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Mobile English learning: An evidence-based study with fifth graders

Jacobijn Sandberg, Marinus Maris*, Kaspar de Geus

ISLA, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands

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ABSTRACT

Three groups participated in a study on the added value of mobile technology for learning English as a second language for primary school students. The first group had classroom lessons in English about zoo animals and their characteristics. The second group took classroom lessons and worked with a mobile application on location in a public zoo. The third group received the same treatment as the second but, as an extension, was allowed to take the mobile application home for a fortnight. A pre- and a posttest were conducted to measure the individual change in mastery of a set of targeted English words. The results showed that the group which took the mobile phone home improved the most. However, when the additional learning time, spent apart from school, of this third group was controlled for, the superior performance of the group disappeared. The results indicate that students are motivated to use the application in their spare time and that this benefits their learning. The conclusion is that formal school learning can be augmented by learning in an informal context, away from school.

1. Introduction

Technology supported learning has a long history. From the early sixties on, new technological developments have inspired and supported new innovative learning arrangements. From computer-assisted learning, to Intelligent Tutoring Systems, to open learning environments, technological advances have been used to reduce classroom constraints during learning and to adapt learning materials to the level of knowledge of individual students. In particular, portable devices, coupled with intelligent teaching techniques allow learners to learn what, when, where and how they want. One such portable device is the modern mobile phone. While the first generations of mobile phones did not offer much functionality beyond phoning and text messaging, the latest 3G generation of smart phones offers far greater possibilities to offer multimedia content, location-based learning materials, and serious games to enhance the learners' enjoyment and motivation (Claudill, 2007). As learning with a mobile phone is fundamentally different from classroom learning, a new field of study has come into shape, namely that of Mobile Learning (Sharples, 2000).

Using a mobile device in a learning context allows a learner to learn anywhere, anytime. Moreover, Internet accessibility allows instant communication with other users, while GPS-functionality makes it possible to access content that is relevant to a learning goal attached to the specific location of the learner. Increasing bandwidth facilitates the combination of different media (video, images, text and sound).

The possibility to learn anywhere, anytime also fits well within a life-long learning framework (Holzinger, Nischelwitzer, & Meisenberger, 2005). At present times, learning is no longer confined to a particular period in life (from four to mid-twenty) nor solely in the hands of formal educational institutes. It is widely acknowledged that children do learn not only at school, but informally out of school as well. Their informal experiences outside the classroom may offer just as meaningful learning opportunities as the structured learning environment established within schools. The availability of digital learning material allows learners access to relevant content inside as well as outside the classroom. When they access such content through a portable device, the flexibility extends beyond that of the home computer. The learner is no longer restricted to learn at fixed locations. Moreover, the location where learning takes place can become a relevant part of the learning context (Baldauf, Dustdar, & Rosenberg, 2007). Being presented with architectural information while looking at a particular building, in the context of an art history class, could be an example.

Although obviously mobile learning may be advantageous to learners, there are also limitations to be considered. For example, the mobile phone has a small screen, which means that little information can be presented at once. Furthermore, the input mechanisms are

* Corresponding author. Tel.: +31 20 5257460; fax: +31 20 5257490.
E-mail addresses: j.a.c.sandberg@uva.nl (J. Sandberg), marinus.maris@gmail.com (M. Maris), kaspar@degroep.org (K. de Geus).

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limited, compared to using keyboard and mouse, and need to be adequately designed to allow easy handling by the user. Also, it is not yet possible to respond in real-time to the learners' actions in the same way a good teacher would (Chinnery, 2006). This means that a careful design is needed to present information on the screen that is inspectable for the learner at a glance. Next, careful consideration has to be given to the way in which the learner interacts with the mobile application. These limitations pose constraints on the kind of learning material that can be offered. For these reasons, mobile learning is best suited for small learning objects that may just take a few minutes to process.

An interesting question therefore is whether a mobile application in the style of a serious game offers sufficient learning opportunities to compete with learning with a human teacher. In this study we introduce a mobile application in the context of learning English as a second language at the level of primary school. We will compare the learning results of a group taking English lessons at school without using a mobile application to the results obtained by two other groups that both received classroom lessons and used a mobile learning application. The remainder of this article is organized as follows. First, we present the necessary theoretical background (Section 2). Then we will introduce the way this study has been carried out (Section 3). Next, we will present the results (Section 4) of this study, and finally, in Section 5, conclusions will be drawn and directions for future work will be discussed.

2. Theoretical background

Modern learning theory stresses learning as an activity employed by the learner him- or herself. Knowledge cannot be handed over from one person to another, i.e. from the teacher to the student. Knowledge has to be constructed by the learner himself. The conditions under which the learner is able to do so form the principles of constructivism:

- Learners construct their own knowledge by integrating new knowledge with previously acquired knowledge (construction principle).
- Learners profit from working with real-life tasks in which they can perform meaningful actions to promote their own understanding (authenticity principle).
- Learners profit from multiple perspectives or representations allowing them to form rich mental models of existing phenomena (elaboration principle).
- Learners profit from collaboration with peers allowing them to articulate, expand and refine their knowledge (social principle).
- Learners set their own learning goals, create a personal understanding of the task at hand and plan and monitor their own learning activities (self-regulation principle).

In the case of constructivism, the availability of rich information sources, such as web-based resources and simulations, interactive representational formalisms, and computer-mediated communication supports the development of learning environments in which constructive learning is supposed to take place (Akhras & Self, 2002). At present, new technologies are strongly associated with constructivist approaches to learning. Although different views on constructivism exist, the principles stated above are shared by most advocates of constructivism (Brown, Collins, & Duguid, 1989; Jonassen, 1991).

2.1. Learning English as a second language

In many countries around the world, English is being taught as a second language at the level of secondary education (De Mooij, 2005; Nelson & Paek, 2007). Previous research (Goorhuis-Brouwer & De Bot, 2005) has shown that children are able to acquire two languages in parallel, from an early age on. Moreover, proficiency in the primary language may even increase through the acquisition of a second language. One of the key elements underpinning second language learning is the acquisition of an elaborate vocabulary, both active and passive. Active vocabulary is needed in oral and written communication, where one has to be able to produce words and sentences. Passive word knowledge is needed to understand spoken and written texts. Second language learning projects are being implemented at the primary level of education. In The Netherlands, an ongoing project promotes and implements the learning of English at an early age, from 4 years onwards. This project is initiated by the Dutch EarlyBird foundation. EarlyBird has established a program for teaching and learning English through all grades of primary education. Some schools have native speakers on their payroll, working together with the group (class) teachers. The majority of the EarlyBird schools, however, do not have native speaking teachers, one of the reasons to seek for various ways of input in native English in other ways. The exposure to English varies from 90 min per week to well over 3 h (weekly schedule contains 22 h). The emphasis in the early years (ages 4 to 7) is on listening, understanding and speaking. Reading and writing are carefully introduced in the middle years of primary education (ages 8 to 10). Children are encouraged to participate in playful situations with ample attention to communicative skills.

2.2. Mobile learning

Mobile learning (M-learning) concerns the acquisition of knowledge through a mobile device. Mobile learning research is conducted at different levels: a macro, meso and micro level. At the macro level, research focuses on how society and its institutions can support an increasingly mobile population. At the meso-level research is being conducted on how mobile learning technology can be coupled with other forms of learning taking place in organizations and schools. At the micro level, research aims for a clarification of the conditions necessary for mobile learning to be successful for an individual or a group of learners.

The current interest in mobile learning is led by two major developments. First there is the wide-spread penetration of mobile technology, combined with increasing technological capabilities, such as location detection, Internet access, and multimedia presentation (video, images, text and audio). This development offers the possibility to create learning environments in accordance with constructivist principles, in which the social context and self-management of learners are central. Combining different media in a learning context is in line with the "dual-channel hypothesis" (Mayer, 2003). This hypothesis states that humans process multimedia information in separate channels in parallel. This means that people can process information from different sources concurrently, allowing them to create richer memory

structures of the information in focus. This universal human capacity can be exploited in current, advanced portable devices. Another major development is the growing consensus that learning in informal contexts is just as important as learning in the context of formal education. This development relates to the constructivist principle of authenticity, allowing learners to be engaged in activities meaningful to them (Mayer, 2003; Sharples, 2000). Meaningfulness can be realized in two ways. First by presenting content that can be linked to previously acquired knowledge and secondly by presenting information which is applicable to the situation at hand.

Fransen (2008) presents an overview of the potential advantages and disadvantages of mobile learning. The freedom to learn what, where, when and how one likes is one of the major advantages. Norbrook and Scott (2003) suggest that the most motivating factor when using a mobile device is the fact that the device is always immediately available anywhere you want to use it. A second major advantage is the possibility to adapt learning content to the context the learner finds him- or herself in. Fransen (2008) stresses the fact that little research as yet has been done on the effectiveness of mobile learning. How does mobile learning compare to other forms of learning? Are learners really able to learn with a mobile device? This is further elaborated by Sharples, Taylor, and Vavoula (2007) who make the observation that most studies on the usability of mobile phone applications for learning focus on questionnaire analysis. Moreover, he states that most questionnaires are not methodologically sound, resulting too often in insignificant results. In other words, there are hardly any studies that measure effectiveness of the mobile learning application in a quantitative manner.

The potential of mobile learning is well explained by Kukulska-Hulme and Shield (2008). Mobile learning can take place both in the classroom and outdoor, across formal and informal settings. As mobile learning can also be done outside of the classroom, without any teacher supervision it may be regarded as a threat by the teacher. This must be considered carefully when designing applications.

A clear trend is the development of game-based mobile learning applications. They are developed on the basis of serious game principles which combine play and fun elements with serious elements. The major aim of a serious game is not entertainment but the attainment of a serious goal. The game elements are meant to motivate and engage the learner (Susi, Johannesson, & Backlund, 2007). The major difference between serious digital games and the games that teachers play with students in normal lessons is that the locus of control is placed completely with the learner (Stapleton, 2004). When we look at current mobile applications for language learning, however, we notice that these are mostly text-based (Kukulska-Hulme & Shield, 2008) and use an "intelligent tutoring" model (Bull, 1994; Chen & Chung, 2008; Collins, 2005; Thornton & Houser, 2005). These applications are developed for secondary school level or adult users. Research studies on these applications have demonstrated their potential as a learning vehicle. Students in general report that they profit from the freedom to learn when and where they want and that they can use snippets of spare time for learning.

A mobile learning application typically augments an already existing learning context, either within a school or e-learning course. Hence, the presented material on the phone should be easy recognizable as such and not present material out of context. Although there exist many mobile learning applications (e.g. in app-stores on the Internet), their usability for professional educational institutions is very limited as they often do not represent the content, format nor methods used by these institutions.

2.3. Mobile language learning studies

In this section, a number of (case) studies, pertaining to mobile language learning, are discussed.

2.3.1. MESLL

Most case studies focus on MESLL, i.e. Mobile Email or SMS Language Learning, dubbed by Li, Ogata, Hashimoto, and Yano (2009). They investigated the added value of an adaptive learning system for Japanese Kanji characters using email. Learning content was adjusted to the learners' interests, their level of proficiency as well as their learning habits, in particular the time and place where they learned. Their study used a control group, which received traditional MESLL type of lessons (pushed at a fixed time and place and no adaptation to the learners' level of proficiency) and an experimental group which worked with the adaptive system. Both groups consisted of five non-native speakers learning Japanese. A pre- and posttest were conducted to investigate the learning effects, and a questionnaire was used to gauge the learners' attitudes towards the systems in use. The results suggest that Group 2 achieved better results and liked the system better for learning the characters.

Levy and Kennedy (2005) present a study on learning Italian vocabulary. SMS messages were sent to the mobile phones of students (situated in Australia) to learn vocabulary related to the lessons taught during class. They also asked for feedback in the form of quizzes and follow-up questions. No quantitative performance measures were reported. In a later study, Kennedy and Levy (2008) reported a system that sent "pushed" SMS messages for learning Italian words, that is, SMS messages were sent at a much lower frequency and with higher information content. Although they noted improved results, they found that each user has differences in preferences related to the rate and information content of the messages.

Thornton and Houser (2005) describe a study which used mobile phones to teach English at a Japanese university, comparing web-based with SMS-based learning. The results indicated that students who learned by SMS remembered over twice the number of vocabulary words as the students who learned through the web-interface. The conclusion was that the SMS-based lessons had been more effective because they were delivered as push media, rather than passive email messages. This motivated the students to rehearse more frequent which resulted in better retention of the material. No quantitative analysis was provided.

Chen and Hsieh (2008) present a study using SMS and MMS messages for the study of English vocabulary. They experimented with four types of annotations: words only, words with written annotation, words with pictorial annotation and words with both written and pictorial annotations (dubbed "Learning Content Representation" types). The experiment was conducted among 160 students from the Industrial Technology Education Department in Kaohsiung. The students were divided into four groups of 40 students each, based on a pre-measurement of their short term memory (STM) capacity for their verbal and visual learning capabilities. The study addressed particularly the issue of content adaptation for these four different cognitive types of learners. In the experiment, all participants received the same 24 questions, divided equally into the four types. The results showed that indeed, providing learning content with pictorial annotation in a mobile language learning environment helps learners with lower verbal and higher visual ability, while the provision of learning content with both written and pictorial annotation helps learners with high verbal and visual ability. Furthermore, the study demonstrated the

validity of both Dual Coding and Cognitive Load Theories, that is, using more than one modality is more effective than the use of a single modality.

2.3.2. Comparisons between PC-based and mobile learning

Kiernan and Aizawa (2004) report a study for learning English as a second language for Japanese freshmen students in engineering. The students were divided into three groups: group 1 used mobile email, group 2 used computer email, and group 3 only oral conversations. The task was for one student to tell a picture book story to another student. The listener had to sort out the corresponding pictures and number them in the right order. A second task was a role-playing game in which the students had to plan a date. No significance in learning difference between the three groups was found, that is learning with the mobile phone was of comparable quality compared to learning with the PC or by oral conversation.

A different approach is to regard learning with the mobile phone as an extension to web-based learning rather than a replacement. Browne and Culligan (2008) for example describe a learning system with the option to learn items on the mobile phone that were not learned yet through the web-interface. In this study, vocabulary flashcards were used to show the material to learn. There was no mention of quantitative measurements.

In NCCA (2009), the results of an Irish vocal learning study on six Irish schools are reported. On a website, teachers could create the lessons. Using their mobile phones, students would call the system and verbally respond to the questions. All conversations, also between students, were recorded in order to provide feedback later by the teacher. All the participating teachers reported an improvement in Irish language competency of their students. As the results show, before the experiment 27% of the students were very good and 36% were good at speaking the language, while afterwards 75% was very good and 25% good. The authors argue that these kinds of learning tools engage the learner more as a part of the responsibility is handed to the learner.

2.3.3. Game based

Mitchell and Saville-Smith (2004) argue that computer games are engaging and seductive, assuming a well-designed game which motivates the player to continue using rewards and feedback. Schwabe and Göth (2005) describe the design and analysis of a hide-and-seek mobile game exploring the opportunities to support learning through an orientation game in a university setting. Their evaluation shows that features such as map-navigation and "hunting and hiding" lead to excitement and fun. The game success is based on the motivating design of the game itself. These studies indicate that game-based learning may have a positive effect on learning quality.

2.4. Implications for our study

From the overview of the literature it occurs that most case studies focus on an adult target audience, and that studies reporting on quantitative evidence of a learning effect using mobile phones are rare. Furthermore, they differ in many respects, that is, in their pedagogical framework, in the extent to which they make use of context awareness, whether they incorporate learner cooperation, and how learning content is being delivered. Given the insights gained from these studies, it becomes clear that a tight coupling between text, speech and images are required to create a rich representation of the target learning material. Moreover, when learning content is combined with game elements, motivation of the learner is positively affected.

In the evidence-based study into mobile learning at primary school level presented in this paper, we focused on answering the question: given a well-designed application, how exactly does mobile learning affect learning performance? As we thoroughly incorporated successful design principles, our expectations were:

1. Children who use the mobile application will outperform children who just follow English lessons in class.
2. Children who are allowed to take the mobile application home with them will be motivated to use it on their own account.

3. Method

3.1. Design

This study was based on a quasi-experimental pre- and posttest design in which each of three participating schools represented one condition. The schools insisted on keeping the class structure intact. Therefore, the children could not be randomly assigned to the conditions. The first condition was a control condition. The children from this group took English lessons at school provided within the context of the EarlyBird program. The children in the other two conditions worked both with the EarlyBird material in school as well as with the targeted mobile application especially developed for this study. The children from Condition 2 went to a public zoo ("Diergaarde Blijdorp" in Rotterdam) with our application to learn the English words related to zoo animals in the context of the living animals themselves. After the zoo visit they handed in their phones. The children from Condition 3 also went to the zoo with our application. Above that they were allowed to keep the mobile phone with them for two weeks. Before the learning phase started for each condition, an English vocabulary test (pretest) was administered. At the end of the learning phase the same test was administered again (posttest). For the data analysis, the difference score between the pretest and the posttest was the dependent variable whereas the learning method which had three levels (conditions) was the independent variable.

3.2. Participants

Grade 5 children, participating in the EarlyBird program have been introduced to two formal skills: reading and writing. The experimental study involved 85 fifth graders from three different schools. The results of 10 of the subjects were removed because of missing data (4) or because they had to share a mobile phone in condition 3 (6). Of the 75 subjects left, 33 were boys and 42 were girls. The age ranged from 8 to 10. The control group ($N = 29$) in fact consisted of two different classes, 1a ($N = 10$) and 1b ($N = 19$), which were taught by two

different English teachers. Unfortunately the teachers did not spend a comparable amount of time on the English lessons during the experimental phase. The first group spent approximately 4.5 h while the second group spent 7.5 h. The final analysis of the learning effects took these differences in learning time into account.

3.3. Materials

3.3.1. Learning theme and target words

As theme we chose zoo animals. The reason for this choice is that first, most children are already familiar with the names of zoo animals in their native language. Secondly, animals are a popular topic in early English programmes and are offered as of group 1. Thirdly, this theme would allow us to use the mobile application at location, i.e. at the zoo. Hundred words were included in the lessons as target words. The words concerned animal names (*snowy owl*, *prairie dog*), the perceivable characteristics of animals (*wings*, *flipper*) the habitat of animals (*savanna*, *ocean*), the preferred food of animals (*plankton*, *hay*), the behavior of animals (*to hunt*, *to hatch*), and an abstract category classifying the animals (*scavenger*, *mammal*).

3.3.2. The EarlyBird material

The zoo animals were selected in a constructivist way: new concepts and words would be introduced in a familiar setting. A lesson plan was devised which contained the following items:

- A general introduction on the 25 animals. This information could be read from a hand-out, but could also be played on the video projector or classroom computers. A slideshow presentation with pictures of the animals was accompanied by stories read by a native speaker.
- The second part of the hand-out comprised assignments such as word webs and other forms of classification. The level of English of the written and spoken information was based on the course books the learners mostly use at the level of Group 5.

3.3.3. The MEL application

For the study, T-mobile Pulse smartphones made by the Chinese company Huawei were used. These phones run the Android 1.5 platform and have the common modern features such as GPS, a touchscreen interface and a digital camera. They also have an SD-card slot and come standard with a 2 Gb SD-card. This storage was necessary for the use of video clips and high quality audio files. The SIM-card was removed from the phones to refrain the children from calling or freely accessing the Internet (Fig.1).

The MEL-application, in the form of a serious game, was built around 25 animals distributed over five continents (Africa, Asia, South-America, North-America, Oceania). As the game was used during the visit to the zoo as well as at home, there were two separate game modes: one especially geared to the zoo situation, were the children were led to the different animals by GPS and one, independent of the GPS-function, allowing the children to access the different continents and the animals therein, in any order. Five different game types were embedded in the application:

1. multiple choice quiz, which asked a question and gave four possible answers of which one is correct,
2. a spelling quiz, which asked a question and gave the answer spelled in three different ways of which one is correct,
3. a memory game, where a picture and a word that represent the same object had to be matched,
4. a *Yes* or *No* game, where a question about a picture was asked that could be answered by either "*Yes*" or "*No*", and
5. a jigsaw puzzle, where questions could be answered by dragging tiles to the correct gap in an image.

Important to note is that all questions and answers were represented by both text and audio. When one of the multiple choice or spelling answers was played out loud the written corresponding item was highlighted, so the user knew which item was being played. The child had the option to replay any text to be vocalized throughout the game (Fig.2).

Before the start of each game, a video clip about the animal was played. The clip contained all the information needed to answer the questions that were subsequently posed in the corresponding games. All audio files as well as the spoken text in the video clips were recorded by a native English speaker. For the analysis of the game play, all clicks where logged, as well as information about location, answers and scores.

Fig. 1. Students playing with the MEL-application.

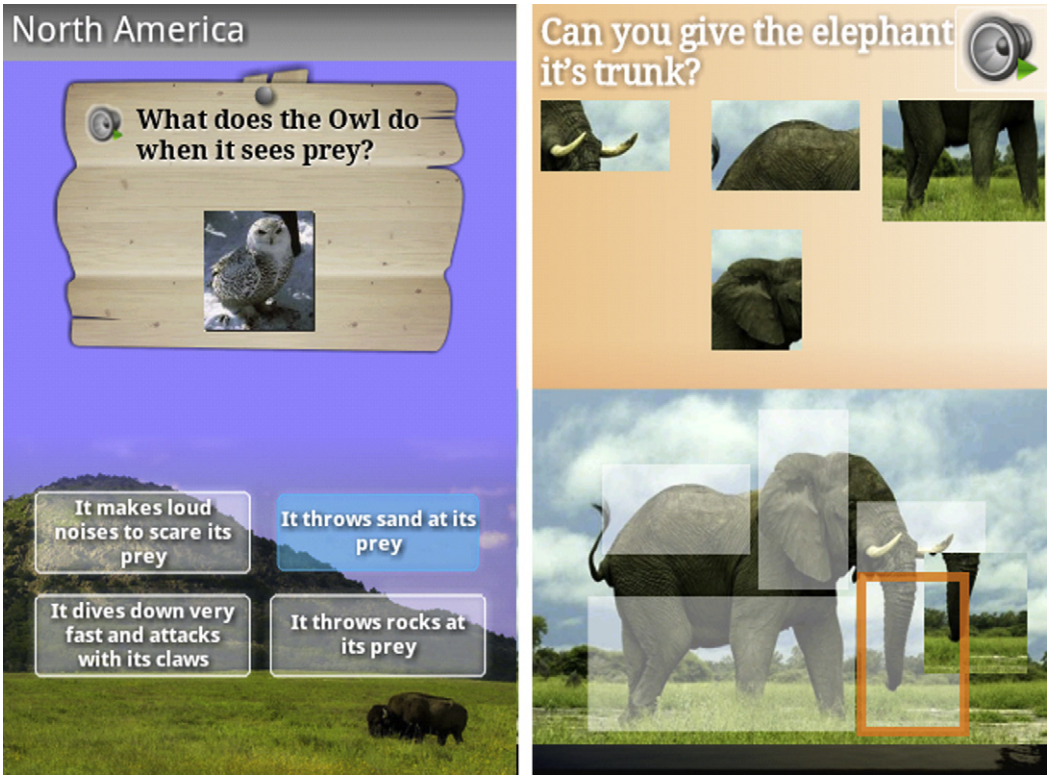

Fig. 2. Snapshots from the MEL-application. On the left a multiple choice game about the Snowy Owl. On the right a jigsaw puzzle about the Elephant.

3.3.4. The pre- and posttest

The pre- and posttest consisted of a vocabulary test which measured passive and active word knowledge. Features of standardized tests like the SOPA and the Peabody Picture Vocabulary Test were incorporated. (Dunn & Dunn, 1997; Thompson, Kenyon, & Rhodes, 2002). Features of the Peabody Picture Vocabulary Test were incorporated in the test by asking the children to choose the right picture out of four possibilities to answer a question. Features of the SOPA/ELLOPA test were used by asking children to point to pictures and name them, and by asking probing questions to elicit free speech.

Fifty words from the hundred target words were selected for the pre- and posttest. Both tests were identical. The words in the test were chosen to be a representative sample of the target words. Thus, all categories were presented (*habitat*, *food*, *appearance*, *behavior* and *abstract category*), and in the same frequency as they appeared among the full learning set. The passive part of the test consisted of 27 items, while the active part contained 23 items. The passive items where the child had to choose among four alternatives were scored as 0 (incorrect) or 1 (correct). The active items were scored as 0 (incorrect), 1 (partially correct, meaning a different word than the target word but still a correct word had been given, for example, *hair* instead of *fur*) or 2 when the target word was given as the answer. Since most words were supposedly new for the children, we didn't expect the children to do very well on the pretest. As we didn't want the children to feel worried about their results (although we introduced the whole test as a game) or to lose their motivation halfway through the test, we added six fillers, asking for words that where probably familiar (i.e. 'to run', 'to sleep' and 'to eat'). In a pilot of the pretest, children had difficulties at the start of the test, starting to name animals right away. To help them to 'get started' we added some passive questions to each subset of active items (i.e. 'Can you point to the sea-turtle?'). These could also be seen as fillers.

The third and last part of the test again concerned active speech. The children were asked to name as many related words they could think of in response to a picture showing an animal. To help them make the transition from 'triggered response' to 'spontaneous speech' we added an introduction to this part of the test. The interviewer asked the children some questions about their favorite zoo animal, trying to elicit as many words as possible. Next, the pupils were asked to make a word web about two animals. They had to mention all the words they could link to *elephant, snowy owl* and/or *sea turtle*. When the children produced the word webs, the interviewer was not allowed to elicit words by asking questions. Only target words mentioned by the children were rated. Each target word received a score of 1.

3.3.5. Test procedure

All children were tested individually by two testers. One of the two, the interviewer, sat opposite to the child, showing him/her pictures of animals and asking questions. The other person was seated behind the child, and did not participate in the interview. That person was seated such that the child wouldn't really notice it and be less aware of the fact that he or she was being observed (see Fig. 3). The observer wrote down and scored the child's answers. The test took about 15 min per child.

During the first part of the test, the active knowledge of the students was tested. The students were shown pictures of zoo animals and enlarged pictures of some salient animal features. They were asked to give the name of the different animals (e.g. "what is this animal called?" [answer: *eagle*]) and to name particular features (e.g. "if you look at the elephant, what is this long thing here?" [answer: *trunk*]). During the second part of the test, the passive vocabulary knowledge was tested. The students were shown a number of cards with four

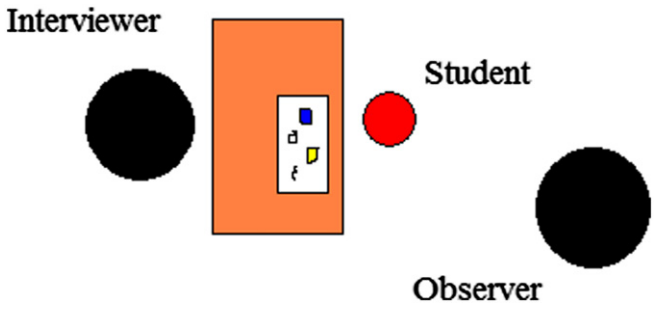

Fig. 3. Schematically depicted test setup.

different pictures, which formed four alternatives to choose from. They were asked to point to the right picture to answer a question (e.g. "In which picture do you see an animal hatching?").

While piloting the pretest, 23 active items and 27 passive items in a row turned out to be too much of the same, causing the children to lose their concentration quickly. We therefore decided to split the active and passive items into two subsets each (11 and 12 for the active items, 13 and 14 for the passive items). The two subsets of active and passive items where altered.

3.3.6. The questionnaires

Three questionnaires were used during this study. One for the teachers which aimed at assessing their attitude towards mobile technology, one for the children participating in one of the experimental conditions, assessing their motivation in relation to the mobile application and one for the parents of the children who took the mobile application home for two weeks, assessing their attitude towards mobile learning as well as their view of the motivation of their children to play the game.

The teacher questionnaire was composed of several open questions and twenty questions which could be answered using a four point Likert-type scale. The questions addressed their attitude to the use of computers in education in general, and the use of mobile technology in particular. Also the teachers were asked to indicate how confident they felt in using modern technology (computer and smartphone) and how competent they considered themselves in using these technologies. The questionnaire was administered prior to, or halfway through, the MEL-lesson period. The student questionnaire was answered by both the children of condition 2 and of condition 3. The questionnaire for condition 2 consisted of two "*Yes/No*" questions, twelve multiple choice questions with four possible answers and one open question. The questionnaire for Condition 3 had three additional multiple choice questions to determine how the children felt about the use of the device at home. Some of the questions of condition 2 were rephrased in the questionnaire for condition 3 to remain sensible (e.g. question for condition 2 "*Would you like to play the animal game, on the mobile phone, at home?*" was rephrased for condition 3 to read: "*Would you also like to play the animal game, on the mobile phone, at home in the future?*"). The parent questionnaire consisted of eighteen four-point Likert-type scales, as well as a number of open questions. Note that all questions were posed in Dutch and were all translated into English for this report.

3.4. Procedure

The study started with administration of the pretest. Subsequently, the three learning conditions were implemented. The control group worked for three weeks with the EarlyBird material on zoo animals with their teacher in the classroom. In parallel, the first experimental group received an instruction on how to use the mobile application. The day after this instruction, the group visited the zoo and was led to the different animals by use of GPS-navigation incorporated in the MEL-application. After the zoo visit they followed the regular EarlyBird program at school in the same vein as the control group. After three weeks, both the control group and the first experimental group took the posttest. At that time, the phones were given to the children of the second experimental group. This group also visited the zoo, after a general introduction of the phone and the MEL-application. After the Blijdorp visit, these children were allowed to keep their phones with them constantly, for a fortnight. They were told that they could play the MEL-application as much as they liked. Upon returning the phones, they also took the posttest.

3.4.1. Mobile lessons at the zoo

During the visit to the zoo, the subjects where divided into five groups, each consisting of five or six students. In these groups they where guided by the phones to 20 different animals. On average this took about two and a half hours. To each group a supervisor was assigned who was given explicit instruction only to help the students with technical difficulties (such as which button to press or how to restart the application) and not with the content of the game (Fig. 4).

3.5. Data analysis

The within-subjects learning data were analyzed with a paired *t*-test. To be able to reliably analyze the between-subjects effects in our nonequivalent groups design, the passive and active pretest scores were adjusted according to the following formula:

$$X_{adjusted} = \overline{X} + r(\overline{X} - X),$$

where r is the reliability coefficient (Trochim, 2000). The between-subjects learning data were analyzed with a one-way multivariate analysis for the gain scores on passive and active word knowledge, as dependent variables, with the adjusted passive and active pretest scores as covariates. Further comparative analyses were conducted to detect specific differences between the three conditions. A separate

Fig. 4. Some students playing with the MEL-game during their visit to the zoo.

one-way multivariate analysis with learning time as additional covariate was conducted to control for the effect of learning time. The acceptance level of significance was .05 in all cases.[1]

4. Results

First we present the general results on the pre- and posttest for the three conditions. Next, we analyze the learning results for each condition and then we compare the conditions on the learning results.

4.1. Pre- and posttest results

In Table 4.1 the results on the pretest and posttest are presented.

Cronbach's α was computed for the 27 passive and the 23 active questions to check whether the pre- and posttest form a reliable measure (see Table 4.2). As an $\alpha > .60$ is considered acceptable for a study test (Frisbie, 1988) the pre- and posttest scores were used in subsequent analyses.

A paired *t*-test was used to test if the pre- and posttest scores were significantly different. All groups scored significantly higher on both the passive and the active part of the posttest than they did on the pretest (Condition 1, passive: $t(28) = -3.78$, $p = .001$, active: $t(28) = -11.97$, $p = .000$; condition 2, passive: $t(23) = -4.25$, $p = .000$, active: $t(23) = -6.47$, $p = .000$; condition 3, passive: $t(21) = -6.57$, $p = .000$, active: $t(21) = -11.21$, $p = .000$).

To investigate the difference between the conditions a one-way multivariate analysis was conducted with the adjusted passive and active difference scores as dependent variables, and the adjusted passive and active pretest scores as covariate. There is a main overall effect for condition, (Pillai's trace, $F(4) = 8.55$, $p < .001$, Partial $\eta^2 = .19$, observed power = 1.00), a condition effect for both passive ($F(2) = 9.57$, $p < .001$ Partial $\eta^2 = .22$, observed power = .98) and active ($F(2) = 15.25$, $p < .001$ Partial $\eta^2 = .30$, observed power = 1.00) word knowledge. Pairwise comparisons (with Bonferroni adjustment for multiple comparisons) of the three groups for passive word knowledge indicate that condition 3 outperforms condition 1 ($M = 3.69$, $p < .001$), and condition 3 outperforms condition 2 ($M = 3.35$, $p < .05$). No significant differences were found between conditions 1 and 2. Pairwise comparisons for active word knowledge indicate that condition 3 outperforms both condition 1 ($M = 8.14$, $p < .05$) and condition 2 ($M = 12.84$, $p < .001$). No significant differences were found between condition 1 and 2.

As learning time correlated significantly with both the passive part of the posttest (.37) as well as with the active part of the posttest (.62), and condition 3 spent significantly more time than both condition 1 (Post hoc Games Howell: $M = 1.90$, $p < .001$) and 2 ($M = 2.24$, $p < .001$), a one-way multivariate analysis was conducted with the passive and active gain scores as dependent variables and learning time as additional covariate. Condition 1 spent 6.3 h on average, condition 2 spent 6.4 h on average and condition 3 spent 8.1 h on average. Again a main overall effect for condition was found (Pillai's trace = .21, $F(4) = 4.11$, $p = .004$, partial $\eta^2 = .11$, observed power = .91). Again an effect was found for condition on passive word knowledge ($F(2) = 4.03$, $p < .05$, partial $\eta^2 = .10$, observed power = .70). Pairwise comparisons between the three conditions for passive word knowledge (with Bonferroni adjustment for multiple comparisons) yielded a significant difference between group 1 and 3 only ($M = 3.00$, $p = .018$). Again an effect was found for condition on active word knowledge ($F(2) = 4.99$, $p < .05$, partial $\eta^2 = .13$, observed power = .80). Pairwise comparisons between the three conditions for active word knowledge (with Bonferroni adjustment for multiple comparisons) yielded only one significant difference, namely between condition 3 and 2 ($M = 4.62$, $p = .008$). This result indicates that the larger learning gains demonstrated by condition 3 were mostly due to the additional learning time spent.

Finally, as an exploration, the highest and lowest scoring students and the students that learned longest and shortest from condition 3 were compared. We selected students that scored one standard deviation above or below the average for passive or active word recollection and students that spent one standard deviation of time longer or shorter than average during the learning phase. The students with the lowest scores[2] spent an average of 7.46 h during the learning phase ($N = 5$). The students with the best scores[3] an average of 9.15 h ($N = 4$).

[1] The data was analyzed using IBM's SPSS PASW Statistics 18 (Release 18.0.0 (Jul 30, 2009)).

[2] Less than 13 points active difference score or less than 2 points passive difference score.

[3] More than 31 points active difference score or more than 9 points passive difference score.

Table 4.1
General results.

	N	Passive items (max. score = 27)				Active items (max. score = 46)			
		Pretest		Posttest		Pretest		Posttest	
		Mean score	Std. dev.	Mean score	Std. dev.	Mean score	Std. dev.	Mean score	Std. dev.
Condition 1	29	11.34	3.83	13.21	3.67	7.38	4.56	21.55	7.22
Condition 2	24	12.29	3.42	14.46	3.06	6.71	4.00	17.38	9.15
Condition 3	22	10.64	3.14	15.96	4.45	5.10	4.00	26.91	8.90

Condition 1 = English lessons at school without mobile application.
Condition 2 = English lessons at school and mobile application at the zoo.
Condition 3 = English lessons at school and mobile application at the zoo and mobile application at home for a fortnight.

Table 4.2
Reliability statistics: Cronbach's α.

	Part	Cases	Cronbach's α	N of items
Pretest	Passive	75	.61	27
	Active	75	.74	23
Posttest	Passive	75	.68	27
	Active	75	.84	23

The students that spent the least time[4] during the learning phase had an average of 18.33 points active difference score and an average of 4 points passive difference score ($N = 3$). The students that spent the most time[5] during the learning phase had an average of 27.17 points active difference score and an average of 7.17 points passive difference score ($N = 6$). This exploration again suggests that learning time is a crucial factor in this analysis.

4.1.1. Learning results further explored

Having established that all groups improve on both the passive and the active part of the vocabulary test, we were interested to find out which words were best retained. Which words were easy to learn and which were difficult? To this end we looked at the proportion of correct answers per item. We divided the proportion of correct answers in three categories:0–.35, .35–.60, .60–1.00. The first category (I) reflects that the majority of the children do not know the word, the third category (III) that a majority of the children does know the word and the second (II) forms the in-between category (Table 4.3).

When we look at the frequency distribution, we see that words have a bigger chance to fall in the third category in condition 3. When we take a look at the nature of the words that are better mastered in condition 3 than in both other conditions, we find the following target words: *to hunt*, *tundra*, *fur* and *bat* (category III), and *to strangle*, *beak*, *calf*, *ostrich* and *scales* (category II). More abstract words like *scavenger* and *predator* are not very well retained in any condition. They fall mostly in the first category. As an example, we present one of the learning texts that had the word predator in it:

"Hyenas are the cleaners of the savannah. When another predator has eaten enough and there is some meat left, the hyena comes and eats what is left. They are scavengers, as they eat the meat of dead animals they find. They have very strong and powerful teeth, and a striped or spotted pelt. Hyenas live in packs, and when they hunt, they hunt with the whole group. The sound they make is like laughing, have you heard it yet?"

Other difficult words are words that do not in any way resemble or sound like their Dutch counterparts, *tusk* (in Dutch: slagtand). Names for something that have equal sounding equivalents in Dutch are easy to remember: gorilla, giraffe, camouflage, plankton. Thus although *camouflage* is an abstract concept, the children are able to remember it correctly, whereas *scavenger* and *predator* which do not have such counterparts in Dutch are less well remembered. The animal names that were represented in the test were in generally quite well retained, and again especially when the name sounded familiar. Unfamiliar sounding names, like *Ostrich*, and *Eagle* were less well recalled.

The data of the word web test have a different status than the passive and active items discussed before, because first of all a lot of children failed to produce any target word in the pretest. The pretest data show that the initial score is really low. The posttest data do show an improvement (see Table 4.4). However, some of the children were very shy when asked to speak about the animals, which may have deflated their score. Moreover, the children responded to different animals, two out of three available, which made a quantitative analysis less feasible. Therefore we did not use the difference scores of the pre- and posttest wordwebs as a separate dependent variable in the quantitative analyses presented before. When we look at the figures in the table, we notice that all conditions improve. The absolute gain scores are 35, 33 and 65 respectively. Again, the children from condition 3 outperform the children from the other two groups. These data confirm the results of the two other parts of the vocabulary test.

4.2. Questionnaires

First we will discuss the student questionnaire. The questionnaires of 43 students (from condition 2 and 3) where handed in; 24 for condition 2 and 19 for condition 3. When asked what they thought about learning with a mobile phone, 81.40% of the students replied that it was very nice and only one student (2.33%) thought it was not so nice (see Fig. 5). When asked how often they would play the game if they

[4] Less than 7.1 h.
[5] More than 9.1 h.

Table 4.3
Proportion of correctly retained words.

	Condition 1			Condition 2			Condition 3		
	I	II	III	I	II	III	I	II	III
Passive									
Frequency	12	5	10	8	8	11	6	7	14
Active									
Frequency	7	8	8	11	8	4	3	10	10
Total	19	13	18	19	16	18	9	17	24

Table 4.4
Word web results.

	N	Pretest				Posttest			
		WW1	WW2	Total	Mean	WW1	WW2	Total	Mean
Cond. 1	29	6	5	11	.4	23	23	46	1.6
Cond. 2	24	0	0	0	.0	11	21	33	1.4
Cond. 3	22	1	1	2	.1	23	44	67	3.0

Note: Both at the pretest and the postest, the children were asked to create two word webs (WW1 and WW2).

would have a phone with a similar game at home (in the future), 41.86% said they would play it every day of the week (see Fig. 6). When asked how they learned best, with the phone or with the teacher, 23.81% said they could learn better with the mobile phone and 71.43% said that learning with the phone was almost as good or exactly the same as with the teacher (see Fig. 7). One student didn't answer this question.

The parents' questionnaire was only submitted to the parents of the children, participating in condition 3 (the home condition). Twenty-two were filled out. Though most parents thought that their child had a lot of fun learning English using the mobile phone and appeared more enthusiastic about learning English only approximately 40% thought their child was more interested in learning English and had learned significantly while using the mobile phone. Some parents expressed their initial doubts about letting their child use the smartphone, but when they saw their children learning new words their attitudes changed. One parent even said (freely translated from Dutch): "My first reaction was; not yet another mobile [device] to play games on! My son is only allowed to play 1 h each day with his consoles. I do not (did not) want to stimulate this. Now, after two weeks, he has picked up quite a few English words! Great!". Some of the parents remarked that their children got bored after having played the same game for a few times. They said it would have been nice to have more games, or even different subjects.

The three teachers, participating in the EarlyBird program, were asked to fill in a questionnaire assessing their attitude towards the use of computers in general and the use of mobile technology in particular. The three teachers appeared to have a positive attitude towards both. All teachers were welcoming mobile technology as a complement to their lessons. As an example, the teachers' replies to the question how they judged the MEL-application are quoted here:

Teacher 1: "The material can be taken to any location and it does not take a lot of space, and it is cheaper than a computer".
Teacher 2: "The children are learning in a fun way with the games, hence their focus and attention spans are higher and I believe they learn better with it than with a book".
Teacher 3: "Children get feedback immediately on how they perform and it makes it personal and thus motivating".

Although the teachers have a positive attitude towards the use of technology, two of them expressed a lack of confidence in their own level of proficiency in handling the computer or a smartphone.

Besides filling in the questionnaires, the teachers were interviewed in the context of the making of a video on the project. One of the teachers who accompanied a group of children during the zoo visit said: "It is remarkable to see, that some of these children who are shy in class, appear to take the lead now. Apparently the mobile application triggers them to play a different role". Another teacher explained that the mobile application being so small and at hand enticed the children into the engagement and flow of learning. As she put it: "the children were really into it".

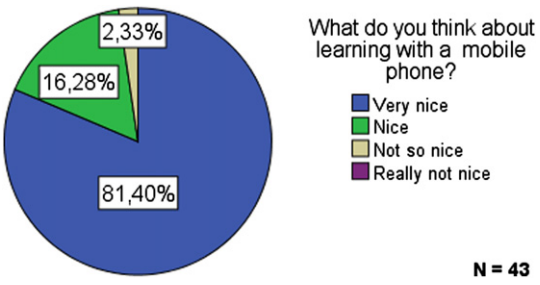

Fig. 5. Student questionnaire result – What do you think about learning with a mobile phone?

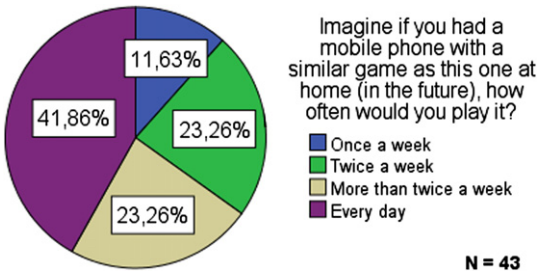

Fig. 6. Student questionnaire result – Imagine if you had a mobile phone with a similar game as this one at home (in the future), how often would you play it?

4.3. Game logs

The game logs were mainly used to determine how much the application on the mobile phone was actually played by the students in condition 3. The learning time was calculated by summing the periods the children were actively using the application. All periods in which the game was running but no button was activated for more than 15 min were ignored. The total time the students used the application at the day of the visit to the zoo was approximately 65 h, which comes to an average of 2.6 h per phone (with a Std. deviation of 1.06). When summing the total playtime of the 25 phones, excluding the "*zoo-visit day*",[6] it comes to approximately 39 h. On average 10 students each played approximately 22 min per day (see Fig. 8). It is clear that the game was played most directly following the time of the visit to the zoo, after which the playtime slowly decreased. The children in condition 3 played on average approximately 1.5 h with the game during their free time, bringing the average learning time to approximately 8.1 h (with a standard deviation of 1.07).

5. Discussion and conclusion

5.1. Hypotheses

The first hypothesis stating that both experimental groups would outperform the control group is partly met. The third condition scored significantly higher on both posttest measures (passive and active word knowledge) than both the first and second condition. The second condition, however did not score any better on the posttest measures than the control condition. The latter finding indicates that the use of the MEL-application during the zoo visit did not have a surplus value for the children. The control group learned just as much at school. The second hypothesis stated that the children in condition 3 would be motivated to play the MEL-application at home. This hypothesis is met with support. The log-files indicate that the children in condition 3 played the game at home, and on average spent 1.5 h on the MEL-application at home. The extra time spent by the children in condition 3 obviously paid off. They outperformed the children in the other conditions on both the passive and active part of the posttest. Evidently, the MEL-application was such that the children were able to learn from it. However, when the learning results of the three conditions were compared, taking the learning time into account, a different picture emerged. Condition 3 only outperformed condition 1 on passive word knowledge and condition 2 on active word knowledge. Thus the overall significant difference between condition 3 and both condition 1 and 2 for both types of knowledge was no longer found. This finding indicates that the learning process inspired by the MEL-application was not systematically more efficient than the learning process that took place in the classroom.

5.2. Study limitations

Although the results, discussed above, are promising, the study reported here has a number of limitations. These will be addressed in the next paragraphs.

5.2.1. Implementation of conditions

The conditions were not fully implemented according to the agreed upon study design. Originally, the first experimental group was meant to use the mobile application at school, alongside the EarlyBird material. The teacher involved, however, did not find any time to do so. According to her, the EarlyBird material provided on the target words was so elaborate that working it through took up all time reserved for the English lessons. We do therefore not know how the results would have been if the children were given the chance to work with the application in school for a more extensive period. Moreover, the control condition actually consisted of two groups whose teachers did not spend the same amount of time on the EarlyBird material (4.5 h versus 7.5 h). We counterbalanced this effect by using learning time as a covariate in the final analysis of the learning result differences between the conditions. Both these findings suggest that the personal opinions of the teachers influenced the actual implementation of the conditions. The teacher of the first experimental group, evidently, was not that enthusiastic about integrating the mobile technology in her lesson plan. Thus, the phones, were kept in a cupboard, instead of being used by the children in addition to the EarlyBird material. The teacher of one of the groups that made up the control condition was so concerned that her students would do less well than the experimental groups that she spent extra time on the EarlyBird material, whenever the occasion arose. Hence, the integration of a mobile application in the classroom calls for careful planning and guidance and should take the role and attitude of the teachers into account.

[6] We explicitly say "zoo-visit day" instead of "at the zoo" because some students also played the game on their way there and later that day which we could not filter out.

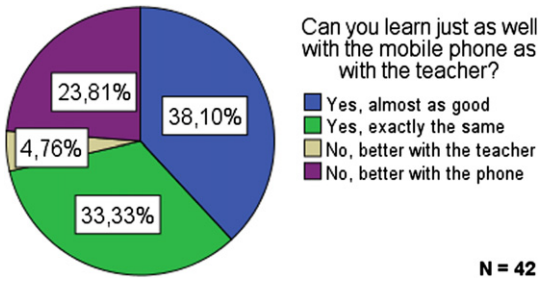

Fig. 7. Student questionnaire result – Can you learn just as well with the mobile phone as with the teacher?

5.2.2. The MEL-application

The MEL-application is a simple application. It does not rely on any artificial intelligence techniques that could make the application more adaptive to the learner's individual level of knowledge and skill. The presentation of the learning material is static. When you fail a game (more than 2 erroneous answers) you are referred back to the movie clip, to view it again, and then again try the very same game. Building a learner profile during the course of working with the application could support offering more tailored content:

- offering more difficult words more often in different ways,
- providing more elaborate feedback than just correct or incorrect, for example by giving an explanation "yes, the skin of the arctic fox is covered by hair, but that is called fur",
- taking into account the words already known by the learner,
- giving a formative test after a certain amount of learning content has been studied and determine subsequent content on the basis of its results.

Besides, many possible "game elements" are not incorporated in the MEL-application. The literature on serious gaming discusses a number of features that are especially meant to keep the learner engaged and motivated (Kenny & Gunter, 2007; Schwabe & Göth, 2005). Thus we believe that using these insights the application could be greatly enhanced, making the learning process more effective and efficient.

5.2.3. The zoo visit

During the zoo visit it became apparent that many children used a trial-and-error strategy to play the games. They skipped the video clip as fast as possible and then tried to guess the right answer. After being sent back to the video clip they just did the same game and tried out a different answer. This process was repeated just until sufficiently correct answers were given and the child was directed to the next animal. The trial-and-error strategy is in fact an affordance of the MEL-application. A further development should aim to at least discourage the use of such an unproductive strategy. The zoo visit brought to light another drawback of the MEL-application. The children were inclined not to look at the living animals but to concentrate on their screen for information. Perhaps, this was due to the fact that immediately after the introduction of the MEL-application the children went to the zoo. The children were very excited about having their own phone and only had eyes for the application at the expense of taking a good look around. Further development of the zoo-application should incorporate questions that would force the children to take notice of the real life animal. Moreover, it is possibly more fruitful to plan such a trip when the children are already used to the application as such.

5.2.4. Difficulty of the vocabulary test

When we look at the general results (Table 4.1), we notice that even on the posttest the scores are not very high. On average the children answer about half of the items correctly. Even the children in condition 3 do not score really high on average, although some of them do very

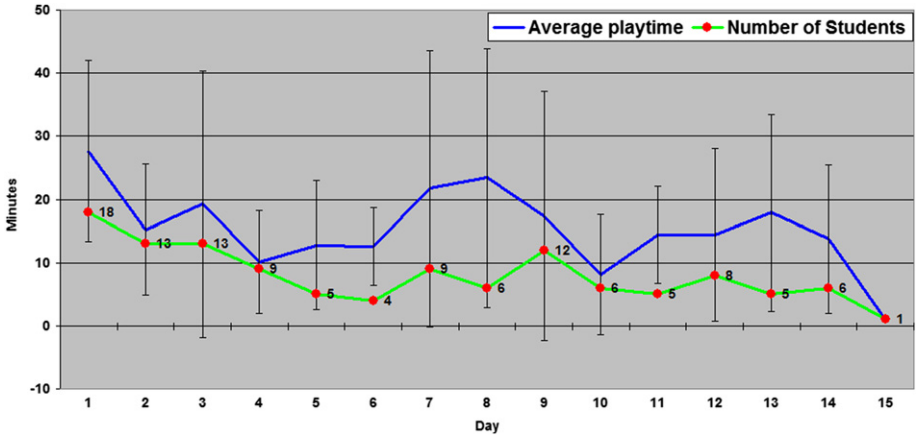

Fig. 8. Average amount of minutes played (and standard deviation) by students in condition 3 and amount of students that played the MEL-game for each day after the zoo visit.

well. At least, the way the test was set up gave sufficient room for improvement and the use of fillers in the test (easy items that were not taken into account in the final test score) helped to keep the children motivated. Looking at the words children find particularly hard, we notice that those are the more abstract words and words that do not in any way resemble their Dutch equivalent. Perhaps, the more abstract words need additional explanation, for the children can fully grasp them. And the words that denote a specific, visible characteristic should be more directly linked to this visible characteristic. In the current version of the MEL-application, for example, the word "tusk" is not specifically related to the picture of the tusk. The picture with the tusk is part of the video clip accompanying the text, but a stronger relation could be formed by highlighting the word and highlighting the tusk picture on the screen at the same time. Furthermore, although the development of the MEL-application followed the guidelines derived from Mayer (2003), the link between the audio and the visual element could be made more explicit.

5.2.5. Formal and informal learning

The literature distinguishes between formal, non-formal and informal learning (Sefton-Green, 2004). Formal learning is associated with formal education. Formal education offers well-defined curricula in structured, institutionalized environments. Non-formal education refers to schooling that is based on programs outside the formal curriculum: taking a second language course, or music lessons. Informal learning pertains to learning that goes on outside an official curriculum and that is not embedded in any particular environment.

The study presented here combines formal, non-formal and informal elements. The learning that goes on at school is part of formal learning. The use of the mobile application at home reflects non-formal as well as informal learning. It is non-formal in the sense that the subject matter provided is still based on the formally set objectives for the attainment of English vocabulary, but the children are free to use the application in their own way, at their own time. It is informal in the sense that the children work with the application in the informal context of their home environment and in that to the children, the use of the application feels more like playing than like learning.

The results indicate that the children can learn just as well outside of the classroom, in their spare time, as at school. This is an interesting finding in itself. It suggests that formal learning at school can be complemented by non- and informal learning (Mifsud, 2002; Sharples, 2000). Apparently the children from condition 3 found themselves in a supportive environment, at home as well as at school. However, these children took part in an experimental program that both the schools and the parents agreed to. Acceptance of non-formal and informal learning cannot be taken for granted. Teachers in general have to get used to the idea that the school is not the sole source of learning and they have to be willing to acknowledge the value of non-formal and informal learning. One way to enhance teachers' views on informal learning could be to engage them in the process of developing applications for out of school use.

5.2.6. Duration of the study

The learning phase was limited. Especially, in order to demonstrate an effect of location-based learning, one zoo visit should be considered insufficient. Moreover, we do not know whether the children who have access to a mobile application at any time, will keep using it over time. We saw an initial peak in usage with the children of our home group. By the end of the two week period average daily use was far less that it was at the beginning. To be able to investigate motivation over time and its relation to learning results and long term retention, calls for a much more extended learning phase, as well as a retention test some period after the posttest.

5.3. Conclusion

The study showed that the mobile application developed motivates students to use it and that the application offers sufficient learning opportunities to create a learning effect. The application has proven its worth as an addition to the formal teaching of English at school. It was demonstrated that time on task can be enhanced by providing the learner with an opportunity to learn in the informal context of his or her spare time.

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