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### Digital game-based learning in secondary education

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## CHAPTER 3

# MOBILE GAME-BASED LEARNING: EFFECTS ON ENGAGEMENT, MOTIVATION AND LEARNING<sup>1</sup>

Using mobile games in education combines situated and active learning with fun in a potentially excellent manner. The effects of a mobile city game called Frequency 1550, which was developed by The Waag Society to help pupils in their first year of secondary education playfully acquire historical knowledge of medieval Amsterdam, were investigated in terms of pupil engagement in the game, historical knowledge, and motivation for History in general and the topic of the Middle Ages in particular.

A quasi-experimental design was used with 458 pupils from 20 classes from five schools. The pupils in 10 of the classes played the mobile history game whereas the pupils in the other 10 classes received a regular, project-based lesson series. The results showed those pupils who played the game to be engaged and to gain significantly more knowledge about medieval Amsterdam than those pupils who received regular project-based instruction. No significant differences were found between the two groups with respect to motivation for History or the Middle Ages. The impact of location-based technology and game-based learning on pupil knowledge and motivation are discussed along with suggestions for future research.

### 1. INTRODUCTION

While schools are aimed at the education of pupils and qualification of pupils for the labour market, they are not always successful today. In the school year 2005-2006 in the Netherlands, for instance, about 19% of the pupils in secondary education left school without a diploma. The majority of the pupils dropping out of the first classes of secondary education came from pre-vocational education (OCW, 2007). The pupil drop-out issue is an issue, moreover, in not only the Netherlands but also all other European countries (Herweijer, 2008; Jonassen & Blondal, 2005) and the USA as indicated by the many newsletters of the Association for Supervision and Curriculum Development. It thus appears that education is not meeting the needs of certain pupils sufficiently. According to Prensky (2001) and others (e.g. Beck & Wade, 2006; Klopfer, 2008), one of the reasons for this failure is that a new generation of pupils is largely being educated with old paradigms and methods. The present generation of pupils is growing up with Information and Communication Technology

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(ICT) embedded in their daily lives. Such pupils handle digital information on a daily basis, are connected to each other via mobile technologies, work interactively, often perform several tasks more or less simultaneously and play games to a greater extent than previous generations (Beck & Wade, 2006; OCW, 2007). According to Van Eck (2006), the popularity of games together with ongoing research on the power of digital game-based learning, on the one hand, and increased disengagement of the so-called 'net generation' or 'digital natives' from traditional instruction, on the other hand, are factors which explain the widespread interest in game-based learning. This interest in game-based learning holds not only for digital natives, but also for a broad group of pupils and researchers today as well as for teachers and parents (Kirriemuir & McFarlane, 2004; Sandford, Ulicsak, Facer & Rudd, 2006). It is thus quite possible that game-based learning may more adequately address the manner in which youngsters learn nowadays and engage them more successfully in meaningful learning than traditional learning methods (Gee, 2003; Shaffer, 2006; Prensky, 2001; Van Eck, 2006). Though some studies report success in learning with games with traditionally disengaged groups of students (see e.g. Egenfeldt-Nielsen, 2005; Squire, 2004) and that using games in lessons is motivating (see e.g. Sandford et al., 2006) the empirical basis for claiming that game-based learning may more adequately engage pupils is still rather thin and far from conclusive.

## 2. GAME-BASED LEARNING

During the last 20 years, the importance of fostering meaningful learning has been elaborated upon under the general heading of situated and active learning (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Lombardi, 2007). So-called mobile and location-based technologies provide opportunities to embed learning in authentic environments and thereby enhance engagement and learning outside traditional formal educational settings. With handhelds, it is possible to mix virtual data with real-world data (i.e., locations and contexts) and thereby connect a virtual world to real life (Klopfer & Squire, 2008). Similarly, games can be played in the real world with the support of such digital devices as Personal Digital Assistants and cell phones, which make it possible to create a fictional layer on top of a real world context and thus an *augmented reality*. Location-based augmented reality games, for instance, are played in specific real-world locations which may include historical or geographical sites. Along these lines, the MIT Teacher Education Program created a game called Environmental Detectives in which handheld computers with a Global Positioning System (GPS) are used to augment the experience of the user with additional text, audio and video data (Klopfer, Squire, & Jenkins, 2002). Under such circumstances, the user experiences his or her environment in a new way and situated, active learning is stimulated. The context sensitivity of mobile devices (i.e., their capacity to gather data which is unique to the current time and location and may be either real or simulated) is one of the properties — according to Klopfer et al. — which makes such mobile devices so well-suited for the support of learning activities. Four other properties which are assumed to make such mobile devices particularly useful for educational purposes concern their portability, their social

interactivity as both face-to-face interaction and the exchange of data between learners is made possible, their connectivity and their individuality as the support for different activities can be tailored to the needs of specific learners (see Klopfer et al., 2002). Given all the possibilities of game-based learning, the question which arises is whether it actually lives up to all of the expectations or not.

Research on mobile game-based learning tends to focus on the motivational effects of the methods. One of the main reasons for this is that when people play such games, they are generally found to be very engaged in the game: They are totally immersed in the game and can play for hours on end with little or no awareness of the more general world around them (Shaffer, 2006; Beck & Wade, 2006). Such a state of complete absorption in a task is referred to as 'flow' (Csíkszentmihályi, 1990). Flow theory is important for motivation in instruction (Watson, 2007). Having motivated learners is what many teachers desire. In fact, a motivated learner is easy to describe: enthusiastic, focused and engaged. A motivated learner shows a clear interest in what he or she is doing and enjoys what he or she is doing, tries hard and persists over time (Garris, Ahlers, & Driskell, 2002). Many studies of games and motivation are based upon the motivation work of Malone and Lepper (1987) who proposed a link between motivation and intrinsic learning. More specifically, seven factors which include both *individual* and *interpersonal* factors have been postulated to promote intrinsic motivation. The individual factors are challenge, curiosity, control, fantasy, competition, cooperation and recognition. According to many authors, many of these factors are triggered by games (see, e.g., Egenfeldt-Nielsen, 2006; Garris et al., 2002; Prensky, 2001).

In their evaluation of mobile game-based learning, Schwabe and Göth (2005) indeed found that technology enables immersion into a mixed reality and thus provides highly motivating learning experiences. In their words, the MobileGame they studied moved the pupils 'into a state where they are mentally ready for learning and where they are in the right environment for learning' (p. 215). However, the authors also admit that they cannot claim that the game actually enhanced pupil learning. There is a need to more thoroughly evaluate the cognitive benefits of mobile game-based learning despite the fact that both the cognitive and motivational effects of game-based learning have been previously studied (see, e.g., De Freitas, 2006; Egenfeldt-Nielsen, 2006; Fletcher & Tobias, 2006; Gros, 2007; Habgood, 2007; Hays, 2005; Mitchel & Savell-Smith, 2004). While the reviews conducted to date show a positive overall picture, many of the relevant studies are nevertheless methodologically flawed, rarely experimental and often present contradictory results. According to De Freitas (2006) in her review of the literature on game-based learning, games and simulations certainly have substantial potential for learning but certain challenges 'in terms of setting and assessing specified learning objectives' (p. 58) in particular must be met in order to effectively use the potential of learning from games and simulations.

In the present study, the motivational and learning effects of a mobile city game called Frequency 1550 were thus examined. Frequency 1550 can be considered as a game, following the definition of Dempsey saying that a game is "a set of activities involving one or more players. It has goals, constraints, payoffs and consequences. A game is rule-oriented and artificial in some respects. Finally a game involves

some aspects of competition, even if that is competition with oneself' (Dempsey et al., 1996, p.2). Although the game Frequency 1550 has won an award as the world's most innovative e-learning application, the educational value of the game has yet to be documented systematically. The effects of the mobile game on pupil knowledge of medieval Amsterdam and their motivation for the study of History in general and the Middle Ages in particular will therefore be examined in the present study in addition to the engagement of the pupils while playing the game.

### 3. THE FREQUENCY 1550 GAME

*Introduction to the game.* The Frequency 1550 game was developed by the Waag Society, which is a Dutch ICT research foundation working in the social and cultural domain. Frequency 1550 is a game about medieval Amsterdam to be played during a single school day. At the start of the game day, the pupils gather at the main location, namely the Waag building or 15<sup>th</sup> century weighing house in the city of Amsterdam. The pupils are introduced to the game, the tasks, the tools to be used and the objective of the game: To gain citizenship in the city of Amsterdam via attainment of the required 366 points or 'days of citizenship' which represent the medieval year-and-a-day rule which requires residence within the Amsterdam city walls for this period of time to earn civil rights. Groups of four or five pupils are formed, and the pupils are randomly assigned the identity of a beggar or a merchant who have different rights and a different status (i.e., order) in the game. The part about earning citizenship and being in an order is called the main story line or the back story. With the help of the Internet, smart phones, video phones and GPS technology, Amsterdam becomes a medieval playground.

*Group and team structure.* Each group of four or five pupils is divided into a city team (CT) consisting of two or three pupils who walk through the city and a head-quarter team (HQT) consisting of the other two or three pupils who operate from behind the computer in the main building. After the lunch break, the teams switch places so that each pupil has participated in both the CT and HQT at the end of the day. The CT is assigned one of six areas (see below) as the starting point for the conduct of small, location-based media tasks to explore, map and gain knowledge of each of the areas and their associated themes. The CT can view a map of medieval Amsterdam (Figure 1) on their smart phones and zoom in on a particular part of the map. The HQT can use two maps: one about medieval Amsterdam and one about present Amsterdam; both maps have coloured dots indicating the routes the six CTs are walking. The HQT digitally follows the route of the CT by means of GPS and guides them towards and through the required learning tasks using various sources of information, including the videos in the game and internet resources.

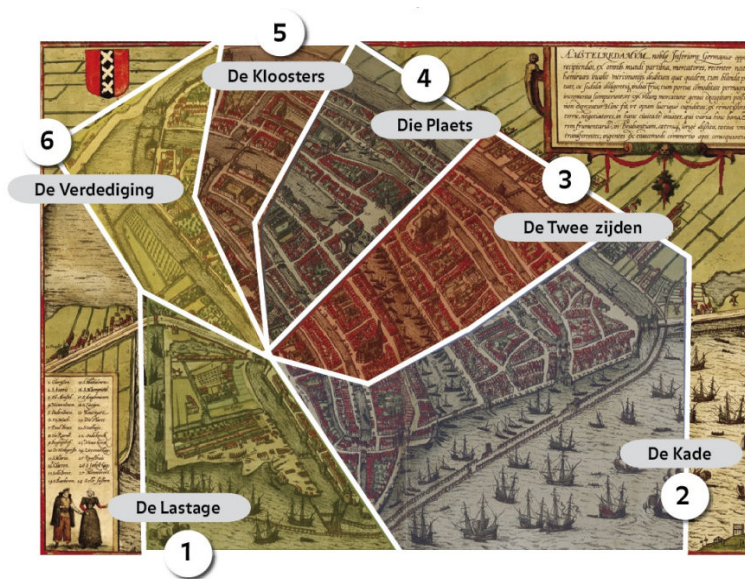


Figure 1: Map of medieval Amsterdam. © Waag Society

*Six areas and associated themes.* The old city of Amsterdam has been divided into six areas in which six different themes from medieval times are addressed. The six themes are: 1) labour in the area called *Lastage*; 2) trade in the area called *de Kade*; 3) religion in the area called *de Twee Zijden*; 4) rules and government in the area called *die Plaets*; 5) knowledge in the area called *de Kloosters*; and 6) defence in the area called *de Verdediging*. Each theme is introduced with the name of the area via an introductory video clip displayed in a telephone message which is sent to the pupils as if it came from the year 1550 as soon as they enter a new area. Each clip presents words which can help the group complete the assignments for the area; the audio background presents the sounds of medieval activities in the area (e.g., the sound of manual work, sawing). After the presentation of key words, the video clip zooms in on a few pages from a diary. The diary for the area *Lastage* reads as follows:

Tuesday. A few sisters' dresses are worn out and I need yarn. The best yarn can be found in Lastage because they make rope out of yarn there. Lastage is a long walk from the monastery because it is located outside the city wall. As soon as you pass the city wall, you will hear hammering in the distance where manual labour is conducted (...) the area is being protected by the new defence tower which lies on the outer boundary of Lastage. It is situated at the intersection of the water of the Amstel and the water of the IJ.

In order to receive assignments, the CTs must try to find a certain area, the so-called hidden location. Following the diary pages, a closing text is presented by the main narrator providing clues about the hidden location:

The hidden location can be found on the outskirts of Lastage. It is situated at the intersection of the water of the Amstel and the water of the IJ. The hidden location is a tower on the east side of Lastage.

*Assignments.* As soon as the GPS data shows a CT has reached a particular location, three video assignments in addition to the introductory video are automatically sent from the server in The Waag to the video phone. For each area, there are three similar types of assignments: an orientation assignment, an imagination assignment and a symbolic assignment. Each assignment consists of three parts and is concluded with a final multiple choice or open-ended question which often requires the CT and HQT to combine their knowledge to find the answer.

The orientation assignment includes texts and tasks which are intended to trigger environmental awareness. This may be done via the creation or selection of photos, the answering of questions about the site.

The imagination assignment includes texts and a task which are again intended to trigger environmental awareness via the creation or selection of photos and the answering of questions about the site but also the imagination of historical actions, events and the work of historical characters. For this assignment, the CTs are asked to act out particular idioms/sayings such as ‘this is monks’ work,’ which is the equivalent of ‘this is sheer drudgery’ in English and refers to the days when monks meticulously copied books by hand. The acting out of the sayings is videotaped, while the HQTs are asked to find out what these sayings mean.

In the comprehensive assignment, the CTs are asked to search for several details – such as a plaque with the medieval name of the area – and take pictures of the details while the HQTs are asked to select the correct picture from various pictures on the Internet or somewhere else. Similarly, the CTs may be asked to take a picture of something such as a depiction of the emblem for a guild while the HQTs have to find out more about the guild itself.

Each group, consisting of a CT and a HQT, can gain points which help them to win the game via the completion of assignments. Each CT also has to decide whether to stay away from the other CTs or enter into a confrontation in which their “order” determines the winner with merchants having a higher order than beggars. The winning group receives points (i.e., days of citizenship) from the losing group. Team members can also drop virtual medieval rats (i.e., the equivalent of a virtual bomb) on the other team which causes the screen of the smart phone to go blank and thus disables the use of this phone temporarily.

*Completion of the game.* At the end of the day, all of the pupils gather at the main building where the HQTs are located. Each of the groups is invited to briefly present some of their collected media to the other groups. An educational staff member of the Waag Society is also present to guide this process and ask questions. Finally, every group is told how many points they have earned and the group with the highest score is announced. With 30 minutes of introduction, a one hour lunch break and almost one hour of presentations at the end of the day, two hours are left of play in a CT and two hours left to play in a HQT.

#### 4. METHOD

Given that the aim of the present study was to enhance insight into both the motivational and learning effects of game-based learning, hypotheses regarding the motivation and knowledge gains of the pupils in the different research conditions were formulated first.

- 1) The motivation of the pupils playing the Frequency 1550 game for History in general and the topic of the Middle Ages in particular will differ from that of the pupils receiving the regular project-based lesson series.
- 2) Those pupils playing the Frequency 1550 game will show different knowledge gains with regard to medieval Amsterdam than the pupils receiving the regular project-based lesson series.

The above hypotheses were formulated non-directional as the literature did not provide conclusive evidence regarding the effects of game-based learning.

Research by Clark and Feldon (2005) and Kanfer and McCombs (2000) suggests that pupil interest in a topic, their prior knowledge with regard to the topic and their learning preferences (i.e., learning styles) may affect their choices and persistence to learn a subject. Given that the majority of the pupils dropping out of secondary education are in pre-vocational secondary education (OCW, 2007), it may be that education is not appealing enough for these pupils and that the Frequency 1550 game may work differently for pre-vocational pupils than for other pupils. Two pupil characteristics, in particular, may interact with the playing of the Frequency 1550 game, namely: the pupil's prior History ability and the pupil's level of education — which can be understood to reflect various aspects of general cognitive ability, motivation and learning style. In keeping with the above, the following two hypotheses were thus formulated.

Pupils with an initially low History ability will generally attain different knowledge of medieval Amsterdam results after playing the Frequency 1550 game than after receipt of a regular project-based lesson series.

Pupils from pre-vocational secondary education will generally attain different knowledge of medieval Amsterdam results after playing the Frequency 1550 game than after receipt of a project-based lesson series.

As pupil engagement in a game is an important condition for learning and having fun we will measure their level of engagement as well.

The regular project-based lesson series of two class hours was designed by the researchers in strong co-operation with five history teachers from the participating schools. The content of the game Frequency 1550 has been used in the design of the regular project-based lesson series, which means that the content of both conditions (games and lesson) was similar. We checked the realisation of this design with teacher reports. However, the instruction of the assignments, the pedagogy and the time devoted to each topic are different between both conditions as these are part of the educational design. In the game condition, the instruction of the assignment is more 'game-like' and narrative-based, the pedagogy has a focus on pupil-centered learning, and the time devoted to each topic was 4 hrs. maximum, including time to navigate through the city, social talk, and attempts to connect with the headquarters.

### 4.1 Participants

The participants in the present study were pupils who ranged in age from 12 to 16 years with the majority having an age of 13 years. The pupils were all in the first year of secondary education in the Netherlands: 14 classes with a mix of pre-vocational secondary education pupils and 6 classes with a mix of upper general and pre-university secondary education pupils. Of the 458 pupils, 232 played the Frequency 1550 game and 226 followed the regular project-based lesson series.

Ten of the classes played the mobile history game in the last week of May and the first two weeks of June 2007. Seven of these classes were pre-vocational; the other three were a mix of upper general and pre-university secondary education. The pupils in these classes form the experimental group. The other 10 – again seven pre-vocational and three upper general and pre-university secondary education – classes followed the regular project-based lesson series which was specifically designed for this research during the same period. The pupils in these classes form the control group.

### 4.2 Measures

*Engagement.* Every CT went into Amsterdam with a guide who observed the game, assisted with small technical issues and saw to the pupils' safety in the busy traffic of Amsterdam. The observation forms included items on just how often specific game activities occurred or how actively pupils were involved in a certain game activity (on a 5-point Likert scale with 1 indicating 'not at all' and 5 indicating '=very often/very strong'). Examples are: 'How actively is the HQT involved in the conduct of the assignment?' and 'How actively is the CT involved in the exploration of the surroundings?'. At the Waag building where the HQTs were located, the activities of each team were also observed by a guide who helped the HQTs with technical issues. In most cases, one guide was observing and helping two HQTs. All of the guides completed observation forms and, at the end of each day, both the guides for the CTs and the HQTs came together to orally report on the day. These guides were staff members of Waag Society or volunteers from outside Waag Society. Moreover, the three researchers made notes on the pupil engagement.

*Motivation for History and the topic of the Middle Ages.* Motivation was measured using a 6-item questionnaire similar to one available to measure motivation for Math (Cito, 1987). In fact, the word 'Math' was replaced by 'History' and an additional item was included to assess the pupil's motivation for the topic of the Middle Ages. The questionnaire was administered directly before (pre-test) and one week after (post-test) playing the Frequency 1550 game or attending the lesson series. The questionnaire items were responded to along a 5-point Likert scale with 1 indicating *(almost) never* and 5 indicating *(almost) always*. Examples of the statements to be rated are: 'I like the subject of History' and 'I learn a lot from the subject of History.' The homogeneity of the questionnaire was found to be satisfactory with a Cronbach's  $\alpha$  of 0.78 (pre-test) and 0.84 (post-test). Motivation for the topic of Mid-

dle Ages was measured using only the item: 'I think the Middle Ages are interesting.'

*Knowledge of medieval Amsterdam.* Historical knowledge of Amsterdam was measured using three multiple-choice questions and two open-ended questions for each of the six themes concerned with medieval Amsterdam: a total of 30 questions. However, none of the groups of pupils were found to have played the Frequency 1550 game for all six themes by the end of the game day. This meant that the test score for each pupil was corrected for the themes and assignments a pupil completed. So, only the scores for those questions for which the pupils had received the necessary information were considered in the test score on knowledge of medieval Amsterdam. The test items were exactly the same for pupils for both groups (game and lesson).

*Background variables.* The school administration provided us with information on the age, gender and level of education for the pupils. The teachers of the pupils estimated the pupils' initial History ability (knowledge or skills regarding the subject of History) along a scale of 1 to 5 with higher scores indicating greater ability. History ability was then recoded as low, medium or high initial History ability.

Given that the playing of the Frequency 1550 game draws upon collaborative learning, the pupils were asked to respond to five statements indicating their attitudes towards collaboration ( $\alpha = 0.78$ ). The questionnaire used to do this was similar to the questionnaire used to assess the pupils' motivation for History in general and the Middle Ages in particular; the same five-point Likert scale was used to respond to the questions. An example of an assessment statement is: 'When I collaborate, I understand things more quickly.' None of the several existing questionnaires we reviewed were found suitable to the group of students we were going to work with, therefore we made our own collaboration scale. We formulated 8 items on collaboration. After a factor analysis we selected those 5 items which loaded on the factor as intended and showed sufficient reliability.

*Analyses.* The oral reports provided by the guides at the end of the Frequency 1550 game day were all transcribed. In a grounded-theory approach, the transcriptions of the oral reports, the observation notes from the researchers and the notes of the guides from 110 observation forms were used to inductively discern the theme engagement (Strauss & Corbin, 1998). Sentences with words which indicate (dis)engagement (e.g., fun, concentration, (de)motivation, enthusiasm, boredom, effort) were marked and the frequencies of comments indicating engagement or disengagement were then counted.

To assess the four hypotheses regarding the motivational and learning effects of playing the game versus following regular lessons, univariate analyses of covariance were performed. For the first two hypotheses regarding the pupils' motivation and knowledge, the independent variable was the intervention (Frequency 1550 game or regular project-based lesson series); the dependent variables were motivation for

History in general and the topic of the Middle Ages in particular (hypothesis 1) and knowledge of medieval Amsterdam (hypothesis 2). Educational level (pre-vocational vs. upper general secondary and pre-university education), initial level of History ability (transformed into low, medium or high), pre-test motivation for the subject of History in general and the topic of the Middle Ages in particular and attitude towards collaboration were entered as covariates. For the hypotheses regarding the interaction effects, the independent variables were initial level of History ability, level of secondary education being followed and intervention; the dependent variable was knowledge of medieval Amsterdam; and the covariates were pre-test motivation for the subject of History in general and the Middle Ages in particular and attitude towards collaboration.

## 5. RESULTS

### *5.1 Engagement in the game Frequency 1550*

The game was mostly played as planned, but with a few exceptions. There was not much elaboration of back story: Pupils were often just told to gather as much points as possible, with no reference to earning civil rights. Moreover, pupils were not always informed about their identities as beggar or merchant. This meant that a certain competitive element of the game was removed. In addition, the technology did not always work as planned. On particularly the first three game days, there were problems with the GPS which either showed the wrong position for the pupils or no position whatsoever. The sending of photographs and videos took a very long time on some days which prevented the pupils from moving on to the next assignment. The pupils could not, thus, progress in the game and therefore completed fewer assignments than expected. These technical problems might have negatively influenced the engagement of the pupils. On about 50% of the 56 occasions when the guides mentioned something negative about the engagement of the pupils, the guide also mentioned a technical problem. Examples of statements where engagement was related to technical problems are: ‘media doesn’t arrive, causing a lot of delay leading to demotivation’; ‘some problems starting up the technique, they get impatient, start chasing each other and playing around’; ‘technical problems tested pupils’ patience and diminished concentration/attention’; and ‘the ladies want to, but get demotivated by technical problems.’ The pupils were not always demotivated in cases of technical problems and the guides sometimes explicitly noted that the pupils were motivated despite the occurrence of technical problems. There seem to be differences in engagement between the HQT and CT. The HQT generally had to wait less than the CT, and some of the guides mentioned that the pupils appeared to like to be in the HQT more than the CT. This higher engagement of the HQTs seemed to be related to the many different tasks of the HQT and their overview of the game play. This image of engagement derived from the observation forms is supported by the oral reports provided by the guides and researchers at the end of the day.

The quantitative observation data obtained from the guides showed the pupils to have a strongly active engagement in the solution of assignments but a bit more for the HQTs than for the CTs.

In general, most of the pupils appeared to like the game and to be engaged by the game. Pupils who were not engaged regularly showed off-task surfing for YouTube videos or other things not relevant to the game or the assignments. Illustrative of observation that pupils were engaged is a teacher mentioning of the fact that he could not normally get his pupils to work and that they now stayed focused for six hours, children being too busy to act up, best friends now able to live without each other for an entire day and some quiet pupils suddenly taking charge of the phone.

Below, we present the results regarding the four hypotheses we formulated. The means for the dependent variables are presented in Table 1 along with the numbers of participants in the analyses of covariance we performed.

*Table 1. Mean scores on knowledge of medieval Amsterdam, motivation for the subject of History and motivation for the topic of the Middle Ages for intervention and control group*

	Frequency 1550 game		Regular project-based lesson series	
	N	Mean	N	Mean
Knowledge of medieval Amsterdam	211	60%	200	36%
Motivation for History subject	141	3.02	136	2.80
Motivation for topic of Middle Ages	139	2.80	134	2.52

### *5.2 Motivation for History and the topic of the Middle Ages*

In our analysis of covariance no significant differences were found between playing the game versus attending regular lessons with respect to motivation for the subject of History in general or the topic of the Middle Ages in particular. As technical problems might have influenced the motivational results, the analyses were repeated for the data when split into days 1-3 and 4-10, but still no significant differences were found for the game versus regular instruction groups. Hypothesis 1, namely that the motivation for History in general and the topic of the Middle Ages in particular would differ for those pupils playing the Frequency 1550 game versus those pupils receiving a regular project-based lesson series, can thus be rejected.

### *5.3 Knowledge of medieval Amsterdam*

A significant effect of the intervention (playing the Frequency 1550 game versus the receipt of a regular project-based lesson series) was found for knowledge of medieval Amsterdam in the analyses of covariance ( $F(1, 410)=153.6; p \leq 0.001$ ). The 211 pupils who played the Frequency 1550 game generally attained higher scores on the knowledge test (with 60% of the questions answered correctly on average) than the 200 pupils who received regular project-based instruction (with only 36% of the questions answered correctly on average). Almost 28% of the variance in the scores

on the knowledge test was explained by the intervention, and this can be judged to constitute a large effect (effect size  $f=0.62$ ; see Cohen, 1988).

In light of the fact that the majority of pupils dropping out of secondary education come from pre-vocational education (OCW, 2007), we expected that the Frequency 1550 game might work differently for pre-vocational pupils than for the pupils from upper general secondary/pre-university education. The research of Clark and Feldon (2005) and Kanfer and McCombs (2000) also gave us reason to expect that a pupil's initial History ability and level of education might interact with the learning effect. For this reason, the two variables which indicate a pupil's ability level – namely, their level of education (pre-vocational vs. upper general secondary or pre-university) and initial History ability (low, medium, or high) were analyzed in interaction with intervention (game vs. regular project-based lesson series). The analyses revealed still a significant main effect of intervention and significant two-way interactions of educational level with intervention and initial History level with intervention. The results of the two-way interactions are graphically presented in Figures 2 and 3.

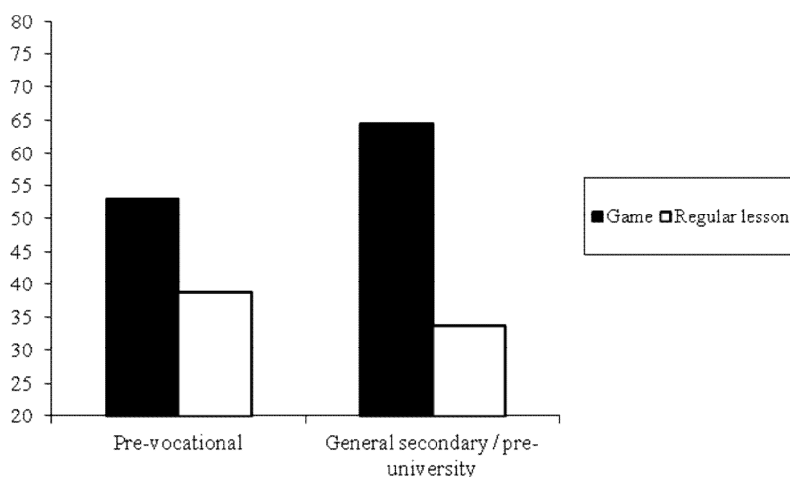


Figure 2. Two-way interaction between intervention (game vs. regular lesson) and educational level (pre-vocational vs. upper general secondary or pre-university).

Pupils from the higher educational level (i.e., upper general secondary and pre-university education) appeared to benefit *more* from playing the Frequency 1550 game than pupils from the lower educational level (i.e., pre-vocational education) (see Figure 2). After playing the Frequency 1550 game, those pupils in pursuit of a higher level of education attained relatively higher scores for knowledge of medieval Amsterdam than pupils in pursuit of a lower level of education. Conversely, after receipt of regular project-based instruction, pupils with a lower educational level

attained relatively higher scores on the test of knowledge of medieval Amsterdam than pupils with a higher educational level ( $F(1, 410)= 19.6; p \leq 0.001$ ).

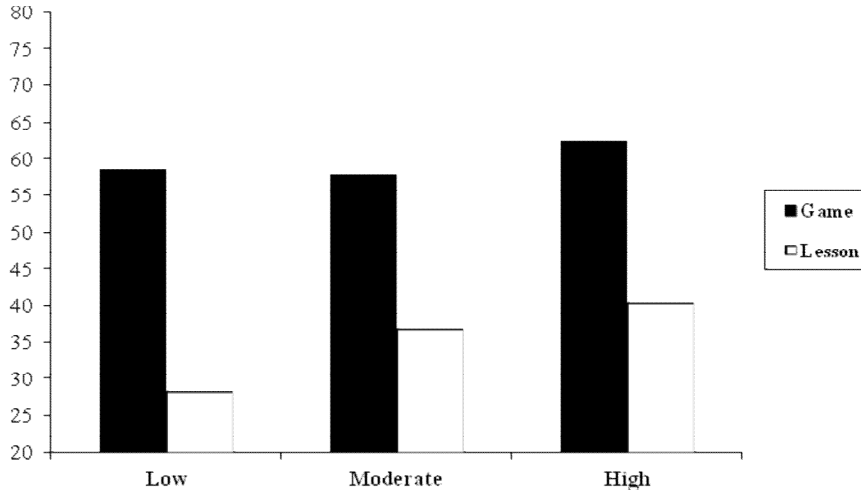


Figure 3. Two-way interaction between intervention (game vs. regular lesson) and initial History ability (low, moderate, high).

From Figure 3, it can be seen that pupils with an initially low History ability benefited *most* from playing the Frequency 1550 game; the difference between playing the game versus attending a regular project-based lesson series is larger for this ability group than for the other two ability groups ( $F(2, 410)= 3.3; p= 0.04$ ).

From Figures 2 and 3, it is clear that a large significant effect of intervention in favour of playing the Frequency 1550 game still remains ( $F(1, 410)= 138.7; p \leq 0.001$ ). Some 26% of the total variance in the scores on the knowledge of medieval Amsterdam test is explained by intervention alone. The interaction effects depicted in Figures 2 and 3 can be understood as small effects and indeed explain only 5% and 2% of the variance in the knowledge of medieval Amsterdam test scores, respectively.

## 6. DISCUSSION

The use of mobile games in education may be an excellent way to combine situated and active learning with fun. The learning potential of mobile and location-based technologies lies in the possibility to embed learning in an authentic environment, enhance engagement and foster learning outside traditional formal educational settings. Although research on game-based learning constitutes an expanding research

domain, claims that mobile games really enhance pupil learning still lack solid empirical evidence (De Freitas, 2006). Despite the various studies conducted to date, there is clearly a need for more thorough evaluation of the motivational and learning effects of mobile game-based learning. Experimental studies in which mobile game-based learning is compared to regular — possibly project-based — learning are needed direly. In this article, we have presented the results of an experimental study involving the mobile city game called Frequency 1550 in which pupils in the first year of secondary education can playfully acquire historical knowledge of medieval Amsterdam. Pupil engagement in the game was investigated in addition to the effects of playing the game on the historical knowledge of the pupils and their motivation for the subject of History in general and the topic of the Middle Ages in particular when compared to pupils receiving a regular project-based series of lessons.

The results showed playing of the Frequency 1550 game to produce a clear learning effect in terms of knowledge of medieval Amsterdam. Those pupils who played the Frequency 1550 game generally attained higher scores on the knowledge test when compared to those pupils who received a series of regular project-based lessons. The pupils in the mobile game intervention presumably gained greater knowledge of medieval Amsterdam because the information was presented in a more realistic, meaningful context and because the pupils had to actively work with the learning content within the context of medieval Amsterdam.

Although we also expected to find motivational effects of playing the game, no significant differences were found between the different interventions with respect to motivation for History in general or the Middle Ages in particular. This is striking in light of the fact that motivation is commonly considered *the* argument for the use of game-based learning in education. However, our definition of motivation was much more specific than the definitions used in the research we read. That is, we specifically examined motivation for the subject of History, whereas researchers define motivation in terms of fun and/or engagement (e.g., Schwabe & Göth, 2005).

In retrospect, it might be that playing the Frequency 1550 game for only *one* day is simply not enough to establish clear motivational effects. It is also possible that the technical problems may be partly responsible for the lack of effects on pupil motivation although separate analyses for those days with lots of technical problems versus those days with considerably fewer technical problems produced about the same results. Nonetheless, technical failures were clearly observed to be responsible for many instances of disengaged behaviour throughout the study days. In future research, more and earlier tests of technology should be performed in order to prevent technical failures to intervene with learning and motivational effects. Finally, many of the pupils did not complete one of the post-tests as it simply was not administered in six of the 20 classes. Given that the missing data was evenly distributed across the two interventions, however, we do not think that the validity of the present results and the conclusions to be drawn was damaged. More data might have revealed some smaller but significant effects, however.

In light of the hypothesis that game-based learning might work differently for pupils with a low level of education or initially low History ability, we also investigated the possibility of interaction effects. The results showed pupils from the higher levels of education to benefit *more* from playing the Frequency 1550 game than pu-

pupils from the lower levels. Stated differently: those pupils with a lower level of education benefitted *less* from the Frequency 1550 game than those pupils with a higher level of education. Conversely, those pupils with an initially low History ability benefitted *more* from playing the Frequency 1550 game than pupils with a higher level of initial History ability. That is, the Frequency 1550 game appears to be particularly worthwhile for pupils with an initially low History ability, and for pupils attending higher educational levels.

While the present study was not about the efficiency of teaching, it should be noted that the regular project-based lesson series involved only two class hours (of fifty minutes each), whereas the Frequency 1550 game involved the entire day. Despite the fact that the pupils who played the Frequency 1550 game required time for explanation of the technical aspects of the game and considerable time for navigation through the city and the search for the areas of the city, the pupils playing the game probably still had more learning time than those receiving the regular lesson series. In the present study, however, we were primarily interested in the effectiveness and not the efficiency of game-based learning.

While the Frequency 1550 game was shown to clearly promote knowledge of medieval Amsterdam, it is not clear which elements of the game contributed to pupil learning. For example, was the 'digital part' of the game accountable for the results, or was it primarily the 'location part', the opportunity for pupils to learn in location? The use of ICT in education has been influenced by several learning theories including behavioural learning theory, cognitive learning theory and social learning theory and thus has roots in work of Dewey, Piaget and Vygotsky. In their constructivist approaches to learning with technology, Jonassen, Peck, and Wilson (1999) and Barak (2006) have described learning principles which involve a synthesis of several learning theories. It is argued, for example, that ICT may only promote meaningful learning when the learners are actively engaged in learning which is constructive, contextual, reflective and social. Unravelling games — and perhaps mobile games in particular — into their constituent learning principles should thus be part of future educational research as only then, in our opinion, can we claim that mobile games constitute an excellent means to combine situated, active and constructive learning with fun.

For future research, it is suggested that the effects of game-based learning when pupils not only play the game but are also involved in the creation of the game, which allows more space for individual story construction and the addition of elements of own interest, be studied in particular. Such learner-centred production was not a part of the design of the Frequency 1550 game as pupils played a game which was developed by someone else with rules, goals, objectives, identities, a story line and assignments which could only be minimally influenced by the player/learner. The potential of *game creation* for educational purposes has yet to be addressed, thus, while it is just this which has taken the newly developed Games Atelier — which allows pupils to create and play their own games in their own urban environment via mobile phones, GPS and the Internet — one step further. Players-as-producers obviously emphasizes the more creative and constructive role of the learner and may therefore enhance learning effects and also trigger greater motivation on the part of pupils relative to the Frequency 1550 game, thus.

In conclusion the present research has shown a mobile game-based learning strategy to be highly effective when compare to a regular project-based instructional trajectory and highlighted promising new directions for future research along these lines.

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