.2%
S10	7	9	28.6%	**S10**	4	7	75.0%
S11	14	18	28.6%	**S11**	9	12	33.3%
S12	5	11	120.0%	**S12**	13	16	23.1%
S13	6	11	83.3%	**S13**	9	15	66.7%
S14	8	16	100.0%	**S14**	4	7	75.0%
S15	10	11	10.0%	**S15**	10	15	50.0%
Δ_{mean}			44.3%	Δ_{mean}			39.5%
Σ			35.3%	**Σ**			20.2%

SD=2.87), the former showed a higher post-test scores. Thus, there is reason to believe that the mobile learning group consisted of more high-achievement students than the traditional learning group, despite randomization (see Figure 4). Nonetheless, another picture is revealed when comparison was made between the different types of test questions. While a test for between-subject effects of type 1 questions (name of species) and type 3 questions (biotope and habitat of species) revealed no significant difference between the groups, tests for type 2 (characteristics of species) showed a significant difference (F=39.2, p=0.028). We believe the reason for the mobile learning group to perform better on type 2 questions is, from our observation, that the students of this group were more engaged in a learner-driven exploration of the species and their biotopes.

The children's multimodal outcomes

Both the mobile learning group and the traditional learning group performed two different post-activities. The post-activity of the mobile learning group encouraged the students to construct a multimodal presentation of the experienced species out of the collected picture data, which they also presented to the whole class. On the other hand, in the post-activity of the traditional learning group, the teacher had a summative debriefing of the outdoor activity. This mainly consisted of explaining the physical objects he had collected (leaves and needles).

The outcome of these post-activities could not be captured by the pre- and post-tests. However, the multimodal presentations made by the mobile learning group conveyed two values: (i) signs of learning, and (ii) opportunities for extended digital learning trajectories. Figure 5 shows the slide presentation of a mobile learning group.

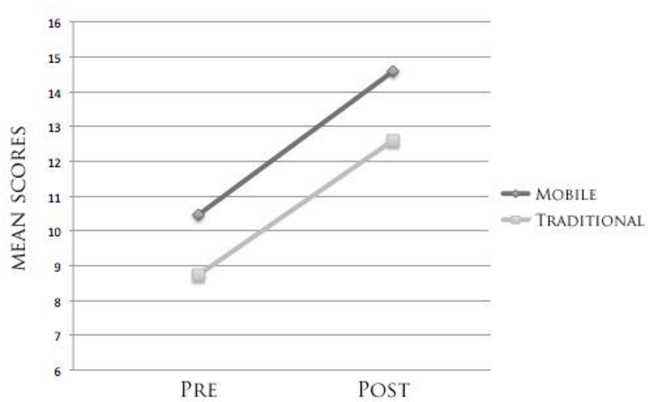

Figure 4. Average performance in the pre- and post-tests as a function of the two learning groups.

Figure 5. The slide presentation of a mobile learning group.

What seems to have been learned here, that is, the learning that is not captured by the pre- and post-tests, is a structure to describe species and the central describing characteristics of species (i.e. the whole species, the branches, and the seeds/fruits). It is likely that this could have been learned outside the mobile learning activity. However, it raises the question of whether the mobile learning activity played a facilitating function, for instance, through supporting the students to explore and take photos of the characteristics, be motivated, and engaged.

The multimodal presentations also embedded the opportunity for further manipulation and extended digital learning trajectories. These particular PowerPoint presentations were uploaded to Google Documents to allow us researchers to access the data and the teachers to provide feedback for the students after the activities. As such, the presentations and learning could continue beyond the activities.

4. Discussions

This paper has critically examined some of the premises and bright promises regarding the role of mobile learning in the 21st century educational system, namely that mobile learning has the potential to transform the very nature of learning, and that students will learn more through mobile learning as compared to traditional instruction methods.

Our analysis emphasizes differences between the traditional field trip without technological support and the inquiry-based field trip with technological support with respect to how the learning processes unfolded. However, our results do not show any significant transformation in the very nature of learning, neither do they provide any evidence that students learned more through mobile learning. The differences observed were determined by the two teaching methods that differently enabled, regulated, and constrained the actions and interactions within the two activity systems. Parts of our findings point to the advantages of learning with mobile technology (i.e. a more learner-centered learning process) in which the technology is, indeed, facilitating students' actions within an inquiry-based learning approach.

However, to only focus on these advantages, without considering how these novel technology-enhanced learning activities fit into the wider social-technical system and networks will only reinforce a "*long history of eagerly anticipated but largely unrealized technological transformation*" (Selwyn, 2010, p. 66). In this respect, our findings suggest a reconsideration of the optimism often associated with mobile learning. In what follows, we articulate this argument in terms of the three themes presented below.

- Understanding the ways emerging activity systems enable and constraint actions differently impacting on students and teachers' role and agency;
- Assessing learning outcomes and performance;
- Understanding the integration of novel learning activities in the context of a wider socio-technical system.

Understanding the ways emerging activity systems enable and constraint actions differently: Impact on students and teachers' role and agency

The findings illustrate that the mobile technology investigated can support actions and operations – and even matrixes of actions – that are required in an inquiry-based methodology of learning – i.e. actions such as collecting data, receiving augmented information, and collaborating with other peers. Additionally, the study showed among other things that the students and teacher's roles differed in the two learning activities compared. This was determined by the specific actions the activity systems made available to the students and the teachers, and the control and ownership of the actions given to the involved participants. In the traditional learning activity, we observed, for instance, a pronounced teacher control and a limited student agency (their possibility to act) – that is, a teacher-centered activity in which the students were responsible for a quite limited set of actions. The mobile learning activity presented instead different qualities. The students were responsible for executing actions depicted by the task instructions, and were given the power and freedom to construct their own actions within the activity system. Moreover, explanations and information were accessed through the mobile device when needed and through the students' proactive decision (*agency*) instead of being provided by the teacher in an order he had decided upon. In other words, the mobile technology supported the learning processes that the teachers and the research team had co-designed, and it allowed them to engage with a learner-centered inquiry-based learning activity. Indeed, the main differences between the two teaching methods were captured by the *different actions that were supported* and made available to the students. This, in turn, reflected on a different enactment of the *students and teachers' role*s, and on the degree of the students' *control and agency*.

Nevertheless, these results should be interpreted in relation to the role of teachers' guidance. In Nouri et al. (2013) we demonstrated, for instance, that in such conditions students have scaffolding needs that are not met appropriately. The results also pointed to a negative correlation between collaborative scaffolding between peers and their performance. As discussed, this was due to the spreading of misconceptions, incomplete and disorganized knowledge among the students. While these conclusions corroborate Kirschner and colleagues' (Kirschner, Sweller, & Clark, 2006) criticism toward instructional methods with minimum guidance, their large body of experiments provide evidence for the negative consequences of unguided science instruction, at all age levels, and across a variety of science and math content. Consequently, if mobile learning approaches are to become an effective learning modality, and not merely an ideological hype, the guidance role provided by the teacher needs to be rethought. A partial solution, albeit not a sufficient one, is the integration of pre- and post-field activities in which teacher guidance has a more profound role (Nouri et al., 2012).

Assessing learning outcomes and performance

In terms of learning outcomes and performance on pre- and post-tests, no statistically significant difference was noted between the traditional teaching method and the one supported by mobile technology. However, with respect to the three learning objectives, namely, identifying species, their characteristics and their biotopes, a difference in performance was observed regarding the students' knowledge about the characteristics of the species studied. In this case, the mobile learning group outperformed the traditional group by demonstrating a richer understanding of the topic. Hence, it is plausible to assume that if the outdoor activity and the pre- and post-tests had only focused on characteristics of species, our conclusion in this paper would have been that the mobile teaching method was a better alternative. This point is quite central, as it raises the question of what learning objectives are more suitable for outdoor mobile learning activities, how they are supported by design, and how assessment is done.

Regarding the impact of new technology on established practices, we observed that this impact depends on how different stakeholders in the educational system evaluate the possible *learning gains* of mobile learning. Strictly speaking in terms of performance based on this study, no strong reasons exists to conclude that mobile learning will unquestionably add a surplus value to the educational system, and thus convince stakeholders of a larger impact.

Understanding the integration of novel learning activities in the context of a wider socio-technical system

Orchestrating mobile learning activities and meaningfully integrating new technologies into education is associated with different costs. These costs have been identified from our experiences gathered from this study on mobile learning activity and the general experiences of designing mobile learning. Firstly, there is the cost of developing mobile learning applications and systems. Secondly, there is the cost of educating teachers in how these technologies can be integrated into educational activities and how technology-supported activities should be orchestrated. Thirdly, there is the cost of planning the activities, preparing the students for mobile learning activities through introduction activities, and the cost to follow up the mobile learning activities with post-activities.

Finally, we have the cost of the required technological resources (such as suitable mobile phones), and the cost of human resources (such as adequate amount of teachers scaffolding students).

Unmistakably, mobile learning may cost more to orchestrate than traditional field-trip activities, such as the one in this study, but it is just as certain that mobile learning may open up opportunities for interesting learning scenarios and learning gains. However, as final remarks, we would like to emphasize that the integration of mobile technology into education should not be approached as a desired mean in itself, and we should abandon the prevailing ideological and glorified views of mobile learning, opening up for the idea that, more than often, mobile technology may not be a shortcut for good education.

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