Author(s): Leinonen, Teemu & Keune, Anna & Veermans, Marjaana & Toikkanen, Tarmo

Title: Mobile apps for reflection in learning: A design research in K-12 education

Year: 2014

Version: Post print

Please cite the original version:

Leinonen, Teemu & Keune, Anna & Veermans, Marjaana & Toikkanen, Tarmo. 2014. Mobile apps for reflection in learning: A design research in K-12 education. British Journal of Educational Technology. Volume 47, Issue 1. 17. ISSN 0007-1013 (printed). DOI: 10.1111/bjet.12224.

Final draft (01-09-2014)

Mobile apps for reflection in learning: a design research in K-12 education

Leinonen, Teemu; Keune, Anna; Veermans, Marjaana; Toikkanen, Tarmo

Abstract

This study takes a design-based research approach to explore how applications designed for mobile devices could support reflection in learning in K-12 education. Use of mobile devices is increasing in schools. Most of the educational apps support single-person use of interactive learning materials, simulations and learning games. Apps designed to correspond to collaborative learning paradigms, such as collaborative progressive inquiry or project-based learning, are scarce. In these pedagogical approaches, reflection plays an important role. This paper presents a design-based research study of mobile device apps, ReFlex and TeamUp, that are specifically designed for use in student-centred and collaborative school learning, in which continuous reflection is an important part of the learning process. The design of the apps has relied on earlier research on digital tools for reflection and research about mobile devices in classroom learning. The design of the apps was accomplished as part of the qualitative design-based research conducted with a total of 165 teachers in 13 European countries. As a characteristic for a design-based research, the results of the study are twofold: practical and theoretical. The apps designed, ReFlex and TeamUp, are practical results of the qualitative research carried out in schools with teachers and students to understand the design challenges and opportunities in schools, to renew their pedagogical practices and to take new tools in use. To understand better the capacity of the apps to facilitate reflection, we analysed the apps in light of earlier studies concerning the levels of reflection that digital tools may support and categorizations of affordances that mobile device apps may provide for classroom learning. Our research indicates that there is potential for fostering the practice of reflection in classroom learning through the use of apps for audio-visual recordings.

Keywords: mobile devices, handheld devices, tablet apps, reflection, qualitative research, design-based research, collaborative learning, project-based learning, inquiry learning

1. Introduction

In a world where more and more social interaction with and acquisition of information is mediated by variety of digital tools, new practices are emerging. For instance, people use their email and social media services to get an overview of their relationship with other people. They check sent and received emails or messages in social media services, timelines, digital photo libraries and other personal media archives to look at previous exchanges, and to remind themselves of life events, before reconnecting with others. Digital media can be used to reflect on these past actions in relation to the present context, and these digital footprints created provide new possibilities to study everyone's personal behaviour.

Today, video streaming accounts for more than half of all Internet traffic (CISCO, 2012). In social media spaces, expressing oneself in and through the creation and sharing of multimedia and audio-visual recordings are common activities, especially among youth (e.g., Davis, 2004). For those who are growing up using mobile devices, recording, editing and remixing media are frequent practices. To respond to the changing ways of media use among young people, many progressive schools have aimed to integrate mobile devices to everyday study work.

In formal education, reflection is often practiced by individuals through writing text, such as lecture notes, journals and essays. Research on the use of computer technology in learning, however, has illustrated potential advantages of technical tools for reflection (see for a review, Kori, Pedaste, Leijen, & Mäeots, 2014). Most of the research emphasizes writing text with computers for reflection. Fewer studies report experiences about the use of digital audio and video for reflection in classroom learning in K-12 education. Examining this group would be important, especially given that there are many new practices, growing generations mastering the audio-visual applications and schools starting to be equipped with mobile devices.

This study takes a design research approach to explore how mobile devices could support reflection in learning. The design research approach was chosen, as it supports designing tools for learning and conducting pedagogical interventions at the same time (e.g., Brown 1992; Collins 1992). It also enables close collaboration among researchers, designers, teachers and students. Specifically, we designed and experimented with mobile apps for individual and collaborative reflection: (1) ***ReFlex***, for individual reflection, and (2) ***TeamUp***, for group work reflection. Although the design is optimized for mobile devices, such as tablet computers and smartphones, it also runs on various devices, laptops and interactive whiteboards among them. The applications are designed for classrooms in which students work on projects both independently and in small groups.

In the following, we present the background for the design research that includes earlier studies on reflection with computers and the use of mobile devices in classrooms. We continue by introducing our methodological approach and research design, the research context and the participants in the research. We describe our results of the design research: the apps designed and developed as part of the research and an analysis of the apps in light of the discussed research and theories. At the end of the article, we will conclude the design process and describe the current and the future work related to the designed apps.

2. Background

The importance of reflection in learning has been acknowledged for a long time, and there exit variety of views emphasizing different levels and processes of reflection in learning. Already Dewey (1916/1944) denoted that sustained thinking about experiences renders them to be reflective experiences. Later, social constructivist theories of learning have emphasized the significance of discourse and knowledge building in light of activities such as returning to and reflecting on (e.g., Paavola, Lipponen, & Hakkarainen, 2004; Senge, 2006). In his seminal book on the Reflective Practitioner, Schön (1983) discusses the ability of experts to reflect on their activity in and on action. For Bruner (1986), it is language that allows distancing from the moment, and this distanced thought invites reflection. Also Engeström's (1987) expansive learning emphasizes reflection on the learning process.

In this article, we want consider reflection in learning especially from the cultural-historical approach, in which reflection differs from the cognition related term metacognition: Reflection can be understood to be directed towards any kind of action, whereas metacognition essentially signifies mental, internal activities about mental, internal activities. According to Vygotsky (1930-1934/1978), reflection can be described as an internalized process of inquiry and conversation, asking questions and trying to answer them. These processes are internalized in social interaction with other people. We are asked to share our internal mediating objects in an understandable form. For example, external objects, such as paintings, can evoke internal mediated objects that can be used to reflect on the external object. Reflections on these internal mediating objects can be considered reflections on previous reflections. This renders reflection as a form of internalized inquiry, modelled after social processes of inquiry that the person who is performing the reflection was part of or participated in. Through social situations with other people, forming and evoking internal mediating objects may be further strengthened and expanded, and a habit of reflection, which is, according to Vygotsky (1930-1934/1978), paramount for developing the skill of reflection, can be developed. In this study, reflection is defined as a process in which people engage in serious thinking and consideration about their own and their social circles' activities with an intention to change their behaviour. Reflection can take place independently or within a group of people and can be enhanced with specific methods or with external artefacts and tools.

Boud and Walker (1998) show that, although the promotion of reflective practices in educational planning has become popular, the actual implementations have often been poor. Many times, attempts to increase reflection lead to instrumental activities with little impact. Sometimes the new practices actually prevent reflection rather than facilitate it. For example, students could be asked to write about learning challenges in an exam or to keep reflective journals during a course (reflective task), but are then assessed in relation to their understanding of the subject matter (non-reflective requirement).

When we move from learners' individual writing tasks, from learners' writing for teachers or from writing journals as part of coursework, to the use of networked digital tools, we see new possibilities for reflective discourse. Digital tools can be used to record dialogue, to categorize contributions through meta-data and to step back in time: reconfigure the dialogue, evaluate it and compare contributions. Furthermore, different representational means other than written text can be drawn on for reflective practices: for example, visualizations, audio and video or interactive simulations and software. By referring to these possibilities, various researches have presented computers' potential advantages for reflective learning (see e.g., Kori et al., 2014) and mobile devices' advantages of being tools for reflection where learners are guided to abstract from a situated activity, to integrate

their experiences in time and place with previous knowledge and in this way construct new interpretations (Looi et al., 2009; Roschelle & Pea, 2002; Sharples, 2000).

In recent years, the rise of social media has opened up new possibilities for reflection in learning: the use of discussion forums, blogs, micro-blogs and wikis has become an interesting topic especially in university education to explore the new practice (e.g., Alexander, 2004; Williams & Jacobs, 2004). Social media has also generated possibilities for innovative forms of educational practices such as participatory assessment with *wikifolios* (Hickey & Rehak, 2013).

In this study, we focus on mobile applications that were specifically designed for use in K-12 school and classroom learning. The motivation behind the research is the increasing interest to use mobile devices in classrooms and the apps' prospect of being information appliances that are easy to use and designed to perform-specific tasks (Norman, 1999). This approach is seen to serve collaborative classroom learning in which technological tools are primarily seen as a means to an end, not an end in itself.

The idea here has been to enhance student-centred and collaborative learning in which reflection plays an important role. In the design of the tools, we relied on earlier research on computer tools for reflection (Candy, Harri-Augustein, & Thomas, 1985; Fleck & Fitzpatrick, 2010) and computers and mobile devices in classroom learning (Looi et al., 2009; Roschelle & Pea, 2002). In the following, we present these two main theoretical frameworks that the design-based research builds on. The frameworks were selected because they provide interesting insights on the use of technology for reflection, in particular the use of mobile devices in classroom learning. The frameworks are Fleck and Fitzpatrick's (2010) five levels of reflection that digital tools may support through interaction and a categorization of affordances that mobile apps may present to classroom learning, as presented by Roschelle and Pea (2002) and Looi et al. (2009).

2.1. Levels of reflection with digital tools

Although digital tools have been claimed to be useful in reflection (e.g., Kori et al., 2014; Hallnäs & Redström, 2001; Fleck & Fitzpatrick, 2010), there are very few studies with analyses aiming to describe or categorize different tools' level of impact in the context of school learning. In the 1980's, Philip Candy's (1985) research group developed several computer tools for reflective learning and presented three steps to facilitate reflection: (1) reflection should be facilitated by providing documentation of behaviour, such as a video of the learning situation to help learners to return to the situation after a break; (2) learners should be taken through the behavioural record by asking them to express why they did what they did, using their own words, and through this reach conscious awareness of their actions and (3) to recognize strategies and values that can be modified and tested in another situation. The essential role of the technology in reflection is the capacity to capture material for later review.

Fleck and Fitzpatrick (2010) have approached the question of digital tools for reflection from the human-computer interaction (HCI) perspective. They see that expanding the focus from usability and meeting requirements to user experience have made the study of tools that support reflection a topic in HCI research in its own right. To advance this, they provide a framework involving five levels of reflection that digital tools may support through interaction. The levels are a hierarchical depiction of the multifaceted form reflection may assume as learning activity.

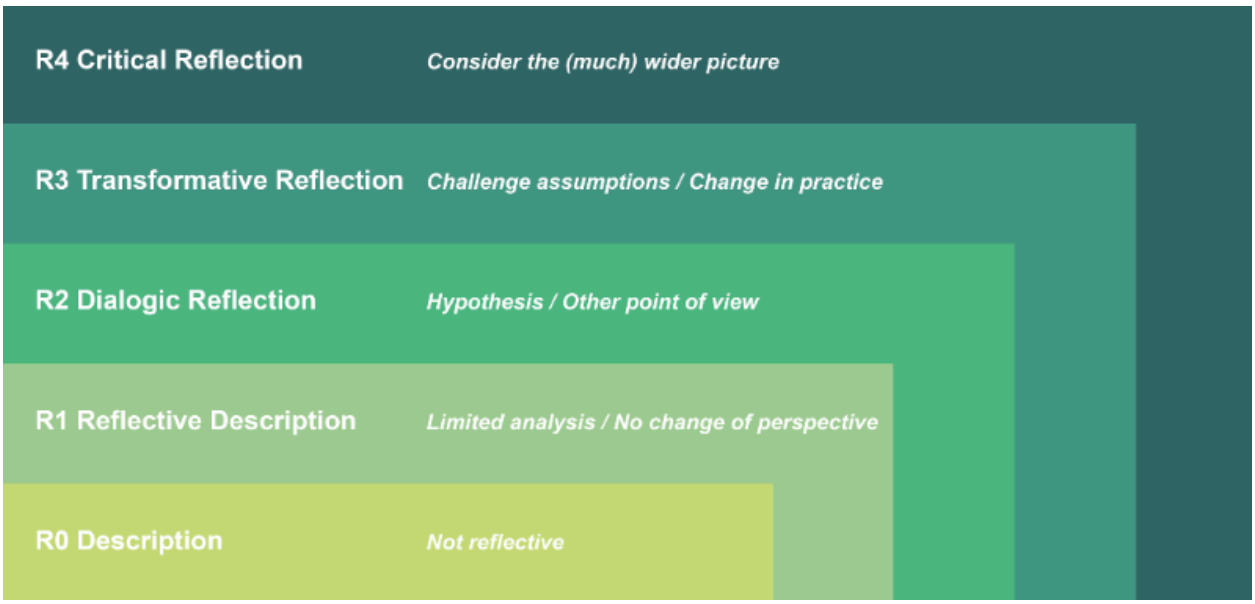

Figure 1. Illustration of reflection levels (based on Fleck & Fitzpatrick, 2010).

Figure 1 illustrates the levels of reflection discussed by Fleck and Fitzpatrick (2010). The lowest level of reflection, (R0) Description, which is not reflective, is located on the bottom of the figure, and the highest level of reflection, (R4) Critical Reflection, which assumes the practice of considering assumptions and challenges of assumptions in a wider context, is located on the top. The three levels of reflection between the ends of the scale are: (R1) Reflective Description with limited analysis and no change of perspective, (R2) Dialogical Reflection with a new point of views, and (R3) Transformative Reflection that results in a change of practice. While the levels of reflection are not necessarily advanced through and supported in stages, the performance of higher levels assumes that lower levels have been mastered or supported (Fleck & Fitzpatrick, 2010).

Fleck and Fitzpatrick (2010) propose their framework of levels of reflection to guide the design of digital tools for reflection. In our case, the framework presented guidance for feature, interaction and visual design choices that direct the learner's attention to the goal of proliferating reflection.

2.2. Affordances of mobile applications in classrooms

According to Roschelle and Pea (2002), Wireless Internet Learning Devices (WILD) can provide new kinds of augmentation of the physical classroom space for students to organize, exchange, compare and share information as topological representations. Also Looi et al. (2009) found that the use of mobile devices in the classroom can facilitate multiple entry points and personalized learning paths, support multi-modality and improvisation in situ and encourage creating and sharing of artefacts on the move. Mobile devices may provide students with choices and voices about where learning inside and outside classroom takes place (Looi et al. 2009). The affordances of the mobile devices in classroom use, as described by Roschelle and Pea (2002) and Looi et al. (2009), can be summarized in two lists of affordances although some of them are partly overlapping:

1) Augmenting physical space,
2) Leveraging topological space,
3) Aggregating coherently across all learners,
4) Conducting the class,
5) Act becomes artifact (Roschelle & Pea 2002).

1) Multiple entry points and learning paths,
2) Supporting multimodality,
3) Supporting improvisation in situ,
4) Creation and sharing of artifacts on the move (Looi et al. 2009).

Over the past ten years, pilots and research experiments have been performed with applications that match some, if not all, of the affordances described by Roschelle and Pea (2002) and those by Looi et al. (2009). Several of the experiments encompassed creation and sharing of artifacts on the move by learners for reflection after the action (e.g., Fies & Marshall, 2006; Roschelle, Penuel, & Abrahamson, 2004; Sharples, 2013).

Although the use of mobile devices and digital tools is increasing in schools, most educational apps for mobile devices support single-person use and the acquisition of content in the form of digital learning materials, simulations and learning games. Applications that build on and are designed to correspond to collaborative learning paradigms, such as collaborative inquiry learning or project-based learning (e.g., Scardamalia & Bereiter, 2006; Lipponen & Hakkarainen, 1997), seem to be scarce.

It was our intention to support high levels of reflection in classroom learning situation through the design of mobile applications. The designed applications employ the function of recording audio-visual data. The apps are designed for pedagogical practices of inquiry and project-based learning in classroom settings. Rather than to replace written reflection, audio-visual recordings are considered to add to the way in which reflection may be performed.

3. Methodological Approach and Research Design

The methodological approach of the study is design-based research (e.g., Brown 1992, Collins 1992) with a strong emphasis on research conducted to serve the design (Leinonen, Toikkanen, & Silfvast, 2008), including aspects of constructive design research (e.g. Koskinen, Zimmerman, Binder, Redström, & Wensveen, 2011). By approaching the research from a design-based research perspective, we aimed to conduct design and pedagogical interventions in formal educational settings and to study the effect of the interventions on learning events. Pairing this with research for design and constructive design research, we aimed to carry out a well-informed design practice that particularly focuses on the designed artefacts and the socio-cultural and pedagogical activities, forms and models the artefacts are expected to support. This makes the design practice an essential part of the research, and the designed artefacts are considered to be an important part of the results. Therefore, reporting the artefacts is central in the documentation of the research work (Fallman, 2005; 2007; Leinonen, 2010). This relates the research also to the art and design research tradition, sometimes called practice-based research (Hannula, Suoranta, & Vaden, 2005), in which artefacts, such as art pieces, prototypes, and models are designed during the research and are acknowledged as a crucial part of the research results (Fallman, 2005; 2007). The way the artefacts are forms part of the research argumentation.

Similar to educational design-based research (Brown, 1992; Bell, 2004), our research approach employed mixed methods, such as qualitative analysis of data gathered from participatory design sessions, design studio work and analyses of the server logs generated by the use of the prototypes of the applications in schools. The research took place in classrooms and in the design studio. The research performed in the design studio can be compared to laboratory work of educational design-based researchers: it takes place outside the classroom context and among the design research team (authors of this paper) only. The idea of the process is to inform and guide the design studio work, kind of work that does not involve participants, through the qualitative research activities, such as participatory design activities.

In the following, we present the participants of the qualitative research and the research procedures and explain how the data collected through the interventions was used in the design studio work to develop two prototypes, the apps for reflection in learning.

3.1. Participants

Qualitative research was conducted among 165 K-12 teachers in 13 European countries. We started with field visits to 7 schools in 3 countries and participated in 3 workshops with teachers and educational experts to create future classroom scenarios.

The developed scenarios served as discussion media in the first set of participatory design sessions, which included 32 sessions in 13 European countries, with an average of 3 participating teachers (n=96). Two of these sessions were also joined by students. The sessions were coordinated by the design research team and facilitated by local expert teachers who were trained for facilitation by the design research team. The participating teachers and students were handpicked by the local expert teachers. The selected teachers were generally interested in the development of digital tools for use in classrooms; hence they were not just randomly chosen.

In the second set of participatory design sessions, we conducted 17 sessions with teachers and students across 10 European countries. The sessions were coordinated and facilitated by the researchers and designers and frequented by an average of 4 teachers (n=69). Students joined 4 of the 17 sessions. The participating teachers and students

were handpicked by the local expert teachers and the researchers. While most of the second set sessions were physical meetings with participants of the same nationality, 5 sessions were facilitated with the help of online synchronous face-to-face meeting tools with participants of diverse national backgrounds. The comments of all the participatory design sessions were discussed and analysed during the sets of design studio sessions among the design research team. The prototype applications were iteratively developed towards functioning tools in the design studio sessions.

The applications were tested in large-scale pilots in 1 324 European classrooms across 18 countries, based on learning activities designed with teachers and having specific times for reflective practices.

3.2. Research procedures

Design research is iterative. When moving forward with sketches and prototypes, researchers are revisiting earlier phases in the process, to build on and to verify information for making design decisions (Leinonen, 2010; Leinonen et al., 2008). Our research included four phases with several interconnected research and design activities. These phases were implemented in a timeframe of 19 months. Figure 2 illustrates the phases in relation to the performed research and design activities.

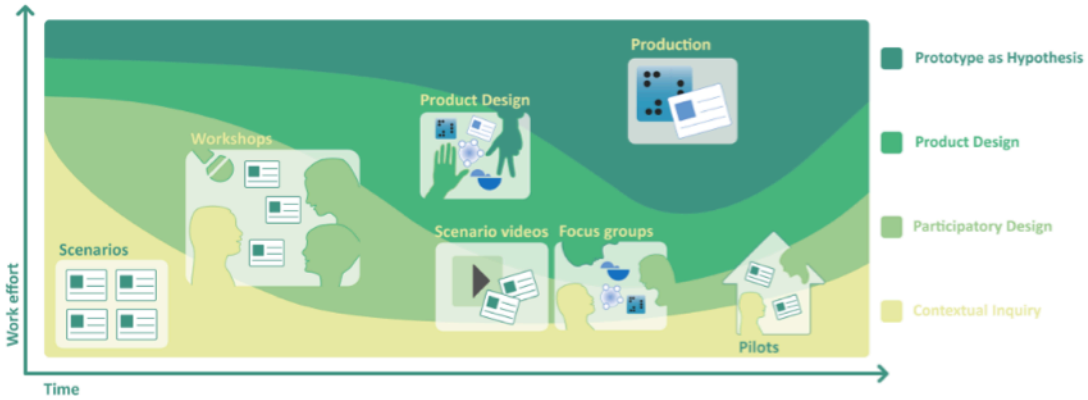

Figure 2. The four phases of the design process (based on Leinonen, 2010).

The contextual inquiry phase is formed around understanding the context, the environment and the culture that the design is aimed for, in this case, future classroom teaching and learning. More specifically, the audience represented European K-12 teachers and students. We studied a total of 31 advanced pedagogical scenarios by de-constructing, visualizing, analysing and reconstructing them. The original scenarios were designed by one of the project partners (Cranmer & Ulicsak, 2011), but they were co-developed further in the workshops. The scenarios included ideas, such as design of games, digital mapping and the production of learning materials. Further, we visited schools and informally interviewed teachers and students about their interests in integrating new technologies, for example mobile devices and interactive whiteboards, into their daily classroom work. We documented this work with field notes and photographs of school facilities, showing also the kinds of tools available in the classrooms.

In the first set of participatory design sessions, the participants were asked to familiarize themselves with all the pedagogical scenarios. For the later sessions, a panel of experts rated and prioritized scenarios that were then selected to be brought to the participatory design sessions. In the participatory design sessions, the participants were examining the scenarios to discuss potential challenges, opportunities and technological implications. The participants were also encouraged to build on the scenarios and to propose ideas for implementing and changing the scenarios. The local expert teachers facilitated the sessions in the local languages of the country in which they were conducted but conveyed the comments of the workshop participants to the design research team through written summaries in English. The collected comments represented the basis for identifying design challenges, design opportunities and design ideas for prototypes of applications. The comments were anonymized and documented online for further discussions with the participants. Finally, some scenarios were selected based on recommendations by us to the project steering committee, which consisted of several project members, including representatives of some of the education ministries across Europe. The committee members voted for scenarios, and the highest voted scenarios were selected to be part of the later workshops with classroom teachers.

In **the first set of design studio sessions** of the product design phase, the participatory design session summaries were elaborated and built on in the design studio among the researchers without the participatory design workshop facilitators, teachers and students. The summaries were printed and taped to a large design study wall that was accessible for the whole design research team. Sections of the summaries were categorized and analysed by the design research team to extract contextual design challenges and opportunities across Europe. Design challenges included, for example, an ambiguous balance between time and value of learning activities, and counterintuitive usability of digital tools for learning. Opportunities included, for example, chance to repurpose digital media, guided and fast documentation of learning processes, and visualization of learning achievements and learning journeys. Building on the opportunities with the aim to address the challenges, five visual prototypes were created in the first set of design studio sessions.

T**he second set of participatory design sessions** was steered towards discussing the role of reflection in school learning and the possibilities of expanding the time and space for reflection beyond the classroom. Feedback on the five visual prototypes was collected, and the challenges and opportunities, identified through the analysis of the first set of participatory design sessions, were further contextualized. During the sessions, the participants acknowledged, for example, the growing role of audio-visual media in the students' everyday life. In intending to merge these emerging informal practices to school practices, we discussed pedagogical practices around learner-created audio-visual podcasts.

Back in the design studio, during **the second set of design studio sessions**, the design research team translated the comments and suggestions of the teachers into affordances for two applications. The comments were analysed based on conversations among the researchers of the design team. Common themes were identified and differences were talked through. This resulted in further developed design challenges and design opportunities as well as concrete design ideas to be implemented in the prototypes. When implementing the changes, wireframes were developed, printed, talked through and iteratively improved while also considering comments of teachers and students from participatory design sessions (of set two). The design studio work was not only informed by comments of teachers and students but also by the critical discussion among the interdisciplinary design research team.

Lastly, **functional prototypes were developed** and produced in the software as the hypothesis phase. The prototypes were expected to ameliorate how learning activities are performed in the classroom. Interaction design, technical design and graphical layout were driven forward through iterative design work between the designers. Considering that the way the artefact is presented and behaves might affect how it will be taken up by teachers and students, a host of careful considerations were involved in the development of graphic interfaces of the tools.

Once the prototypes were functional, **four large-scale pilots were conducted** in a total of 1 324 European classrooms across 18 countries. During the pilots, the participating teachers were asked to use the prototype applications in the context of a project-based learning process that was scaffolded by learning activities, which included specific times for reflection. Although the teachers were encouraged to use both of the prototype applications, they were free to choose which ones to use or whether to use them at all. Prior to the pilots, the pilot-teachers attended workshops that discussed the novel learning activities and prototype applications.

Piloting teachers filled out various questionnaires, pertaining to both tool use, teaching methods and their effects in the class. A subset of teachers were interviewed, and some were asked to keep online diary of their piloting activities. As teachers were free to plan the details of their own pilot activities, the analysis was mainly qualitative, although some general descriptive statistics could also be gleaned from the data. In this study, we focused on the participatory design workshops, teacher's answers to questionnaires as well as conclusions drawn from all the data by Lewin et al. (2013).

4. Results

The results of the study are twofold: practical and theoretical. The apps designed are practical results of the qualitative research conducted to understand design challenges and opportunities in schools, to renew pedagogical practices and to pilot the new applications in context. To better understand how the apps facilitate reflection, we analysed the apps in relation to Fleck and Fitzpatrick's (2010) framework of levels of reflection, based on insights gained from the qualitative research. Similarly, based on the qualitative research, we analysed how the apps respond to the affordances of mobile devices that Roschelle & Pea, 2002 and Looi et al., 2009 presented.

4.1. Apps designed

In the contextual inquiry, and later in the participatory design and design studio sessions, we recognized emerging practices, especially the informal practices of recording and sharing audio-visual media rapidly, inside and

outside of the classroom – in school and during free time (see e.g., Taalas, Tarnanen, Kauppinen, & Pöyhönen, 2008). These practices formed opportunities for the design of the applications. Furthermore, during the contextual inquiry and participatory design sessions, we noticed that the existing school culture does not necessarily accept recording and sharing of audio-visual media among students, because the recording tools are often considered to disrupt class. Recognizing the potential of creating, showing, sharing and discussing audio-visual recordings for reflection, during the first set of participatory design sessions we agreed with the teachers that an application precisely designed for reflection would be a good goal to strive for. Based on these insights and agreement with the participants, we designed two mobile applications for recording audio-visual reflections: (1) ***ReFlex***, for individual reflection, and (2) ***TeamUp***, for group work reflection. Both are functional mobile applications based on open standards and free/libre/open source code, primarily designed to run on tablet computers and other touch-screen devices.

Although the design is optimized for mobile devices, it also runs on various devices, such as laptops and interactive whiteboards. The apps are designed for classrooms in which students work on projects independently and in small groups. Examples of a possible group learning process using Reflex and TeamUp include long-term (several months) self-organized learning environment (SOLE) projects, in which groups of learners are asked to perform online research on broad questions and to present their findings to others (Mitra, 2012; 2013). The functionality and appearance of ReFlex and TeamUp is described in the following.

4.1.1. ReFlex

ReFlex (see Figure 3 and http://reflex.aalto.fi) is a tool for learners to record 60-second audio-visual clips of their personal learning experiences, store the clips on a timeline and share them with teachers, peers and parents.

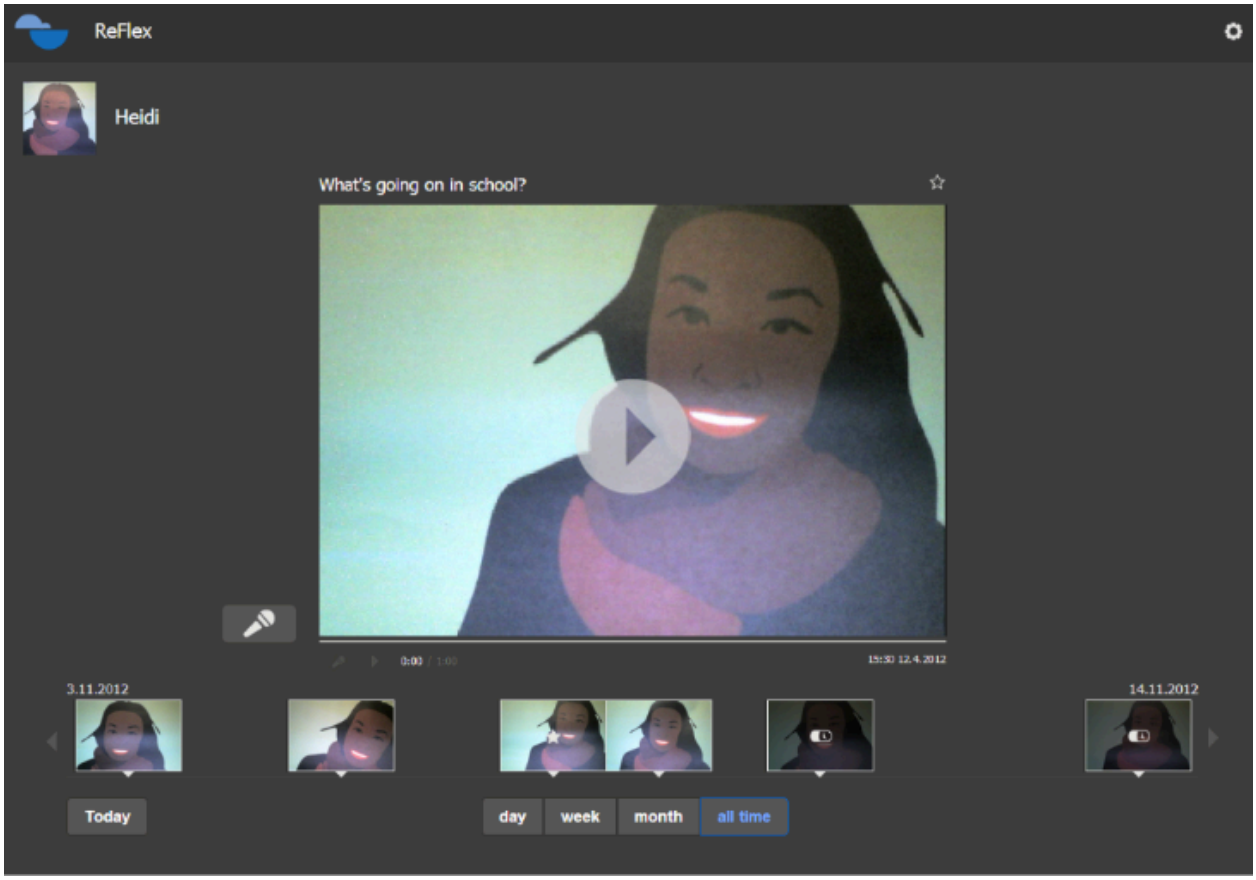

Figure 3. Illustration of the ReFlex interface.

The audio-visual clip is created and composed of a single still image, automatically taken with the front camera of the learner's device and of an audio recording made by the student. The 60-second time limit is considered to support students in focusing on the task of reflection and on presenting essential aspects of an experience in a

summarized form. The 60-second limit also enables teachers to follow the progress of many students in a relatively short time. In ReFlex, the reflection is scaffolded by a simple question "What's going on in school?" The question guides students to reflect on their learning experience and their general relationship to learning and school.

Once a recording is made, it can be listened to, and then either accepted or rerecorded. Once a recording is accepted, it cannot be removed, as students often tend to delete their initial thoughts after they've learnt and seen how naive their thoughts earlier were. However, returning to those initial naive ideas allows students to recognize misconceptions that were not clear to them earlier or process flows of their own approaches to learning that are not visible without artefacts as explicit reference points.

All recordings by one learner are stored on a personal timeline and are accessible for later viewing. In addition to the present, students may also create *time capsule* recordings for specific times in the future. Time capsules can be opened on their set date only and used as recorded messages to future self. At a time in the future, students can listen to, for instance, their hopes for accomplishments, their ideas, scenarios and considered challenges. Deliberately recording messages into the future might support a person to consider future as a concept more frequently.

From the entire pool of recordings, students can highlight important clips for revisiting. Revisiting recordings is further facilitated through a sliding toggle and a zoom function that can display recordings of one day, one week, one month or all time. Teachers can access learner recordings to see summarized updates of the students' progress and to plan individual guidance and consultation.

4.1.2. TeamUp

TeamUp (see Figure 4 and http://teamup.aalto.fi) is a digital tool for forming groups based on interests and for recording and sharing group work progress.

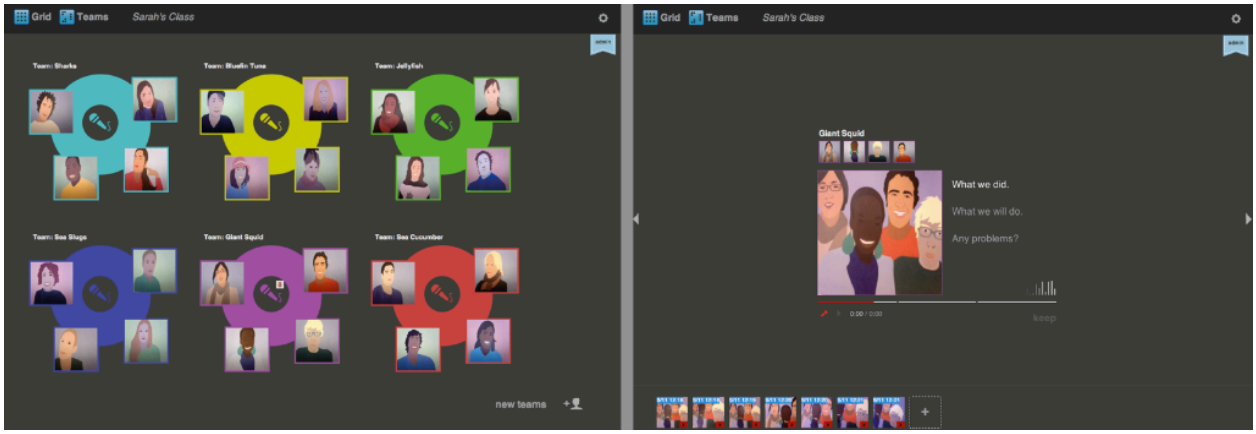

Figure 4. Illustration of the TeamUp interface.

Similarly to ReFlex, with TeamUp students can record 60-second audio-visual clips and store the clips on a timeline. Just like in ReFlex, each audio-visual clip contains a still image automatically taken with the camera of the device when the team members start to record. TeamUp, however, is focused on facilitating reflection for small groups and recordings created together after group sessions in which a specific topic was studied independently inside or outside of the classroom. To scaffold reflection, TeamUp asks each group to respond to three prompts: (1) What we did (2) What we will do and (3) Any problems? These prompts are based on good practices found in agile project work, especially in software development (see e.g., Beck & Andres, 2012). The application's scaffolds, however, should be regarded as complementary means to support reflection. They are not considered to promote deeper reflection alone; the role of the teacher is also an important one (e.g., Lakkala, 2010).

To encourage sharing and the building of appreciation for ongoing projects and work in progress, all members of the class can view all recordings of any group. Further, everyone can record feedback, questions or remarks to any group space, enabling students to reflect in depth about their own work while staying updated about other groups' activities. Students can switch between two views: a visualization of the groups plus their members and a grid-view displaying, for example, the seating order of the students in a traditional classroom. From both views, the recording space can be accessed, encouraging the recording of reflections. During the second set of participatory design sessions, teachers mentioned that the group visualization presents a valuable way for getting an overview of group members.

4.2. Analyzes of the apps for reflection

The directing design aim was to develop apps that are easy to use, support high-level reflection in K-12 classroom settings and support affordances for learning. To see whether the designs meet the design aim, we analyzed the apps in light of earlier research.

4.2.1. Reflection in learning with the apps

From the participatory design session and pilot studies we found that using ReFlex and TeamUp made it easy for teachers and students to integrate more reflection into everyday classroom learning. The following two excerpts illustrate the teachers' general positive views of using the apps:

> "*TeamUp was definitely the most popular among our pupils. At first they were very shy to record and always tried to have their classmates do it, but right now they all want to record and we have many recordings, although some are better than the others, obviously. At first it was very hard to complete the task in one minute, for myself and them, because you must have very strong summarising skills and the right timing to end a sentence in the time given."*

> *"They also practised oral presentations, the need for clarity and good diction. [The interviewer asks whether these challenges arising from the use of TeamUp prepared the pupils for some of the 21st century challenges.] Yes, because it helps develop skills such as comprehension, teamwork, summary and critical thinking, which are also reflected in the other school subjects. As pupils develop comprehension and speech skills, and summarising in Science, these are naturally reflected in the other subjects."*

The teachers were asked also to elaborate more on their views and describe the main benefits of recording reflections. Table 1 shows teachers' answers from the third phase of research, based on data-driven categorizations.

Table 1: Categories of the benefits of recording reflections

Categories of the benefits of recording reflections	**Teachers' answers (examples of the categories)**
Making process/progress visible, more understandable	Conceptualization of problems and experience in drafting. To do progress on the work visible. Further work to improve the organization. Track the progress of the work phases. Get in front of the problems, understand and overcome. Feedback received from the children about their experiences, difficulties, success on the work carried out. Understanding of emerging issues, the work group 's progress monitoring. Allow you to reflect on their activities.
Collaboration, cooperation, peer learning	Cooperation can improve. Peer learning. Being able to reach agreement in the group. Getting to know each other's values. Students learn about other students' views of their work, what can be improved. To contrast the different views of the students.
Improving skills of reflection, deeper learning	Learning what is important to bring to the reflection. A better reflection of the opportunity. Students analyze their operations. Reflect on their work, synthesize. Self-criticism and self-evaluation.

	Reflect on the work done to correct for self-criticism. Reflect Learning to communicate in a quick but effective. The meta-reflection and awareness of the guys. Total reflection analysis. These reflections are more mature, they have to perform them and analyze them. Project skills, taking responsibility, are developing.
Promoting interest, new ways of studying	Students found it interesting. It was new way to do reflection. Always great fun when the people themselves can hear / see back :-) The students enjoyed the work and learned a lot from it. It was more a tool to engage and motivate students for reflection. Interesting.
Making process easier	Easiness. Simple. Are registered with your picture and they can use it in anywhere at anytime.

As a conclusion from the participatory design workshops and teachers interviews, we may summarize that, while the apps alone did not encourage students to perform higher levels of reflection, well-guided use of the apps by teachers supported students to reach higher levels of reflection. To reach the higher levels of reflection, the teachers, for example, facilitated discussions with the students about their recordings and asked the students to explain and to elaborate them. Through this practice, the teachers were able to *lift* the students towards higher levels of reflection.

From the participatory design workshops and teachers interviews, we may also conclude that without teacher guidance ReFlex and TeamUp guided students to engage in the three first levels of reflection identified by Fleck and Fitzpatrick (2010): R0 Description, R1 Reflective description and R2 Dialogical reflection. The limited functionality and clear interface prompted students to use the applications for these purposes.

Additionally, ReFlex and TeamUp were also considered to support teachers in designing activities that could support students' practice of higher levels of reflection, R3 Transformative Reflection and R4 Critical Reflection, which include challenging students to reconsider their assumptions and to think about ideas in a wider frame. In the facilitation of students' transformative and critical reflection, to challenge them to reconsider their assumptions and to make them to think about their ideas in a wider picture, the possibility to return to the reflection recordings and to use them as starting points for discussions was found useful.

During the design research, the participatory design and the design studio sessions, we recognized various classroom use-cases the apps could support. In the process of designing the use-cases, we focused on functionalities and interface solutions that would afford teachers and students to integrate reflection in daily classroom learning. To keep the tools simple, we disqualified functionalities and interface elements that were considered uncritical for supporting reflective practices and highlighted others. For example, we did not further investigate the inclusion of video-recording functionalities, because some children were discouraged from recording that way. Also, we included buttons to get to the audio-visual recording space in TeamUp from anywhere in the tool with one click. Table 2 presents the recognized use-cases in relation to the levels of reflections they correspond to.

Table 2: Levels of reflection and use case of the ReFlex and TeamUp

Level of reflection	**Use case**
R0 Description R1 Reflective Description	By recording answers to the prompted questions of ReFlex and TeamUp, students can highlight important activities, plans and challenges of their work process. The limited recording time asks students to summarize their thoughts, making it even a constructive challenge, and makes reviewing of the recordings by teachers and

	students more probable.
R2 Dialogic Reflection	Viewing and creating recordings with ReFlex and TeamUp for others can foster dialogue and sharing among the people in a classroom. Recordings can be discussed and described collaboratively. Knowing that others can listen to the recordings further supports task focus. By sharing the URL with a TeamUp classroom on social media sites, pilot teachers extended discourse beyond their school and country.
R3 Transformative Reflection	One-to-one discussions with students, asking students to comment on past ReFlex or TeamUp recordings and recording ReFlex time capsules that are revisited after a course represent activities through which more in-depth understanding of the study work in project-based learning can be obtained. Teachers mentioned that premises, ideas and concepts can be formed, areas for further development can become more explicit, additional insights or supplementary explanations can be joined to past recordings and it can be determined whether learning goals are being met.
R4 Critical Reflection	With the permission of students, TeamUp or ReFlex recordings can be projected for whole class discussions. According to teachers who used the tools this way, future challenges can be articulated and a pool of strategies for how to tackle challenges in the future can be documented.

4.2.2. Affordances of the apps in classrooms

During the first set of participatory design workshops, teachers highlighted the need for classroom technology that does not isolate students behind devices and does not disrupt attention and collaboration in the classroom. Teachers also pointed out that technology in classrooms often monopolizes students' attention on learning the tool, as opposed to the study topics of class. To that end, teachers promoted the idea of the "*invisible computer*" (Norman, 1999), which refers to hiding technology from sight and consciousness. According to Norman (1999), computers should be designed to seamlessly merge with work processes and contexts and become non-disruptive information appliances: easy to use and designed to perform specific and sometimes single tasks well. In the first set of participatory design sessions, teachers considered always-on and easy-to-use tablet computers less disruptive than, for example, PC or laptop computers. According to the teachers, the form of the tablet computers decreases boundaries between students as the tablets can be placed flat on the table, take less space and can be opened and closed more rapidly than other electronic devices. This suggests that applications that are designed for reflection should perhaps not take the center stage in a reflection activity but accentuate reflection as an iterative activity within a learning process that takes place across a longer timeframe and several lessons.

To better understand the affordances of the designed apps, we considered the functionality of Reflex and TeamUp by analyzing the data of the participatory design sessions in light of the affordances described by Roschelle and Pea (2002) and Looi et al. (2009) (See Table 3 and Table 4).

Table 3: WILD affordances of ReFlex and TeamUp (based on Roschelle & Pea, 2002).

	Augmenting physical space	**Leveraging topological space**	**Aggregating coherently across all learners**	**Conducting the class**	**Act becomes artifact**
ReFlex	Creating and revisiting reflection recordings can guide and expand classroom activities. These activities can take place outside the classroom (e.g., When looking at some of the recordings, one	Students can arrange narratives of their reflection recordings on a timeline.	Individual students are provided with a personal space for reflection recordings. When recording, an image of the student is taken. The image can communicate the student's emotions.	Teachers can listen to reflection recordings and use the insights to guide the developments of the individual students or the entire class. Teachers can better understand where students are on their learning	Analysis of a large amount of reflections recording from many schools can present patterns of general activities and challenges among students.

	can see that the background of the picture is not the classroom, but a child's personal living spaces.)			paths.	
TeamUp	Creating and revisiting reflection recordings can guide and expand classroom activities, for example when students record reflections from home or record comments to other teams from their smartphones outside of class time.	In the grid view, colour codes and numbers inform about the old and new recordings. The amount of recordings a group created is presented for each group in the group view. Images of each student represent who belongs to which group.	All groups are provided with a space for recording reflections. When recording, an image of the student group is taken. The image can communicate the students' emotions and group dynamics.	Teachers can listen to reflection recordings and guide students based on mentioned progressions and challenges. Teachers can record feedback and questions for students. Teacher can play recordings as examples to the whole class.	Analysis of a large amount of reflection recordings from many schools can present patterns of general activities and challenges among students. Analysis of the recordings at classroom level can present group dynamics and challenges within groups.

Table 4: Mobile Computing affordances of ReFlex and TeamUp (based on Looi et al., 2009).

	Multiple entry points and learning paths	**Supporting Multimodality**	**Supporting Improvisation in situ**	**Creation and sharing of artifacts on the move**
ReFlex	Reflection recordings can be created about any learning-related topic at any time and space.	The app can be accessed through different devices (i.e., tablets, smart phones, PCs). The app makes use of hearing (recording), sight (image) and touch (touch screen use). With this, multi-modality is supported through the senses.	Students can record, for example, learning aspirations and insights at any time and place on any topic of their interest.	All reflection recordings are shared with the teacher in real time. By sharing a link the recordings can be shared with anyone with Internet access and a web-browser.
TeamUp	Creating and listening to the reflection recordings can guide students to ask open-ended questions about their activities, challenges and intentions and may lead a group to new learning paths.	The app can be accessed through different devices (tablets, smart phones, PCs). The app makes use of hearing (recording), sight (image) and touch (touch screen use). Multiple modes of engagement are supported through the sense.	Groups can express and document insights about a project at any time and place on any topic of their interest.	All reflection recordings are shared with the class in real time. By sharing a link, the recordings can be shared with anyone with Internet access and a web-browser.

This analysis shows that, although ReFlex and TeamUp are limited in their functionality and purpose, they meet most of the affordances described in the earlier studies. Multimodality is partly supported by enabling students and

teachers to approach reflections through different sense modes but also by offering children different modes of engagement. However, further exploration of the applications in use would be required to better understand the kinds of modes the apps afford students and teachers to perform in action.

5. Conclusions and future work

During the pilots, we found that not all students enjoyed the recording of audio-visual reflections. In early prototypes, we supported the recording of videos and noticed that some students felt uneasy in front of the camera. Therefore, for the pilots, we decided to record still images and audio. Teachers and students considered the benefits of the audio-recording mode to lay on the ease and speed of creating reflective artifacts, as well as in the informal character and personal touch of the recordings. In the participatory design sessions, teachers and students mentioned that they are more likely to record reflections with spoken words than by writing; for teachers, recording spoken words requires less effort than writing qualitative, highly reflective text. In comparison to written reflections, teachers reported that after overcoming the learning curve of using the apps, the recording of audio-visual reflections would save time. We suggest that audio-visual reflection is a useful form of reflection in classroom learning.

In the participatory design workshops, teachers suggested that the recorded reflections could also support the development of listening skills, facilitate an increased listening to others and conceivably lead to more equitable distribution of teachers' support for students. For example, after spending considerable classroom time focusing on the challenges of one group, teachers were able to listen to reflection recording of another group after the lesson and guide them during a follow-up session more directly. The participatory design sessions and pilots suggested that reflection recordings also support peer learning and self-evaluation through the possibility to follow and share work in progress. By sharing and revisiting their recordings over time, students could perceive their personal development and teachers could learn about the individual challenges of the students and adjust their teaching accordingly. (Lewin, McNicol, & Haldane, 2013.) It was a deliberate design decision to not support deletion of recordings, but let the students to be able to see their possible misconceptions in the earlier recordings, and the teachers to see the students' entire learning process.

Since the apps were designed to be used especially in collaborative learning settings, it would be important to investigate how students are collaborating, and especially to let them evaluate *their* learning while working together. The current design of the study made it possible only to analyze personal learning results in collaborative settings, in the future it would be also interesting to design a study to further explore the effect of using the apps after each other, exploring the depth of learning on intra-mental and inter-mental levels (See e.g. Vygotsky, 1930-1934/1978).

The design of the tools is mostly based on qualitative research. Nevertheless, website log data derived from the apps' websites, where anyone can take the tools in use, presents evidence of the wide use of the tool in school learning. The quantitative data from the website logs shows that the tools are used in hundreds of classrooms in tens of countries daily. This indicates that the apps have been used outside of our pilot studies, and the active use strongly points out the interest in using them.

We may speculate that the use of audio-visual reflection with the apps could create a path toward more process-oriented and qualitative assessment. When used for a longer time, such as a month or one semester, teachers and students alike can see and evaluate the progress of their studies. To explore this, it is necessary to design a longitudinal study of teachers and students using the apps continually for one semester or even entire school year.

Our research indicates that there is a potential for fostering a practice of reflection in classroom learning through the use of carefully designed apps for audio-visual recording. However, Cobb, Boufi, McClain & Whitenack (1997) remind that, although socio-cultural tools and activities are essential for reflection, these tools cannot guarantee the development of habitual in-depth reflection. For example, in a reflective classroom discourse, learners may choose not to reflect, resulting in an uneven participation. Further research should focus on how the tools can be used to support habitual reflection skills. More research is also required on the differences between the cognitive processes required for audio-visual recording in contrast to written reflections, as well as on the advantages of both modes for the development of children. In addition, the role of revisiting past recordings, creating recordings and opening time-capsule recordings in learning process needs to be further studied. Our research confirmed earlier findings that reflection can reach higher levels when facilitated not by tools alone but

combined with human interaction (see for a review, Kori et. al, 2014). More detailed analyses related to teachers' guidance and peer support for reflection could indicate the kinds of interactions that could strengthen reflection. One interesting approach to study the relation of teachers' scaffolding, peer support and scaffolding provided by technical tools is to study distributed scaffolding, in which various supporting elements are implemented in complex educational settings (e.g., Puntambekar & Kolodner, 1998).

References

Alexander, B. (2004). Going nomadic: Mobile learning in higher education. EDUCAUSE Review, 35(5), 29–35.

Beck, K. & Andres, C. (2012). Extreme programming explained: embrace change. Boston: Addison-Wesley.

Bell, P. (2004). On the Theoretical Breadth of Design-Based Research in Education. Educational Psychologist, 39(4), 243–253.

Boud, D., & Walker, D. (1998). Promoting reflection in professional courses: The challenge of context. Studies in Higher Education, 23(2), 191-206.

Brown, A.L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. The Journal of the Learning Sciences, 2(2), 141-178.

Bruner, J. (1986). Actual Minds, Possible Worlds. Cambridge, London: Harvard University Press.

Candy, P., Harri-Augustein, S., & Thomas, L. (1985). Reflection and the self-organized learner: Model of learning conversations (pp. 100-116). In D. Boud, R. Keogh, & D. Walker (Eds.), Reflection: Turning experience into learning. London: Kogan Page.

Cranmer, S., & Ulicsak, M. (2011), D2.1. Summary report of scenario development process. A public deliverable of the iTEC -project. Retrieved from http://itec.eun.org/web/guest/deliverables

CISCO (2012). Cisco Visual Networking Index: Forecast and Methodology, 2012–2017. White Paper. Retrieved from http://www.cisco.com/c/en/us/solutions/collateral/service-provider/ip-ngn-ip-next-generation-network/white_paper_c11-481360.html

Cobb, P., Boufi, A., McClain, K., & Whitenack, J. (1997). Reflective Discourse and Collective Reflection. Journal for Research in Mathematics Education, 28(3), 258-277.

Collins, A. (1992). Towards a design science education. In E. Scanlon, & T. O'Shea (Eds.), New directions in educational technology. Berlin: Springer.

Davis, A. (2004). Co-authoring identity: Digital storytelling in an urban middle school. THEN: Technology, Humanities, Education, & Narrative Journal, 1(1). Retrieved from http://thenjournal.org:16080/feature/61/

Dewey, J. (1944). Democracy and education. New York: Free Press. (Original work published 1916).

Engeström, Y. (1987). Learning by expanding. Helsinki: Orienta-Konsultit Oy.

Fallman, D. (2005). Research-oriented design isn't design oriented research. Proceedings of Nordes: Nordic Design Research Conference, Copenhagen, Denmark.

Fallman, D. (2007). Why research-oriented design isn't design-oriented research: On the tensions between design and research in an implicit design discipline. Journal on Knowledge, Technology and Policy, Special Issue on Design Research, 20(3), 193–200.

Fies, C., & Marshall, J. (2006). Classroom response systems: A review of the literature. Journal of Science Education and Technology, 15(1), 101-109.

Fleck, R., & Fitzpatrick, G. (2010). Reflecting on reflection: Framing a design landscape (pp. 216-223). Proceedings of the 22nd Conference of the Computer-Human Interaction Special Interest Group of Australia on Computer-Human Interaction (OZCHI 2010). Brisbane, Australia: ACM.

Hannula, M., Suoranta, J., & Vaden, T. (2005). Artistic research: theories, methods and practices. Helsinki: Kuvataideakatemia.

Hickey, D., & Rehak, A. (2013). Wikifolios and participatory assessment for engagement, understanding, and achievement in online courses. Journal of Educational Multimedia and Hypermedia, 22(4), 407-441.

Hallnäs, L., & Redström, J. (2001). Slow technology; designing for reflection. Personal and Ubiquitous Computing, 5 (3), 201-212.

Kori, K., Pedaste, M., Leijen, Ä. & Mäeots, M. (2014). Supporting reflection in technology-enhanced learning. Educational Research Review, 11, 45-55.

Koskinen, I., Zimmerman, J., Binder, T., Redström, J., & Wensveen, S. (2011). Design research through practice - From the lab, field and showroom. Boston: Morgan Kaufmann.

Lakkala, M. (2010). How to design educational settings to promote collaborative inquiry: Pedagogical infrastructures for technology-enhanced learning. Studies in Psychology; vol. 2010, no. 66. Helsinki: University of Helsinki.

Leinonen, T. (2010). Designing learning tools: Methodological insights. Ph.D. Aalto University School of Art and Design. Jyväskylä: Bookwell.

Leinonen, T., Toikkanen, T., & Silfvast, K. (2008). Software as hypothesis: research-based design methodology. In 10th Anniversary Conference on Participatory Design 2008, PDC '08. Bloomington, IN: ACM.

Lewin, C., McNicol, S., & Haldane, M. (2013). Cycle 3 Evaluation Report. European Schoolnet: iTEC Project. Public Deliverable.

Lipponen, L. & Hakkarainen, K. (1997). Developing culture of inquiry in computer-supported collaborative learning. Proceedings of 2nd international conference on Computer support for collaborative learning (CSCL 1997), New York: ACM.

Looi C.K., Wong L.H., So, H.J., Seow, P., Toh Y., Chen, W., Zhang, B., Norris, C., & Soloway, E. (2009). Anatomy of a mobilized lesson: Learning my way. Computers & Education, 53(4), 1120–1132.

Mitra, S. (2012). Beyond the hole in the wall: Discover the power of self-organized learning. TED Books.

Mitra, S. (2013). SOLE: How to bring self-organized learning environments to your community. Retrieved March 16, 2013, from Technology, Entertainment Design (TED): http://www.ted.com/pages/sole_toolkit

Norman, D. A. (1999). The invisible computer: why good products can fail, the personal computer is so complex, and information appliances are the solution. MIT press.

Paavola, S., Lipponen, L., & Hakkarainen, K. (2004). Models of innovative knowledge communities and three metaphors of learning. Review of Educational Research, 74(4), 557-576.

Puntambekar, S. & Kolodner, J. L. (1998). Distributed scaffolding: Helping students learn in a learning by design environment (pp. 35-41). In A. S. Bruckman, M. Guzdial, J. L. Kolodner, & A. Ram (Eds.), ICLS 1998, Proceedings of the International Conference of the Learning Sciences.

Roschelle, J., & Pea, R. (2002). A walk on the WILD side: How wireless handhelds may change computer-supported collaborative learning. International Journal of Cognition and Technology, 1, 145–168.

Roschelle, J., Penuel, W. R., & Abrahamson, A. L. (2004). Classroom Response and Communication Systems: Research Review and Theory. Proceedings of Annual Meeting of the American Educational Research Association, San Diego, CA.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: theory, pedagogy, and technology (pp. 97-118). In K. Sawyer (Ed.), Cambridge Handbook of the Learning Sciences. New York: Cambridge University Press.

Schön, D. (1983). The reflective practitioner, how professionals think in action. New York: Basic Books.

Senge, P. M. (2006). The Fifth Discipline: The Art & Practice of The Learning Organization. Broadway Business.

Sharples, M. (2000). The design of personal mobile technologies for lifelong learning. Computers & Education, 34, 177-193.

Sharples, M. (2013). Shared orchestration within and beyond the classroom. Computers & Education, 69, 504-506.

Taalas, P., Tarnanen, M., Kauppinen, M., & S. Pöyhönen (2008). Media landscapes in school and in free time – two parallel realities? Nordic Journal of Digital Literacy, 3, 240-256.

Vygotsky, L. S. (1930-1934/1978). Mind in society: Development of higher psychological processes (14th ed.). MA: Harvard University Press. (Original manuscripts ca. 1930-1934).

Williams, J. B., & Jacobs, J. (2004). Exploring the use of blogs as learning spaces in the higher education sector. Australasian Journal of Educational Technology, 20(2), 232-247.