The concept of flow in collaborative game-based learning

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Wilfried Admiraal [a,*], Jantina Huizenga [a], Sanne Akkerman [b], Geert ten Dam [a]

[a] Department of Child Development and Education, Faculty of Social and Behavioural Sciences, University of Amsterdam, Spinozastraat 55, 1018 HJ Amsterdam, The Netherlands
[b] IVLOS Institute of Education, Utrecht University, Utrecht, The Netherlands

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ABSTRACT

Generally, high-school students have been characterized as bored and disengaged from the learning process. However, certain educational designs promote excitement and engagement. Game-based learning is assumed to be such a design. In this study, the concept of flow is used as a framework to investigate student engagement in the process of gaming and to explain effects on game performance and student learning outcome. Frequency 1550, a game about medieval Amsterdam merging digital and urban play spaces, has been examined as an exemplar of game-based learning. This 1-day game was played in teams by 216 students of three schools for secondary education in Amsterdam. Generally, these students show flow with their game activities, although they were distracted by solving problems in technology and navigation. Flow was shown to have an effect on their game performance, but not on their learning outcome. Distractive activities and being occupied with competition between teams did show an effect on the learning outcome of students: the fewer students were distracted from the game and the more they were engaged in group competition, the more students learned about the medieval history of Amsterdam. Consequences for the design of game-based learning in secondary education are discussed.

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1. Introduction

Some of the more persistent educational problems facing students today include underachievement as well as learning, behavioral, and emotional difficulties that eventually lead to school dropout for many students (Battin-Pearson et al., 2000; Jonassen & Blondal, 2005). Dropping out of school is theorized to be a gradual process of student disengagement and alienation, marked by a chronic cycle of tardiness, absenteeism, failing classes, suspensions, and transitions between schools (Bridgeland, DiIulio, & Burke Morison, 2006; Finn, 1989). Even among students who finish the required years of schooling, some research has found high rates of boredom, alienation, and disconnection with schooling (Larson & Richards, 1991). Studies have characterized high-school students, in particular, as bored, staring out classroom windows, counting the seconds for the bell to ring, and pervasively disengaged from the learning process (Goodlad, 1984). Young people develop their identities in light of flexible communities in which new technologies play a major role: they like to be connected, need immediate responses, require social interaction, and desire experiential learning (Oblinger & Oblinger, 2005). According to Ziehe (2004) the personal experiential world has come to function as a standard for all spheres of life. And such changes obviously have an impact on the attractiveness and meaningfulness of school learning.

Students do not experience alienation and disconnection during all encounters with school learning. Certain conditions may promote excitement, stimulation, and engagement in the learning process leading to meaningful learning. Games in education seem to be excellent ways to combine meaningful learning with fun (cf., Author, 2009a, 2009b; Gee, 2003; Rickard & Oblinger, 2003; Schwabe & Göth, 2005; Shaffer, 2006; Shaffer, Squire, Halverson, & Gee, 2005). In this article, we use the concept of flow (Csikszentmihalyi, 1990) as a way to investigate game activities of student teams and evaluate their effects on team game performance and student learning outcome.

2. Flow theory

Flow is a state of deep absorption in an activity that is intrinsically enjoyable, as when artists or athletes are focused on their play or performance (Csikszentmihalyi, 1990). Individuals in this state perceive their performance to be pleasurable and successful, and the activity is perceived as worth doing for its own sake, even if no further goal is reached. Individuals function at their fullest capacity, and the experience itself becomes its own reward (Nakamura & Csikszentmihalyi, 2002). Flow theory is based on a symbiotic relationship between challenges and the skills needed to meet those challenges. The flow experience is believed to occur when one's skills are neither overmatched nor underutilized to

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* Corresponding author. Tel.: +31 20 5251396; fax: +31 20 5251290.
E-mail address: w.f.admiraal@uva.nl (W. Admiraal).

meet a given challenge. This balance of challenge and skill is frag-ile; when disrupted, apathy (i.e., low challenges, low skills), anxiety (i.e., high challenges, low skills), or boredom (i.e., low challenges, high skills) are likely to be experienced (Csikszentmihalyi, 1997) (see Fig. 1).

The experience of anxiety or boredom may induce a teacher to change the level of challenge, and also prompt students to increase their skill level in order to reenter flow. Issuing appropriate chal-lenges and providing opportunities to enhance skills (e.g., provid-ing immediate feedback, incrementally teaching more complex skills that build upon previously learned skills and scaffolding the learning process, see van der Pol, Volman, and Beishuizen (in press)) may be one of the most ideal ways of engaging students. Because the flow state is intrinsically rewarding, students seek to replicate flow experiences. This introduces a selective mechanism into psychological functioning that fosters growth (Nakamura & Csikszentmihalyi, 2002). As students seek to master new chal-lenges, they develop greater levels of skill. Once mastered, they must identify progressively more complex challenges to create an ideal match for their skills. Flow thereby invokes a growth prin-ciple, in which a more complex set of capacities is sought after and developed.

Based on flow theory, it is said that concentration, interest and enjoyment in an activity must be experienced simultaneously in order for flow to occur (Csikszentmihalyi, 1997). Flow experiences are described as states of intense *concentration* or absolute absorp-tion in an activity (Csikszentmihalyi, 1990). In educational con-texts, deep absorption in activities has been shown to promote optimal learning experiences. For example, Csikszentmihalyi, Rathunde, and Whalen (1993) reported that a sample of talented teenagers concentrated more than their average peers during classroom and study activities, but comparatively less while watching television and engaging in social activities. This finding suggests that the ability to exploit concentration for more complex mental tasks may be one of the hallmarks of achievement and tal-ent development. *Interest* in an activity is a fundamental aspect of flow experiences, setting the foundation for continuing motivation and subsequent learning. Researchers have argued that interest provides the basis for becoming engaged with a topic for its own sake (Deci & Ryan, 1987). Acting on intrinsic interest alone, indi-viduals seize opportunities to learn, read, work with others, and gain feedback in a way that supports their curiosity and serves as a bridge to more complex tasks. Flow activities, including intellec-tually demanding tasks, can also be *enjoyable* and satisfying. They may provide a feeling of creative accomplishment and satisfaction. Such feelings may occur mainly in retrospect because all concen-tration is focused on the task during actual engagement

(Csikszentmihalyi, 1990). In any event, individuals who have developed their talent and creativity are those who continue to fol-low their sense of enjoyment in chosen activities (Csikszentmihalyi, 1996).

Due to the relationship between challenge and ability, the con-cept of flow has been used by designers, teachers, and coaches in such wide-ranging fields as sports, tutoring, and increasingly infor-mation technology in education (see for some examples, Hsu & Lu, 2004). In game-based learning, the game activity must balance the inherent challenge of the activity and the player's ability to address and overcome it in order to maintain a player's flow experience. If the challenge is beyond that ability, the activity becomes so over-whelming that it generates anxiety. If the challenge fails to engage the player, the player quickly loses interest and tends to leave the game. Fortunately, we have tolerance for a temporary lack of stimulation – assuming we are given hope that more is on the way (cf. Csikszentmihalyi, 1990).

3. Game-based learning

Computer and video games can let student experience ways of learning that stress immersion in a practice, supported by struc-tures that lead to expertise, professional-like skills, and innovative thinking. Digital games are seen as excellent tools for facilitating and supporting situated learning of students (cf., Gee, 2005; Prensky, 2001; Shaffer et al., 2005; Winn, 2002). Rich virtual worlds are what make games powerful contexts for learning. In game worlds, learning no longer means confronting words and symbols sepa-rated from the things those words and symbols are about in the first place. In virtual worlds, students can experience the concrete realities that words and symbols describe. Through such experi-ences, across multiple contexts, students can understand complex concepts without losing the connection between abstract ideas and the authentic problems that can be used to solve. Games are being recognized as fruitful narrative learning environments, moving be-yond fragmented information (Akkerman, Admiraal, & Huizenga, 2009; Jenkins, 2004). The developments of location-aware and mobile technology give many exciting opportunities to create such new ways of learning. These technologies can embed learning in a natural environment, using the treasures of information that the environment conceals. It is possible to merge digital and urban play spaces to connect locations, contexts, and meaning.

It can be argued that digital games – with or without location-aware and mobile technology – can transform education and change the widely shared perspective that games are "mere enter-tainment". The attitude of today's young people towards their video and computer games is the very opposite of the attitude that most of them have towards school. Yet it is the very attitude we would like all our learners to have: interested, competitive, coop-erative, results-oriented, and actively seeking information and solutions. It therefore makes a great deal of sense to try to merge the content of learning and the engaging and thereby motivating strength of games. 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, coop-eration and recognition. According to many authors, many of these factors are triggered by the use of games (see, e.g., Egenfeldt-Nielsen, 2006; Garris et al., 2002; Prensky, 2001). Other researchers examine various conditions of using games in order to trigger
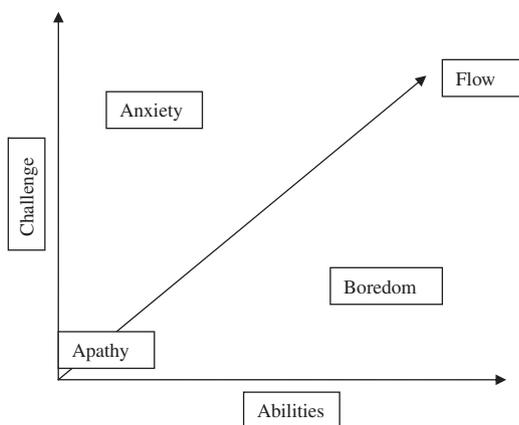

Fig. 1. Model of flow (adapted from Csikszentmihalyi (1990, 1997).

engagement or flow, such as user-friendly interface (Pilke, 2004), challenge matching the level of difficulty (Sweetser & Wyeth, 2005), immediate and appropriate feedback (Kiili, 2005), reflection on game experiences (Lim, Nonis, & Hedberg, 2006), competition (Jayakanthan, 2002), content creation (Kiili, 2005) and gamefullness (Inal & Cagiltay, 2007; Kiili, 2005).

However, the relationship between the engaging aspect of games and its learning effects is still under-researched. 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 students 'into a state where they are mentally ready for learning and where they are in the right environment for learning' (p. 215).

In this article, we will address the motivational aspects of a location-based game, called Frequency 1550. This game has been developed by the Waag Society, which is a Dutch IT research foundation working in the social and cultural domain (www.waag.org). Frequency 1550 is a game about medieval Amsterdam to be played in student teams during a single school day as part of the History lessons in secondary education. We will use the concept of flow as a way to investigate game activities of the student teams and evaluate the effects of these activities on team game performance and student learning outcome. The three research questions are:

(1) how can game activities of student teams be characterized and how do these relate to the concept of flow?
(2) to what extent do game activities affect team game performance?
(3) to what extent do game activities affect student learning?

4. The Frequency 1550 game

4.1. Introduction to the game

At the start of the game day, the students gather at the main location, which is the Waag building – a 15th century weighing house in the city of Amsterdam. The students are introduced to the game, the tasks, the tools to be used and the objective of the game. Before the students actually start playing, the game is placed in the context of a larger story (back story), an ideal story that the players have to imagine. *Frequency 1550* seems to magically incorporate a different time period – the year 1550 of the late medieval era via the UMTS-network, the medieval city's bailiff is getting in contact with the present, that is, 21st-century Amsterdam. Students are told that they can earn citizenship in Amsterdam by collecting as many of the required 366 so-called Days of Burghership as possible. These 366 points refer to the medieval year-and-a-day rule, which is how long you had to be living inside the city walls to earn citizenship rights. Groups of four students each – two located at the headquarters at the Waag, the other two walking the streets of Amsterdam – are randomly assigned the identity of beggars or merchants, who have – as in the Middle Ages – a different social status in the game, causing merchants to win a confrontation in the city. With the help of the Internet, smart phones, video phones and GPS technology, Amsterdam becomes a medieval playground.

4.2. Group and team structure

The game is played in groups of four students. Each group is divided into a city team (CT) of two students who walk through the city and a headquarter team (HQT) of the other two students who remain in the headquarters room with a computer. The teams switch places in the second half of the day so that each student participates in both the CT and the HQT. The CT is assigned one of six areas (see below) as the starting point for walking and is asked to conduct small location-based media tasks (which will be described later) in order to explore, map and master the area and its theme, before moving to the learning task of the next area. The CT can see a map of medieval Amsterdam on their phones. The HQT digitally follows the route of the CT and guides them toward and through the learning tasks by using various information sources, both in-game and from the Internet (such as Wikipedia). The HQT also collects all the materials that are produced to complete the tasks. The HQT can use two maps: one representing the medieval Amsterdam and one depicting present-day Amsterdam, both with colored dots representing the route of the six CTs. Because the HQT is able to see each player walk through the city in real time – on the medieval map as well as on a current map of Amsterdam – they can work out the team's strategy and use their phones to guide their team toward the locations where the assignments are hidden. The CTs have the medieval map of Amsterdam on their videophone, and a paper version of the modern map in their bag. They cannot see the routes. The CT has the possibility
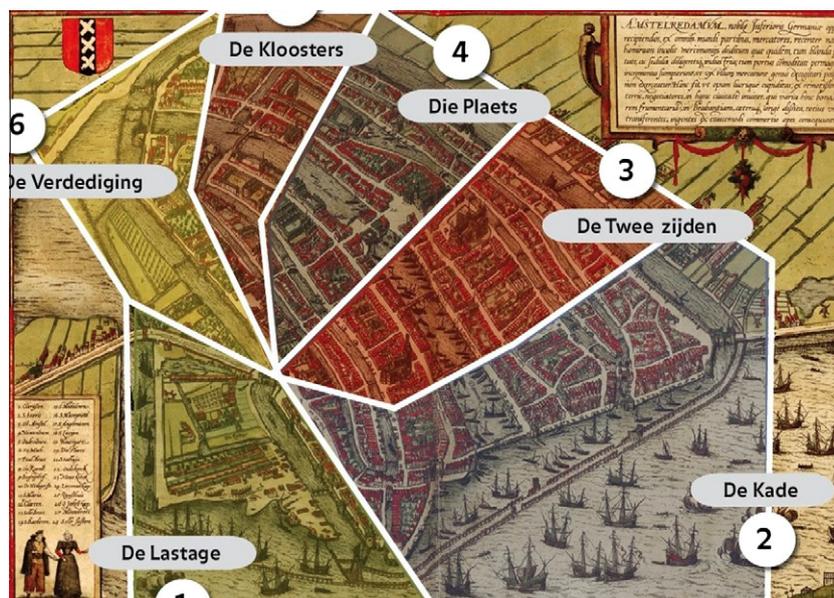

Fig. 2. Map of medieval Amsterdam with the six areas © Waag Society.

to zoom in the map on a particular part of the area where they were walking.

4.3. Six areas with additional stories

The old city of Amsterdam has been divided into six areas, each dealing with a different theme in medieval times. In Fig. 2, the medieval map is divided into six themes. The six themes 'labour' (for the area called *De Lastage*), 'trade' (*De Kade*), 'religion' (*De Twee Zijden*), 'rules and government' (*Die Plaets*), 'knowledge' *De Kloosters*), and 'defense' (*De Verdediging*) are introduced to the students by an introductory video clip that is sent to them as soon as they enter a specific area – with the name of that area appearing on their phones. For example, trade is connected to the harbor area of Amsterdam, while defense is connected to the boundaries of the old city. The clips present words that can help the group complete the assignments of that area, while the sound of the video represents the sound of that area (e.g., sound of manual work, sawing). After these words, the video shows and zooms in on a few pages from a diary, which are read by a medieval character. Following the diary pages, a closing text appears (from the main narrator) about the hidden location where the assignment can be found.

4.4. Assignments

As soon as a city team (CT) has reached a certain location, video assignments are automatically sent from the server of the Waag to the UMTS videophone with the help of a global positioning system (GPS). Each assignment starts with an introductory video clip. In each area, there are three similar types of assignments (each composed of three parts): an orientation assignment, an imagination assignment and a symbolic assignment. Each assignment is concluded with a multiple-choice or open-ended question which often requires the CT and headquarter team (HQT) to combine their knowledge to find the answer.

The orientation assignment includes texts and tasks intended to trigger environmental awareness by creation or selection of photos, questions about the site and imagination about the viewpoint, work or actions of historical figures. The CT needs to act or film (e.g., carry out work of a shipbuilder or walk the route of a procession as a pilgrim) and the HQT needs to select parts of the medieval map that indicate the work and search for more information on the Internet. In the case of the procession route, students are asked to name the participants (pilgrims), select the part of medieval city where the pilgrims walked, select examples of the proof pilgrims received as they completed the pilgrim route, and search on the Internet (by Wikipedia or Google) for the name of this pilgrim route.

The imagination assignment includes not only texts and a task that again intends to trigger environmental awareness by creation or selection of photos and by answering questions about the site, but also imagination about historical actions, events, or work of historical characters. An example is the idiom 'fire test', which means 'it will be a big test'. The meaning of the phrase can be understood once the students discover the history behind it: an accused had to put his hand in a fire, walk on glowing coals, or walk through a fire in order to prove his innocence. If he was unhurt, he proved to be innocent. For this particular example, the CTs are asked to 'act out' a fire test (or its meaning) and tape this on video. The HQTs are asked to interpret the meaning of a fire test, albeit with the help of information from the Internet (such as literal translation of the idiom, examples of its use, etc.).

The symbolic assignment that calls upon deep learning activities includes texts and tasks for the team to select details of the site that represent a certain symbolic value. The CT is asked to search for and take photos of these details (e.g., take a picture of a church tower) and the HQT is asked to interpret these details. The answers of both CT and HQT must be combined in order to get the correct interpretation of the symbolic meaning of the details from the city. In case of the church tower, the symbolic meaning includes that a church tower bridges earth and heaven.

Each group (with a CT and a HQT) can win points for these assignments, helping them to win the game. At the same time, the groups are competing with each other. Each CT has to decide whether to stay away from other teams or to take the chance to call on a confrontation – their social status (with merchants being of a higher order than beggars) determines who wins. The winning team takes away hard-earned medieval points (Days of Burghership) from the team who loses. The CT can also drop virtual medieval rats by pressing a key on their videophones to kill the communication facilities of another team with their HQT.

4.5. Technical tools

Each CT is provided with a game phone linked to a GPS receiver in order to communicate with their group members at the headquarters and a UMTS videophone with which they can receive and send pictures, video clips, text, and video messages. Each HQT is provided with a phone, and a computer with an Internet connection and a digital environment to collect assignment material. The HQTs have Internet access in order to look up information, check out historical references, and send relevant information to the players in the city, thereby helping them complete their assignments. Each HQT creates a website with all materials that have been collected during the day (the multimedia box). At the end of the day, the HQT is responsible for the collection of all the data in the multimedia box.

4.6. The closing of the game

At the end of the day, all students gather at the main building where the HQTs are located. Each of the groups is invited to shortly present to the other groups some of their collected media from their multimedia box. The group with the most correct answers wins the most game points, which are shown in the multimedia box. The playtime includes a 30 min plenary introduction, a 1-h lunch break, and a 1-h presentation at the end of the day; this means that students play some in a CT and 2 h in a HQT.

5. Method

5.1. Participants

Frequency 1550 was played by 216 students spread over 10 school classes in five schools for secondary education in Amsterdam, the Netherlands. The students ranged in age from 12 to 16 years old; most of them were 13 years old and they varied in educational level from lower secondary vocational education to pre-university education. Each school class was randomly divided into groups of four students, forming two teams of two students for each group (a city team and a head quarter team). In total, 54 groups of students played the game, spread over 10 game days (one school class per day).

5.2. Measures

Data have been collected by structured observations of the 54 city teams and 54 headquarter teams, by the groups' logs of their game play, school data base with student information including gender, cultural background and educational level, a knowledge

Table 1
Data and measurements.

Variables	Data						
	Structured observation	Game log	Test	Questionnaire	Teacher assessment	School administration	Meeting
1. Team game activities	X	X					
2. Team game performance		X					
3. Student learning outcome			X				
4. Student background information						X	
5. Student motivation				X			
6. Student ability					X		
7. Game process	X						X

Table 2
Measurement of team game activities.

City team	M	s.d.	Headquarter team Item	M	s.d.
Flow					
Working on the completion of the assignment	4.1	0.7	Working on the completion of the assignment	4.2	0.6
Navigating the urban environment (students look around and discuss what they see)	3.1	0.8			
Using the tools (video phone, GPS)	3.7	0.6	Searching the Internet	3.5	0.7
Collaborating within the city team	3.6	0.9	Collaborating within the head quarter team	3.7	0.7
Collaborating with the head quarter team	3.9	0.7	Collaborating with the city team	3.8	0.6
Competition					
Competing with the other student groups	3.3	0.9	Competing with the other student groups	2.9	0.8
Distractive activities					
Working on technology issues (tools, interface, connections)	2.6	0.8	Working on technical problems (tools, interface, connections)	2.8	0.8
Working on navigation issues	2.0	0.8			

Note: s.d. = standard deviation.

test on medieval Amsterdam, a questionnaire on students' motivation for History lessons and evaluation meetings at the end of each game day. In Table 1, we present an overview of the measurements.

5.2.1. Team game activities

Data about each group's game activities have been gathered by structured observations. Each headquarter team (HQT) has been observed by one observer and each city team (CT) was accompanied by a guide who conducted the observations, along with assisting with small technical issues and protecting the students' safety in the busy traffic of Amsterdam. These observers and guides had experience with guiding students and were informed about their role at the beginning of each game day. Observation forms were used for each assignment in each area and includes items on how students in each team were engaged in a certain game activity (on 5-point Likert scales with 1 = not at all and 5 = very often/very strong). In Table 2, we present these items for both CT and HQT, along with some descriptive statistics.

We did not find any significant differences in both means and standard deviations among the three assignments. The observation of the activities of the CT and HQT was based on various items, some of which were similar between CT and HQT (e.g., "How actively engage is the team with defeating another team" measuring competition) and some different (e.g., "How actively engaged is the HQT with searching the Internet" or "How actively engaged is the CT navigating the urban environment"). On the items that were similar, no differences have been observed between the CT and HQT, except for a trend that CTs generally tend to be more competitive than HQTs ($t(104) = 1.89$; $p = 0.06$).

For our study into flow in game-based learning, we divided all items of the observation form into team game activities that show the engagement of each team in the game play itself (referred to as

flow), competitive activities (which are focused on the competition with the other groups), and indirect activities including being occupied with technology and navigation issues. The latter we refer to as distractive activities. The cluster of game activities we labelled flow shows a satisfying homogeneity of $\alpha = 0.77$, and both distractive activities of CTs show a significant positive correlation.

5.2.2. Team performance

Data about each group's game performance have been gathered by logs of their game play. These logs include – among other performance information such as the number of medieval rats used and received, and the number of confrontations won or lost – the number of points (i.e. days of citizenship of Amsterdam) each group received for each assignment. We summarized team performance into one total game score of each team, ranging from 23 to 126 with a mean of 71.2 and a standard deviation of 26.5.

5.2.3. Student learning outcome

The student learning outcome referred to the historical knowledge of Amsterdam. It has been 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. All answers on the open-ended questions have been scored (correct or not) by one researcher with a satisfying interobserver agreement of Cohen's $\kappa = 0.91$ (with a 95% confidence interval of $0.82 < \kappa < 1$ for two researchers). The internal consistency of the five items for each of the six themes in terms of KR-20 equals 0.97. None of the student groups played the Frequency 1550 game for all six themes by the end of the game day. As a consequence, the test score for each student has been corrected for the themes and assignments each student completed. So, only the scores for those questions for which the students had received the necessary information were considered in the test score on knowledge of

medieval Amsterdam. The test score measuring the student learning outcome ranged from 0% to 100%, with a mean of 59.6 and a standard deviation of 23.6.

5.2.4. Students' level of education, ability and motivation for History lessons

The school administration provided students' background information (age, gender, and cultural background) and their level of education (with 1 = low pre-vocational, 2 = moderate pre-vocational, 3 = upper pre-vocational, 4 = upper-secondary, and 5 = pre-university).[1] Student ability has been estimated by the school teachers by marking each of their students on knowledge and skills regarding the subject of History on a 5-point Likert type scale with higher scores indicating greater ability. This teacher classification was based on students' previous grades in History. These grades themselves could not be used as schools applied different grading systems. Motivation for History lessons has been measured using a 6-item questionnaire similar to one available to measure motivation for Math (Cito, 1987). The questionnaire items were responded to along a 5-point Likert scale with 1 = (almost) never and 5 = (almost) always. Example items 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 α of 0.78.

5.2.5. Game process

At the end of each day, both the guides of the CTs and the observers of the HQTs came together to orally report on the day. They discussed the student engagement, their game play and game performance, as well technical issues and practicalities. These oral reports were transcribed into written protocols structured by the following themes: technology issues, collaboration within teams, competition between teams, student engagement in-game activities, student game performance, student ability to complete the assignments, and student reflection on game process and performance.

5.3. Analyses

Descriptive statistics were used to describe the team game activities in terms of flow, competition and distractive activities.

Stepwise regression analyses were performed to examine the relationships between the team game activities (independent variables) and the group game performance (dependent variables), with students' level of education, ability and motivation as additional independent variables on group level.

In order to examine the relation between team game activities and student learning outcome, multi-level regression analyses have been used with the team game activities and group performance (both on group level) and students' level of education, ability and motivation (all on student level) as independent variable and students' knowledge of the medieval history of Amsterdam as dependent variable.

The qualitative data of the evaluation meetings have been analyzed by scrutinizing and summarizing the evaluations in relation to the game activities and structure of the game itself. The results of this content analysis were the input for the text reported in the first section of the results section, addressing the game process. Only interpretations were included on which the three researchers reached agreement.

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[1] In the Netherlands, secondary education includes three main stream curricula offering five levels of education: pre-vocational a 4 years curriculum for students aged 12–16, upper secondary a 5-years curriculum for students aged 12–17, and pre-university a 6-years curriculum for students aged 12–18.

6. Results

6.1. Game process

The game Frequency 1550 was mostly played as planned, but with a few exceptions. First, students had some difficulties in recognizing the story line and 'living the narrative' of Frequency 1550. This story line was supposed to be one of effective game elements triggering flow with the game play. The observations show that during the introduction of the game most students paid attention to the procedures and the technology of the game and did not take the story (of earning citizenship of Amsterdam) too seriously. One of the reasons might be that students were often just told to gather as much points as possible, with no reference to earning civil rights. Another reason might be that most teams, particularly the CTs, barely watched the video clips which introduced the area and the diary that introduced the perspective of the year 1550. This diary invites students to sympathize with a medieval character by describing intentions (e.g., need to buy a yarn), actions, and sensed reality (e.g., smells, sense of safety, weather experience). The observations also show that students did not read the text messages very well most of the time. Sometimes the message for the CT was difficult to read from the videophone (too small, sunlight glare), but, more generally, most students were focused on completing the assignments (and collecting days of citizenship). This was indicated by the fact that many students scrolled down straight to the last part of the introductory text and the first words of the assignments. In the video messages, the words, diary text, and closing text also repeat the main concepts and include signs that point to the hidden location of the assignments. Participants' little attention to video and text messages illustrated their focus on playing the game, and their lack of focus on the historical narrative embedded in these messages.

Second, the competitive elements of Frequency 1550 have been less emphasized as planned. Students were not always informed about their identities as beggar or merchant. This meant that they were not always aware that they won or lost confrontations with other CTs. Moreover, the reception of a medieval rat caused a loss of connection between CT and HQT for 10 min. However, as some groups already had connection difficulties, losing connection (again) was not very motivating.

Thirdly, 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 students or no position whatsoever. Sending photographs and videos took a very long time on some days which prevented students to move onto the next assignment. Although many observations of decreased student engagement were related to technology difficulties, most students appeared to like the game and to be engaged in their game activities. Illustrative observation that students were engaged includes a teacher mentioning that he could not normally get his students to work and that they now stayed focused for 6 h, students being too busy to act up, best friends now able to live without each other for an entire day and some quiet students suddenly taking charge of the phone.

6.2. Team game activities: flow, competition and distractive activities

In Table 3, descriptive statistics are presented for the team game activities, separate for the CTs and HQTs. Generally, there were no significant differences in all items describing flow in teams between the three assignments, except that students in HQTs learn to search the Internet more during the third assignment than in the first one ($t(160) = -2.1$; $p = 0.04$). A decreasing trend can be seen in the distractive activities: students were less occupied by both the

Table 3
Team game activities during the three types of assignments in each area (means with standard deviations between brackets).

Flow	Assignments		
	1. orientation	2. imagination	3. symbolic
Working on the completion of the assignment			
CT	4.1 (0.9)	4.1 (1.0)	4.1 (1.0)
HQT	4.2 (0.9)	4.2 (0.8)	4.2 (0.9)
Navigating the urban environment			
CT	3.0 (1.1)	3.2 (1.3)	3.2 (1.1)
Using the tools			
CT	3.6 (1.0)	3.7 (1.0)	3.8 (0.8)
Searching the Internet			
HQT	3.3 (1.1)	3.6 (1.2)	3.7 (1.0)
Collaborating within the team			
CT	3.6 (1.2)	3.6 (1.1)	3.8 (1.0)
HQT	3.8 (1.1)	3.7 (1.1)	3.8 (1.1)
Collaborating between teams			
CT	4.0 (1.0)	3.9 (0.9)	3.9 (1.0)
HQT	3.8 (0.9)	3.8 (0.9)	3.8 (0.8)
Competition			
Competing			
CT	3.2 (1.3)	3.5 (1.2)	3.5 (1.2)
HQT	2.8 (1.3)	3.1 (1.1)	2.8 (1.2)
Distractive activities			
Working on technology			
CT	2.7 (1.3)	2.6 (1.3)	2.3 (1.3)
HQT	2.8 (1.4)	2.8 (1.1)	2.4 (1.2)
Working on navigation			
CT	2.0 (1.2)	1.9 (1.2)	1.7 (1.1)

technology issues and navigation issues during the third assignment ($M = 2.4$ and $M = 1.6$, respectively) compared to the first assignment ($M = 2.9$ and $M = 2.0$, respectively; with $t(328) = 2.4$; $p = 0.02$ for technology issues and $t(163) = 2.1$; $p = 0.04$ for navigation issues).

The observers who have monitored both CTs and HQTs noticed that students in HQT and CT differed in engagement: the HQT generally had to wait less than the CT, and students 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 qualitative observation data is not supported in the quantitative data: HQTs and CTs did not differ significantly in flow, competition and distractive activities. But we did see a tendency that CTs are generally more focused on competition than HQTs ($t(104) = 1.89$; $p = 0.062$ with $M = 3,26$ for CTs and $M = 2,93$ for HQTs).

6.3. Team game activities and group game performance

In order to examine the relationship between team game activities and group game performance, stepwise regression analyses have been performed. The results are presented in Table 4. Four models have been examined: the first three models including a subset of independent variables, and the final model only including the independent variables that showed significant effects in an earlier model.

The analyses of model 1 show that team flow in game-play has a significant effect on group game performance, explaining 24% of the variance in team performance. Analyses of model 2 show that the fewer teams were occupied with both types of distractive activities, the better they performed in the game, explaining 33% of the variance in scores on group game performance. From the student background variables in model 3, only the mean educational level of a student group appears to have a significant effect on game performance of a group, explaining 13% of the variances in scores. All these effects were included in the final model. In the final model, 43% of the variance in game-performance has been explained by team flow and both types of distractive activities in a team. This means that the more flow in game-play student teams showed, and the less distractive activities they carried out, the better they performed in Frequency 1550. These variables explained 14%, 6% and 26% of the variance in team game performance, respectively. This relationship appears not to be moderated or mediated by the mean ability or motivation of a group.

6.4. Flow and student learning

In order to examine the relationship between team game activities and student learning outcome, multi-level regression analyses have been performed. The results are presented in Table 5. Six models have been examined: a variance components model (model 0) to examine the variance components on student and group level, four models including a subset of independent variables, and a final model only including the independent variables that showed significant effects in an earlier model.

The results of the variance components model (model 0) indicate differences between groups and between students and the proportion of variance that can be explained by group characteristics and student characteristics. The results ($\sigma^2 u_{0j}$ and $\sigma^2 e_{0ij}$ in Table 5) show that the variance on group level does significantly differ from zero: the 54 groups in our sample appear to vary in student learning outcome. The variance partition coefficient (Goldstein, 2003) equals 0.24, which means that 24% of the

Table 4
Stepwise regression analyses with group game performance.

	Model 1 Flow and competition N = 50 B (s.e.)	Model 2 Distractive activities N = 50 B (s.e.)	Model 3 Student ability ad motivation on team level N = 50 B (s.e.)	Model 4 Final N = 50 B (s.e.)
Flow and competition				
Flow	29.30 (7.29)			19.98 (6.68)
Competition	–			n.a.
Distractive activities				
Technology		−12.25 (4.60)		−10.05 (4.32)
Navigation		−13.87 (3.97)		−11.19 (3.78)
Mean student ability and motivation				
Mean ability in History			–	n.a.
Mean educational level			6.07 (2.96)	–
Mean motivation for History			–	n.a.
Adjusted R²	0.24	0.33	0.13	0.43

Note: N = number of students included in the model; s.e. = standard error. Only effects are printed that significantly (with $\alpha = 0.05$) improved the model; non-significant effects are printed with' –'; n.a. = not applicable.

Table 5
Multilevel regression analyses with scores test on History knowledge.

	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5
	Variance components	Flow and competition	Distractive activities	Group performance	Student ability and motivation	Final
	$N = 215$	$N = 210$	$N = 215$	$N = 215$	$N = 212$	$N = 206$
	B (s.e.)	B (s.e.)	B (s.e.)	B (s.e.)	B (s.e.)	B (s.e.)
Fixed effects						
Flow and competition						
Flow		9.86 (3.58)				–
Competition		7.52 (2.31)				6.42 (2.86)
Distractive activities						
Technology			–7.50 (2.71)			–7.02 (2.72)
Navigation			–6.21 (2.59)			–
Group performance						
Group performance				0.19 (0.06)		–
Student ability and motivation						
Ability in History					–	n.a.
Educational level					5.13 (1.32)	3.58 (1.24)
Motivation for History					–	n.a.
Random effects						
Level 2 (group) $\sigma^2 u_{0j}$	131.42 (47.43)	0	0	0		0
Level 1 (student) $\sigma^2 e_{0ij}$	423.15 (46.82)				394.84	418.94
2*loglikelihood	1953.08	1903.62	1841.75	1874.94	1908.20	1845.32

Note: N = number of students included in the model; *s.e.* = standard error. Only significant fixed effects (with $\alpha = 0.05$) are printed; non-significant effects are printed with' –'; n.a. = not applicable.

variance in the scores of student learning outcome is due to differences between groups (and 76% to differences between students). All other models show a significant (with $\alpha = 0.05$) improvement of the variance components model, based on the difference in 2 * loglikelihood.

The other models (models 1–4) in which subsets of independent variables have been included, show that flow, competition, both types of distractive activities, and group performance (all on group level) and educational level (on student level) are significantly related with student learning outcome. The variables on group level all explain 100% of the variance on that level; a result that is confirmed by the relatively high inter-correlations. These results cause the disappearance of most of the variables on group level in the final model. The final model shows that the more groups were engaged in competition with other student groups and the less they were distracted by technology issues, the higher the scores student received on the knowledge test. These effects explain all the variance on group level. Congruent with earlier findings (Huizenga, Admiraal, Akkerman, & ten Dam, 2009) students with a relatively high educational level (upper-secondary education and pre-university education) performed better on the knowledge test, compared to students from lower vocational education. Flow with game play is not related to student learning outcome; it disappears after entering the variable educational level. Post-hoc analyses show that team flow is significantly positive correlated to the mean education level ($r = 0.47$), which means that groups with relatively more students from upper-secondary and pre-university education show more flow in game-play compared to the other groups. This result confirms our earlier thoughts that Frequency 1550 seems to be more tailored to the needs and skills of students from a higher educational level.

7. Discussion and conclusion

In this study, we have examined excitement and engagement in Frequency 1550, a location-based city game for secondary education students about the medieval history of Amsterdam, in terms of flow. This game was played with groups with two types of stu-

dent teams, a city team and a head quarter team. Generally, the student teams showed flow with the game play, although they were distracted by activities that were focused on solving problems with technology and navigation in the city. Team flow appears to be related to the group performance in the game, but not with student learning outcome. This conclusion is in line with the results of other studies on game –based learning and engagement. For example in an experimental study, Annetta, Minogue, Holmas, and Cheng (2009) conclude that students did not show a greater conceptual understanding – as measured in a teacher test –, although they were more engaged in instructions and learning activities compared to a non-playing group of students. These results might question the idea that being in flow during gaming also leads to more long-term cognitive outcomes and foster growth as Nakamura and Csikszentmihalyi (2002) suggest.

However, other game activities that are related to flow show relationships with student learning outcome: the less groups of student were distracted from game play by solving technology problems and the more they were engaged with competition with other student groups, the more students appeared to learn about the medieval history of Amsterdam. Moreover, Frequency 1550 seems to be more tailored to the students from upper-secondary and pre-university education, compared to students from lower vocational education. This educational level was found to be related to both flow with game play and student learning outcome: the higher the educational level of students, the more flow their teams showed and the more student learned about the medieval history of Amsterdam. Following Csikszentmihalyi's flow theory (1997), the challenges of the game activity and the skills needed to meet those challenges seemed to be more in balance for those students. For students from lower vocational education, playing a game like Frequency 1550 apparently asks for more support, whether or not incorporated in the design of the game. These results confirm our finding from an earlier study (Huizenga et al., 2009) showing that students from the higher educational level (i.e., upper-secondary and pre-university education) appeared to benefit from playing the Frequency 1550 game, whereas students from lower education levels attained relatively higher test scores after receipt of regular project-based instruction. Although

scaffolding seems to be an effective teaching method in order to enable students to do what they cannot do independently, the challenge should nevertheless be within their reach (van der Pol et al., in press). Student differences are not only determined by ability. In their study of rather straightforward computer games, Inal and Cagiltay (2007) found that the ludology of a game (rules and gameplay) has more effects on the flow experiences of boys, whereas the narratology (story and themes) affected more the flow experiences of girls. This gender difference might explain the fixed idea that most games are toys for boys. Future research might focus on how secondary school students with different abilities and capacities can be effectively and efficiently supported in game-based learning.

Flow refers to a state of deep absorption in an activity, and concentration, interest and enjoyment in an activity should be experienced simultaneously in order to flow to occur (Csikszentmihalyi, 1997). One way to measure the experience of flow is to observe behavior of people experiencing flow. In this study, students playing the game Frequency 1550 show game activities which are understood as overt indications of experiences of flow. However, other research on flow in education use self-reports to measure experiences of flow. Shernoff, Csikszentmihalyi, Schneider, and Shernoff (2003) used the so called Experience Sampling Method (ESM), developed and tested by Csikszentmihalyi and Larson (1987). The ESM measures participants' location, activity, and affective and cognitive experiences at random moments. It is said to be particularly valuable for eliciting the subjective experiences of persons interacting in their natural environments. As in the current study the participants were 13 years old students, we thought a self-report measure of flow would be too complicated. We therefore observed students' playing and involvement in the game. However, observations leave out the subjective experiences necessary to decide whether gaming activities might be interpreted as flow or just indicate student engagement and involvement, without the subjective experience of interest and enjoyment. Research using both observation and ESM measures could shed a different light on the role of flow in game-based learning, and the fostering and impeding factors for flow to occur for different groups of students (e.g., boys and girls, or students from different educational levels).

As flow is a state of deep absorption in which an activity is perceived as worth doing for its own sake, students in secondary education might seek to replicate flow experiences. However, in this study the game Frequency 1550 has been played only once (in 1 day). Probably playing a game for only one day – albeit an engaging and stimulating experience – is too short, not only to trigger a process of seeking flow, but also to indicate effects of flow experiences on student learning. Playing Frequency 1550 more than 1 day – in more areas of the city or with more sets of assignments that increase in complexity – could trigger experiences of flow more frequent.

For future research, we would suggest to study the effects of game-based learning when students 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. This probably increases the meaningfulness of learning for students and thereby stimulates experiences of flow (cf., Kiili, 2005). Such learner-centred production was not a part of the design of the Frequency 1550 game as students 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 to be addressed more often, thus, while it is just this which has taken the newly developed Games Atelier – which allows students to create and play their own games in their own urban space 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 trigger more flow with game play and enhance learning effects compared the Frequency 1550 game.

In conclusion, the present research has shown the potential of the concept of flow in research on game-based learning. Promising new directions for future research might focus on flow with game play as an important explanatory variable of student learning. As students might seek to replicate flow experiences, flow can be understood as invoking a growth principle in which a more complex set of capacities is sought after and developed, leading to long-term learning effects.

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