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Crossing Classroom Boundaries in Science Teaching and Learning Through the Use of Smartphones

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Abstract

The aim of this study was to better understand how smartphones can be applied as a means for personalized learning. Altogether, 49 fifth grade pupils and 3 teachers in an elementary school in the area of the capital of Finland participated in design-based research. Together the teachers, pupils, and researchers designed and implemented the use of smartphones in personalized science learning inside and outside school situations. After having time to become acquainted with the smartphones, the pupils used the phones during the water-themed science project. During the project, students were asked by web questionnaire what kind of applications and for what purposes they used the smartphones, while the teacher emphasized certain applications. Based on pupils' responses to questionnaires and teachers' logs, pupils used phones primarily for making notes, revisions, and information gathering. It seems that pupils need strong guidance in order to apply smartphones in learning.

Keywords: Personalized learning, science learning, inclusion, mobile learning.

Primary teachers face diverse challenges when organizing primary science activities according to the national-level curriculum and in heterogeneous classrooms in which several pupils with special needs are integrated into the class (Futurelab, 2003). Moreover, in this rapidly changing society, the technological environment and family life generate their own challenges to everyday classroom practices. Most teachers are willing to adopt new technology for use in their classrooms and respond well to the challenges (Lavonen, Juuti, Aksela, & Meisalo, 2006). However, it is not clear how technology should be used in a way that supports primary science learning amongst pupils with different needs (Warwick, Wilson, & Winterbottom, 2006). There is on-going educational policy discussion on twenty-first century competences among Organisation for Economic Co-operation and Development (OECD) countries, of which Finland is a member. Essential to this policy discussion is the question of future challenges. The twenty-first century competences emphasize novel ways of thinking and working and how engagement in thinking and working are supported. Moreover, it is essential to ask what the future context and tools needed for working will be (ITL-Research, 2011; James & Pollard, 2004; Lavonen, 2012). In order to prepare pupils for future challenges, the notion of personalized learning is often acknowledged in policy discussions.

This paper presents the results of a design based research (DBR) project conducted with smartphones in science classrooms. There was a special focus on personalized learning. First, we introduce the theoretical background for personalized mobile learning, and then describe the three cycles of the DBR and the data collection techniques in the method section. The results section describes the outcomes of the

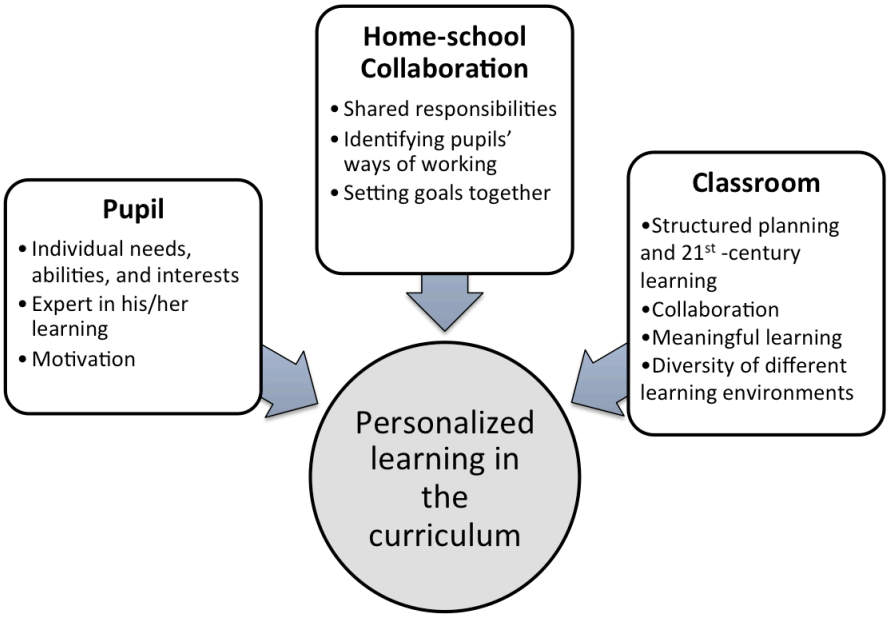
study and explains how pupils use smartphones in personalized science learning. A discussion and conclusion are provided in the final section of the paper.

Theoretical Background

Personalized Learning

The term *personalized learning* has been defined in different ways. Primarily, the term is used in studies that deal with software design in computer science (e.g., Samson & Karangiannidis, 2002). However, we understand personalized learning in a broader way. In this study, we are interested in the use of technology as a means for personalizing learning for pupils inside and outside school. For us, personalized learning is a process in which pupils are exposed to high-quality teaching and learning, and their abilities and working and learning skills are further developed by offering variation in the selection of content, the learning process, and concrete outcomes of the process. Personalized learning is a reaction to the fact that pupils come to school with different knowledge and skill bases, as well as varying learning preferences, interests, and aptitudes (Heller, Mayer, Hockemeyer, & Albert, 2005). Therefore, each pupil must be taken into account and schools need to create equal learning opportunities for everyone tailored to their individual knowledge, skills, and needs (Järvelä, 2006).

The origin of personalized of learning is political. In practice, the Finnish National Core Curriculum for Basic Education 2004 (FNCCBE) is the political document that schools should follow. The FNCCBE (2004, pp. 16–18) provides teachers with a guide for organizing personalized learning in a classroom. Figure 1 summarizes how the FNCCBE defines personalized learning at the pupil, home-school collaboration, and classroom levels.



Education 2004 (pp. 16–18).

The term *inclusion* is part of the notion of personalized learning. In the inclusive education pupils identified with special educational needs are learning in mainstream classes. Their diversity of interests, abilities and attainments are noticed (Hick, Kershner & Farrell 2009). The idea of inclusion is present in Miliband's (2006) definition of personalized learning, which has five components:

- Learning should be based on personal knowledge of each pupil's strengths and weaknesses;
- Students should learn a variety of learning strategies, from which they can pick their own characteristic way of learning;
- Students should be able to choose their own breadth of study and their own learning paths;
- Class work should support those individual learning paths; and
- The school's immediate environment and the wider community should support personalized learning.

Differentiation is a key issue in planning personalized learning. Fullan (2009) noted that in the United States, *differentiated instruction* is a more common term to describe a concept similar to personalized learning. At the practical level, teachers can

engage in differentiation in terms of the content, process, or product. *Content* is what the teacher wants pupils to learn and the materials or mechanisms through which this is accomplished. *Process* describes activities designed to ensure that students use key skills to make sense out of essential ideas and information. *Products* are vehicles through which pupils demonstrate and extend what they have learned (Tomlinson, 1999).

Mobile Learning Expands Learning Environments

The aims for the use of information and communication technology (ICT) in education are also written in the FNCCBE. Basic education has to offer a fundamental knowledge of technology. Instruction must advance understanding of the operating principles of tools, equipment, and machines, and teach the pupils how to use them (The FNCCBE, 2004, pp. 36–41). As personalized learning is learning for today's concept (Miliband, 2006), mobile learning and mobile tools, like smartphones, provide pupils an opportunity to work wherever and whenever they need to (Kotilainen, 2011).

Sharples, Taylor, and Vavoula (2005) stated that the basic assumption related to mobile learning is that learners are continually on the move. Students learn across space, taking ideas and learning resources gained in one location and applying or developing them in another. Effective mobile learning involves learning knowledge, the assessment of the learning process and outcomes, and collaboration.

Sharples et al. (2005) concluded that a social-constructivist approach is best suited for mobile learning, as it emphasizes learning as an active process of building knowledge and skills through practice within a supportive community. Hakkarainen (2009) introduced collaborative knowledge building as an object-oriented process, where the objects being developed can be problems and theories, ideas and concepts,

prototypes and materially embodied artefacts, or projects or practices being subjected to development and transformation. Knowledge-building competences are needed in a knowledge-creation society. The learning described above is also emphasized in the FNCCBE: learning is both an individual and a collaborative process in which a pupil builds knowledge and skills.

In this study, we are interested in how the smartphone as an ICT tool works as a means of personalized learning. The smartphones are used to support individual learning and for the collection and analysis of information. Pupils have their own smartphones and are familiar with using them. They have the same skills for handling these devices as many adults. They are also eager to use them and learn more about them. Research on learning and motivation shows that the use of ICT tools in science education could support meaningful learning and student motivation (Hakkarainen, 2009; Lavonen, Krzywacki, Koistinen, Welzel-Breuer, & Erb, 2012; Osborne & Hennessy, 2003).

Research Questions

In this paper, we aim to answer the following two questions:

- How do pupils use smartphones in personalized learning while engaged in a science project?
- How does the teacher's guidance during the science project influence the frequency of smartphone use?

We will answer these research questions by analyzing daily reports from the pupils about their smartphone use and the teacher-researcher's field notes.

Method

The study was conducted according to the principles of DBR (Sandoval, 2013). In order to acquire novel educational knowledge concerning smartphone use

by pupils in personalized learning, a science project was designed to include several ways to apply smartphones.

The DBR had four phases (Figure 2). In the first phase, all the practitioners familiarized themselves with the devices. Data about actions in that phase were collected through the teacher-researcher's field notes. In the second phase, practitioners planned the process with a view to generating models for smartphone use in science learning.

In the third phase, the developed models were tested in action. The uses of the smartphone were determined using a questionnaire filled out by the students every evening after school for a three week period. The questionnaires were administered through the smartphones (using the Socrative application). The questionnaire had both yes/no and open-ended questions. The teacher-researcher also wrote field notes during the testing period.

The fourth phase, which was only completed by the researchers, involved reflections on the actions of the first three phases. In this final phase, the uses of the developed models were also assessed. The answers to the questionnaires were analyzed through statistical methods (frequencies and correlations). Open-ended answers were analyzed through content analysis. The results were compared and reflected upon in the field notes.

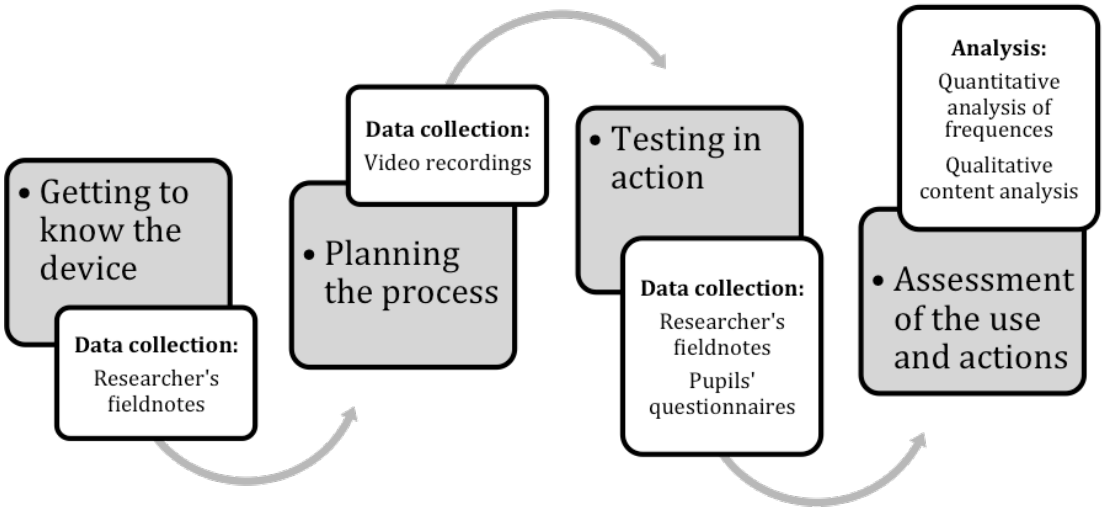


Figure 2. The phases of design-based research.

Context of the Study

This section briefly describes the first and second phases of the DBR project in order to illustrate how students familiarized themselves with the smartphones before phase three: the science project. Altogether, 49 pupils (54% male, all age 11) and three teachers (the teacher-researcher and two classroom teachers) were active practitioners in the study. One of the teachers is the first author of this paper.

Phase One: Getting to Know the Devices

At the beginning of the cycle (the end of August 2012), the pupils received smartphones (Nokia Lumia 800). Each smartphone had a data package on it allowing the use of the Internet, but the ability to make or receive calls with the phones was not activated. This reduced the expense. During the first month, the pupils learned to use the smartphones together and actively shared their experiences (Table 1). The smartphones had been set up before being given to the pupils and the pupils played with and examined the devices as they desired. The practitioners shared ideas and the teachers used these in several learning situations. A meeting was also organized with

the parents to discuss the use of the smartphones. The teacher-researcher also created a video tutorial that showed how to create an account.

Table 1

Familiarizing Students with the Smartphones, Their Applications, and the Use of Applications in Learning

Personalizing the Device	**Using Applications**	**Phone as a Learning Tool**	**Support for Pupils/Parents**
- Getting started - Creating a Windows Live ID - Setting a picture as wallpaper - Setting the style and ringtone - Pinning websites to the start menu - Syncing pictures and videos to SkyDrive	- Taking pictures and videos - Making calendar marks and notifications - Adding contacts - Windows Live settings and functions - Sports Tracker - Multiplication app - Sending emails and SMS	- Searching information (arts) - Practicing English vocabulary with OneNote - Making short films with phones - Writing down logging information for OneNote - Making an English word test with Socrative or SMS - Completing homework and sending it to the teacher - Submitting work with Socrative	- Parental meeting to introduce the phones - Setting up an Xbox account and using Marketplace - Creation of a video tutorial on how to create the Xbox account - Making and accepting friend requests in Messenger

Phase Two: The Brainstorming and Planning Processes

During the second phase (Figure 2), together the teachers designed the basic structure of the water project and generated preliminary models for active smartphone use in science learning. The pupils were included in the planning process, especially for the planning of models for smartphone use. It was decided that an idea generation session with pupils would be organized in order to get novel ideas on smartphone use in project type learning. The teachers took into account the characteristics of the personalization of learning in the form of the content and in the learning process in their planning. In this personalization, the individual needs, abilities, and former learning experiences of each pupil were taken into consideration. The teachers

decided to use varied methods in their lessons, like group work and guided inquiry, and focused on the differentiation process.

After the teachers' planning and pupil idea generation session, the pupils were introduced to the water project and working methods, including an orientation to the inquiry process and the use of smartphones during the project. After this introduction, pupils were divided into 12 groups, with four pupils in each, including both girls and boys. Groups were given the task of generating ideas for the versatile use of smartphones during the project. One group member was designated as the group leader; this individual was given quick training on idea generation techniques and how to support all pupils during the idea generation session. Support for all group members and the minimization of critical evaluations during the idea generation sessions were especially emphasized. Group leaders were chosen according to their ability to take video recordings with an iPad. Leaders had a note sheet with them to support note taking during idea generation. Group sessions were recorded using an iPad and the ideas from the groups were collected during a session with the whole class (Table 2); the ideas were then printed on posters that were put up on the classroom walls. Then the pupils were given the opportunity to establish aims and special working methods as well as to decide on the physical space for learning.

During the pupils' idea generation, the planning, and the testing phases, the pupils were divided into three groups of 16 pupils each. Each group worked with one teacher for one week (two teachers with three lessons administered by each). The science project topic was water and its properties (states of water, surface tension, buoyancy, capillarity, dissolution, and solution) and the pollution and purification of water. Teachers guided pupils in inquiry activities in which they used smartphones. The pupils looked up information from various sources and made reports, which they

emailed to the teachers at the end of the project. In the reporting phase, the pupils used different tools like cameras, voice recorders, and notepads.

Table 2

Classification of Pupils' Ideas for Smartphone Use in Personalized Science Learning Formulated in the Idea Generation Sessions

Content Spaces	**Tools Supporting the Learning Process**	**Cooperation Tools**	**Tool Applications**
- Search engines Google and Bing → Picture search → Video search - Wikipedia - YouTube - *Helsingin Sanomat* (newspaper)	- Taking pictures - Making podcasts - Writing - Taking videos - Making lists - Listening to podcasts	- SkyDrive - Messenger - Vimeo - Skype - Email	- Office programs - Sääkaveri (weather app) - Map software/navigator - Calculator - Water level app - *Helsingin sanomat* app - Vimeo - Skype

The generated ideas were analyzed and evaluated together, first with teachers and then with pupils. Teachers supported the implementation of the ideas in the classroom situation. In order to support personalized learning, the teachers, along with the pupils, decided to emphasize the making of notes (process) and searching for information (content) using the Internet. In particular, the use of different tools in their learning process, such as voice recorders, video recorders, notepads, and calendars, personalized the note making and allowed appropriate tools to be employed, especially in the case of pupils with special needs. Moreover, teachers also decided to share information through email (cooperation). Other ideas could be freely implemented for learning.

Data Gathering

The research data—pupil self-evaluation of smartphone use in learning—was collected through smartphone questionnaires at the end of each school day during the three-week period of the water project. The questionnaire was designed and

administered using Socrative (a free web-based student-response system). Socrative was familiar to the pupils. They had used it, for example, on English word tests and peer reviews. The week before data collection, we pinned the Socrative website to each phone's start screen. We also created calendar notifications about the questionnaire.

The questionnaire contained yes/no questions that aimed to clarify the use of smartphone tools and collaboration between pupils and teachers. After each question, there was an open-ended question. The response rate during the first week was 77.5%, the second week it was 60.4%, and the third week it was 53.0%. The data were analyzed using quantitative methods. During the first four days, the teacher-researcher made sure that everyone answered the questionnaire, and calendar alarms were created to accomplish this. If a pupil did not respond, the pupil completed it the next day at school. During the second and third weeks, the teacher only reminded pupils to answer and sent emails home, asking parents to remind the pupils as well. This is why the response rate declined over the course of the project. However, this did not affect the reliability of the study, because we were interested in how pupils adapted the smartphones to their learning.

During the DBR, the teacher-researcher kept a field notebook. This included descriptions of how the teacher had guided the pupils' use of the smartphones, how the pupils used the phones, and what successes and difficulties were evident. The notes were compared to the results of the questionnaire. If there were differences between the questionnaire data and field-notes, students were asked to resubmit their answers or notes were clarified. For example, on the tenth day of the project, only one pupil responded through the questionnaire that he had been in contact with a teacher. The field notes indicated that thirteen pupils sent emails to the teacher. This was

reported to the pupils and they were asked to answer the questionnaire more carefully. Therefore, it was important that the teacher-researcher kept the field notebook, because the notes supported the interpretation of the questionnaire data and strengthened the reliability of the analysis.

Results

Table 3 shows the frequencies of pupils' self-evaluations of the smartphone use in science learning. We grouped the data into three main categories based on the review on personalization (content, process, and cooperation). Subcategories were also formed, specifically process (making notes, exercises, and using the calendar) and cooperation (help from home, contact with friends, and contact with the teacher). In the table, categories are given in the top row, and under each of these the pupils' daily usage is shown. Underlined numbers show that the teachers supported pupils in applying smartphones in their science learning project in a personalized way. The science project days are marked with an asterisk. The last row of the table shows the total usage during the project.

Table 3

Smartphone Use in the Science Project (All Respondents)

	Content	**Process**			**Cooperation**		
Day	**Searching information**	**Making notes**	**Exercises**	**Using the calendar**	**Help from home**	**Contacting friends**	**Contacting the teacher**
1	**28**	**12**	17	**18**	**17**	7	4
2	10	5	**7**	12	16	4	2
3*	**19**	**41**	**31**	5	13	7	7
4	9	12	14	9	4	4	1
5*	**6**	**13**	**15**	4	3	2	5
6	14	13	**13**	4	14	6	4
7	8	**21**	**12**	3	8	6	2
8*	**17**	**26**	**14**	3	13	6	12
9	8	8	12	4	9	4	2
10*	8	**24**	**11**	4	4	6	13
11	3	4	**13**	3	11	3	**9**
12	11	4	**15**	3	15	3	**9**
13*	**12**	**25**	**12**	3	8	4	11
14	3	3	9	2	9	4	3
15*	**6**	**20**	**14**	2	3	4	15
SUM	**162**	**231**	**209**	**79**	**147**	**70**	**99**

Note. Science project days are marked with asterisks. Underlining shows tools emphasized in teaching.

Pupils primarily used smartphones in their working processes. They made notes with different applications (Office, OneNote). Pupils were guided to make notes in diverse ways, including through writing, voice recordings, pictures, and videos. They also had homework on project days in which they were asked to review learned

topics by reading their notes (exercises). Playing educational games and watching educational videos where also included in the exercises. Pupils used the calendar during the first two days. On the first day, they made calendar entries at school with the teachers. Pupils also used smartphones for information gathering. The methods that pupils employed for using smartphones were similar to the teachers' aims for the use of smartphones during the water project. In accordance with these aims, teachers also guided pupils to use OneNote and Office for note taking and to employ the smartphones to search for information.

Pupils exhibited different kinds of cooperation during the water project. Primarily, they received help from home. Help generally involved reminders to answer the data-gathering questionnaires. Contact with friends or the teacher was minimal, even though pupils were expected to contact the teacher.

Discussion and Conclusions

Pupils reported an increase in the use of smartphones when the teacher asked them to apply smartphones in their learning activities rather than in situations where the students were able to work according to their free choices (marked with an asterisk in Table 3). The use of smartphones for making notes and completing exercises seemed to be connected to the teacher's actions, such as the recommendation to use the phone tool. Pupils searched for information fairly consistently during the project, but searches increased when such information gathering was included as part of the learning activity. Help from home was stable during the cycle, as was contacting friends. Pupils used the calendar most on the first day when they marked it as a class. Contact with teachers increased towards the end of the project. In the second and third weeks, contact with the teacher increased both through email and text messages.

At present, teachers are educating children who are used to interacting with digital technology. These "diginatives" have diverse skills in using contemporary ICT tools. During this project, several pupils had their own smartphones, allowing them to access information and support quickly. Unfortunately, these devices were used almost entirely for entertainment purposes. Such issues bring challenges for educators. There has been a vivid discussion in the leading Finnish newspaper, *Helsingin Sanomat*, concerning smartphone use at school. The common opinion seems to be that smartphones disturb learning at school (Juntunen, 2013).

In this research, we dealt with a device that is relatively unfamiliar to adults and teachers. However, the device had great potential to elicit learning, especially from those who have special needs, such as dyslexic students. The main result of this research was the insight that pupils do not spontaneously use smartphones in learning. Therefore, they need continuous guidance, at least at the beginning of the project, related to how to apply smartphones in learning. Further, teachers require pedagogical support when it comes to the use of smartphones. This must be taken into consideration in the teachers' pre- and in-service education, as well as in the implementation of education policy.

Personalized learning is a process that aims to support effective learning in which pupils' abilities, work habits, and strategies are developed. It is important to create concrete models that clarify how to personalize learning in practice in the way that Järvelä (2006) and Miliband (2006) described and in line with what the FNCCBE expects. Figure 3 introduces an approach to personalizing learning with smartphones. Based on the results of this research, the adaptation of smartphones as a tool for personalized learning is a long process that requires teachers to engage in a great deal of structured planning, followed by the introduction of the use of smartphones to

pupils along with continuous guidance. The guiding teacher must also offer divertive learning materials for different learning strategies.

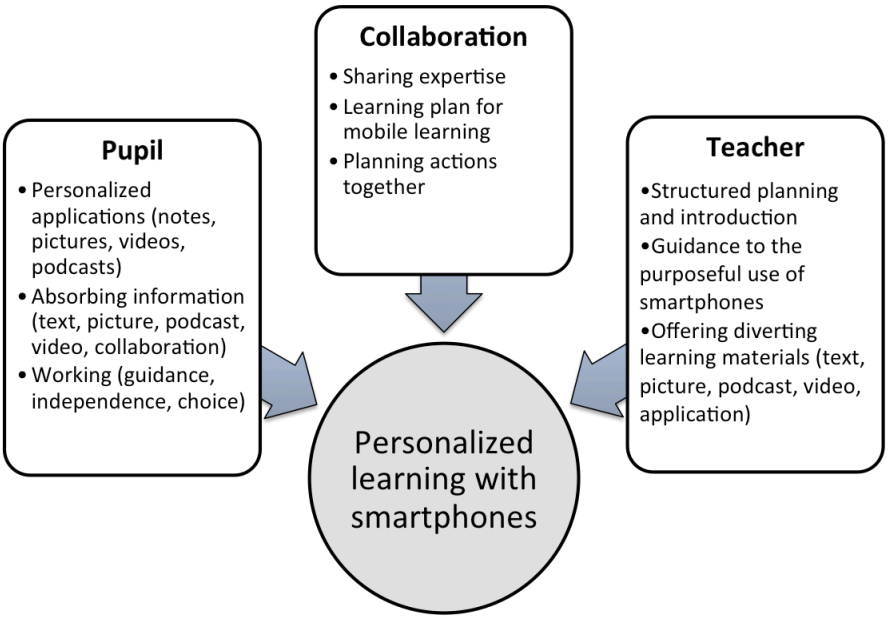


Figure 3. Model of the use of smartphones in personalized learning.

This study emphasized the importance of working with the device collaboratively in the initial stage. Co-planning and empowering pupils to engage in activities in which the approaches to smartphone use are generated will support pupil ownership of smartphone use. Pupils are motivated to explore the possibilities of the device, and the teacher has the pedagogical expertise to use those ideas in learning situations. At the same time, pupils reflect on their learning strategies and find tools that both support and help them plan the next steps in their learning. This process is important when we want to personalize learning, as Miliband (2006) described. These metacognitive skills need time to develop and the teacher must offer situations that allow student self-reflection.

The study shows that the types of smartphone use that have been carried out regularly in real educational situations mirror everyday use. For example, information searches and the use of OneNote to make notes and do exercises were exhibited

regularly in every phase of the study (see Tables 1, 2, and 3). It was difficult to convince students to employ tools not typically used in making notes, such as the voice recorder, video recorder, and calendar, even though these functionalities could personalize student note taking. Therefore, the teacher from time to time must review the various mobile learning tools that can be used so that the pupils' employment of mobile devices in their learning becomes more versatile. Teachers also need to create ways to support pupils and parents, both in terms of learning and problems they experience with the device itself. In this study, a parent night was organized and tutorial videos were shared.

During this process, teachers and researchers produced a learning plan that included mobile learning. The process of initiating the use of smartphones in personalized learning is still on-going. The second iteration cycle of the DBR with the same pupils was performed in spring 2013, when the phones were used in collaborative settings and data on this use were collected. In fall 2013, smartphone tools were used in diverse ways in the learning.

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