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Mobile game-based learning in secondary education: Students' immersion, game activities, team performance and learning outcomes

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ABSTRACT

Studies on game-based learning show positive effects, but insights into the relationship between students' game activities and the outcomes of these activities are lacking. In this study of the game "NoCredit, GameOver!" (NCGO), students' game activities are explored and related to their learning outcomes and performance in the game. Secondary school students used tablets to access virtual information about having debts and to perform tasks in an urban environment. Data were gathered from 181 students who completed questionnaires concerning their game activities in a team, immersion into the game and character assigned to them, and learning outcomes. The extent to which students empathized with the game characters appeared be negatively related to their interest in and knowledge of the subject. In addition, perceived content authenticity was negatively related with students' spending money wisely. Searching the internet with a team was positively related to students' self-reported spending money wisely. Visiting organizations, which was one of the scheduled game activities, showed a positive relationship with team game performance. Implications for teaching with games and future research are suggested.

1. Introduction

Educational practices with mobile learning and game-based learning show positive effects on students' learning achievements, motivation for learning in school and interest in the subject matter that they learn in school (Abdul Jabbar & Felicia, 2015; Furió, Juan, Seguí, & Vivó, 2015; So & Seo, 2018; Sung, Chang, & Liu, 2016; Wilson et al., 2009; Wouters, Van Nimwegen, Van Oostendorp, & Van der Spek, 2013). Mobile learning in schools is mostly applied in environmental education or out-of-class schooling (Chiang et al., 2015). This type of learning with mobile devices with wireless network connections, cameras, RFID readers and GPS (Jeng, Wu, Haung, Tan, & Yang, 2010) expands learning with games from the screen to learning in a mixed-reality environment using urban spaces as a game board. These types of games are called mobile location-based games or urban games when they are played in an urban environment (De Souza e Silva & Hjorth, 2009).

Enabled by technological developments, new possibilities for teaching with mobile games are emerging. However, much information remains to be discovered regarding the processes by which mobile game-based learning cause positive effects (Iten & Petko, 2016). Insights into the relationship between students' activities during a mobile game and the outcomes of these activities still need to be developed. The current case study in secondary education explores students' game activities in a location-based game and examines how these activities are related to students' learning outcomes and their game performance.

2. Mobile game-based learning

Mobile or location-based games provide teachers in school the possibility of moving their teaching outside the classroom and connecting their teaching to student learning using meaningful objects and environments outside of the school. Most studies on mobile game-based student learning have focused on the usability of these games for teaching and learning in school settings, on their effects on students' motivation for both learning and the game itself, and on learning from the game (e.g., Klopfer & Squire, 2008; Rubino, Barberis, Xhembulla, & Malnati, 2015; Squire & Jan 2007; Vieira & Coutinho, 2016). These studies show that the use of mobile games in teaching and learning has positive effects on student learning and on students' motivation for learning, although not in all cases. In their review on the relationship

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between game attributes and students' learning outcomes, Wilson and colleagues (Wilson et al., 2009) indicate that one-to-one causal relationships between game attributes and learning outcomes are difficult to be determined. Not only are various game attributes often combined in the design of a game, process information about game activities and their relationships with learning outcomes is often lacking as well.

Some studies go beyond examining learning effects and investigate student activities during game play. Ardito, Costabile, De Angeli, and Lanzilotti (2012) examined students' game activities during the mobile excursion game *Explore!* This game integrated information from real and virtual sources, and students were supposed to acquire knowledge on archaeology and life in Roman times. In this game, an augmented reality environment was created based on 3D models of places and objects, and context-relevant sounds were used to enrich the physical environment. *Explore!* was designed to stimulate students' interest in archaeological sites and to facilitate history learning during site visits. The students explored the environment in small groups and needed to identify meaningful places in an archaeological site to solve the game's mission. Two second-year middle school classes played two versions of *Explore!*: one with contextual sounds and one without. In a between-subjects design, the authors reported positive experiences with both versions of the game, but unexpectedly students often ignored the 3D reconstructions of places and objects in their original state even though these reconstructions were part of the game. The students explained that they skipped the 3D construction because they experienced time pressure and that their first goal was to win the game. Thus, they missed opportunities to learn about the objects and places in their original states. This finding of students playing a game as efficiently as possible to win it and thereby missing opportunities to learn was confirmed by Guribye, Wake, and Wasson (2014), who found some adverse effects of playing a mobile location-based game for teaching and learning history called *Premierløitnant Bielke*. To win the game, students used as little time as possible, which meant that learning opportunities were missed because the students did not take time to dwell and reflect upon their historical surroundings.

A desire to win the game can have negative effects on learning outcomes, but this is not always the case. For example, in their review of 27 courses with game-based learning, Nadolny, Alaswadi, Culver, and Wang (2017) found mixed effects of competition in games. Competition appeared to be prominent in secondary education, but less motivating than other game attributes such as challenging tasks and game mission and instant feedback. However, Admiraal, Huizenga, Akkerman, and Ten Dam (2011) did find competition to be effective. They studied the game process of *Frequency 1550*, which is a mobile city game set in medieval Amsterdam. They investigated the game activities of student teams and their effects on team game performance and student learning outcomes. The game was used in history classes and played by 216 secondary school students, most of whom were 13 years old. The game was played in groups of four students who had to complete assigned tasks. Two students navigated the city using a medieval map and completed the assignments. The other two students stayed in a room with computers and searched for information, collected the completed assignment and guided the city students with the use of a contemporary city map that displayed the locations of the city teams. The study showed that the more students were engaged in competitive activities, the more they learned about the medieval history of Amsterdam. However, the greater the students were distracted by solving technological problems, the less they learned and the poorer their performances. Navigating through the city, which is another distractive activity, also had a significant negative effect on team game performance.

Hwang and Chang (2016) had a more specific focus on the role of competition in games than the studies from Admiraal et al. (2011) and Ardito et al. (2012). Hwang and Chang examined whether competition in mobile game-based learning improved students' learning interest, learning attitudes and local cultural identity. They also examined whether adding competition decreased the cognitive load. They designed a mobile game for learning based on local cultural activities. In this system, which used a board game interface, each location on a map was associated with a real-world learning target with a set of relevant questions. During a field trip, two fifth-grade classes using the mobile game-based learning system were compared; in the first class, the students competed with their peers, and in the second class, no peer competition took place. The students in the peer competition-based approach were more motivated to learn, had a more positive attitude regarding learning from the game and developed more of a local culture identity than the student groups without competition. Additionally, the cognitive load was decreased to a greater extent than that achieved with conventional m-learning.

In addition to competition with their peers, students' game activities can refer to how they collaborate with their peers or in groups, their navigation through the environments, their on- and off-task behaviour during the assignments and their engagement with particular game elements, such as the mission, characters and story (Arnab et al., 2015; Clark, Tanner-Smith, & Killingsworth, 2016; Sanchez & Mandran, 2017). These game activities of students refer to game attributes related to the interaction and communication, which are understood to have crucial effects on game-based learning. For example, Hämäläinen, Niilo-Rämä, Lainema, and Oksanen (2018) showed that collaborative game activities can have a positive effect on players' knowledge construction in the actual gameplay. This kind of collaboration seems to work best if collaborative activities are scripted in the game. These scripted roles lead to more construction of knowledge and meaningful interactions, compared to emergent collaborative roles. The game examined in the current study focused on interaction and communication as the central cluster of game attributes that can be distinguished (c.f., Wilson et al., 2009).

3. The case: NoCredit, GameOver!®

The game examined in the current study is a serious mobile urban game called "NoCredit, GameOver!®" (NCGO) and is a project and registered brand of Lieve Achten for the '[ew32]' organization (http://www.ew32.be/about/about-ew32-english-version/, info@ew32.be). The game is designed to offer an interactive learning context about debts and is played in a city using a tablet. The goal of the game is for players to decrease their debts.

Secondary school students played the game in groups of two or three. Each team was assigned one tablet on which students could find information about the game and game content. A specific character was assigned to each group of students, each with his/her own reasons for being in debt, such as frequently calling a boyfriend abroad or having a gambling addiction. These characters were randomly assigned to the teams, with the exception that female teams were assigned a female character and male teams a male one. All game characters enable students to perform all game activities. In total, 10 characters were designed, each with a debt of €1400. To decrease their debt, the student teams needed to find ways to earn money and reduce expenses. They started the game by going into the city (in real life) to interview passers-by regarding their opinions of people in debt and to obtain advice for getting out of debt. They also visited organizations that could help them. The organizations, such as banks, job centres, unions and social organizations, participated in the project. In every participating organization, one or more of the employees were informed that students might visit their organization. The organizations were indicated on a city map on the tablet. The teams presented themselves at the organizations with the name and background of their character. While navigating through the city between organizations, the teams had to think of options to reduce their expenses and send pictures of the ways in which they reduced expenses (e.g., travelling by bike or on foot through the city instead of by public transport). All organizations were visited in real life and students spoke with real persons and made pictures in the

Table 1
The three stages of the game No Credit, Game Over.

Stage	Duration	Description
1) Introduction	30 min	Introduction at the headquarters of the game
2) Play	120 min	Interview at the starting location in the city followed by visiting organizations and searching options to save money
3) Debriefing	30 min	Discussing the scores and decisions at headquarters

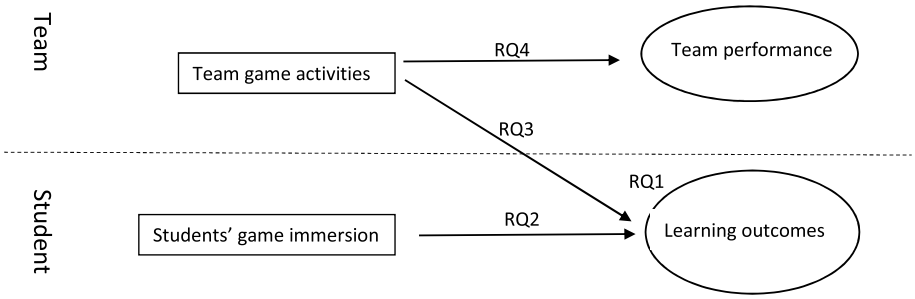

Fig. 1. Research model.

real world. The backstory and information about scores and their character however, were only available from the tablet, and options to reduce expenses had to be sent via the tablet to the game master who would then change the team score. The actual score of a team was updated in real time and was visible to all teams. The game play included three stages; see Table 1.

The goal of the current study was to obtain insights into the relationship between students' game activities within the NCGO mobile game and students' learning outcomes, and game performance. We also examined whether the students' learning has increased after playing the game. Accordingly, we formulated the following four research questions, which are graphical presented in Fig. 1:

1. Do students' learning outcomes change after playing the game?
2. Do students' immersion into the game explain differences in their learning outcomes?
3. Do students' team game activities explain differences in students' learning outcomes?
4. Do students' team game activities explain differences in their team game performances?

4. Materials and methods

4.1. Participants

The participants of this study were 181 students who played the game in the city of Oostende (Belgium). The students (66 males and 115 females) varied in age from 15 to 22 years. Most students (169) were in the fifth to seventh grades from four secondary education schools. The students played the game in teams of two or three students (N = 69 teams). The teachers of the students had signed their students up to play the game. Most students played the game as a part of their secondary education curriculum (*Project Algemene Vaardigheden*, Project General Skills). This subject is an interdisciplinary course that integrates learning contents of several school subjects with financial literacy.

4.2. Procedures

The students completed a pre-game questionnaire when they entered the headquarters. The game was introduced by the game master, who was an employee of the organization. The students started the game by going to their appointed starting location in the city and then conducting a short interview with someone in the city and working on reducing their debts. Halfway through and at the end of the game, each student team completed an online questionnaire regarding game activities as a team. Immediately after the debriefing at the headquarters, the students completed the post-game questionnaire.

A pilot study of the questionnaires was conducted with 24 secondary education students who had played the game approximately two weeks before. The information from this pilot study was used along with additional feedback from colleagues to improve the questionnaires used in this study.

4.3. Measures

4.3.1. Students' immersion in the game

Each student team was randomly assigned one out of ten characters with a certain reason for being in debt. Students' immersions with the game and their character was measured by seven items in the post-game questionnaire. The items were answered on a four-point Likert scale with 1 = *completely disagree* and 4 = *completely agree*. After exploratory factor analysis three pairs of items were distinguished (see Table 2 for the factor loadings): 1) the extent in which students' empathized with the character (*Empathizing character*, item 1 and 6 with r = 0.73), 2) the extent in which students perceive the character situation as similar to their own situation (*Situation similarity*, recoded items 2 and 5 with r = 0,35), and 3) the extent in which students perceive the situation the character is in as realistic (*Content authenticity*, items 3 and 4 with r = 0.39). Item 7 was not included in one of

Table 2
Varimax-rotated component loadings for 7 items on students 'game immersion.

Items	Component		
	1	2	3
1. I could really imagine myself as my character.	0.816		
2. The situation the character is in is not all similar to my situation.		0.733	
3. The situation the character is in is similar to a situation of someone else I know.			0.873
4. The game is about problems I could also encounter.	0.393		0.648
5. The character is far from my own situation.	0.370	0.663	
6. When playing the game it felt like I was the character	0.846		
7. This game is about problem young adults can encounter in their real life.	0.373	−0.560	
Eigenvalues	1.846	1.351	1.257
Percentage of total variance explained	26.4	19.3	18.0

Note. Only factor loadings ≥ |0.30| are shown.

Table 3
Team game activities.

	Time 1 (N = 65) Mean (SD)	Time 2 (N = 69) Mean (SD)	Average time 1 and 2 (N = 69) Mean (SD)
Game activities specific for this mobile game			
We were busy thinking how to save money.	3.76 (1.24)	3.87 (1.25)	3.80 (1.12)
We were imagining ourselves as our character.	3.62 (1.21)	3.71 (1.29)	3.65 (1.18)
We were busy looking at the route.	3.54 (1.31)	3.74 (1.27)	3.64 (1.22)
We were deliberating.	4.68 (0.75)	4.56 (0.81)	4.62 (0.74)
We were busy visiting organizations.	3.91 (1.24)	3.88(1.17)	3.89 (1.07)
General game activities			
We were looking to see whether we scored better than our fellow students.	2.00 (1.38)	2.48 (1.52)	2.21 (1.31)
We were looking up information on the internet.	1.82 (1.21)	1.71 (1.18)	1.74 (1.08)
Off-task behaviour			
We were busy doing something other than the game.	1.49 (0.94)	1.62 (1.03)	1.56 (0.86)
We had technical problems.	1.91 (1.31)	1.86 (1.18)	1.90 (1.15)

Table 4
Varimax-rotated component loadings for 15 items on learning outcomes.

Items	Component		
	1	2	3
8. I think seriously before I borrow money.		0.629	
9. I think debt is an interesting subject.	0.620		
10. I know what to do to help someone get rid of debts.			0.840
11. I sometimes buy something I cannot afford right away.		−0.574	
12. I know which organizations can help me if I have debts.			0.496
13. I do not spend more money than I truly have.		0.548	
14. I think it is interesting to know how someone can get rid of debts.	0.738		
15. I can prevent getting into debts.		0.491	0.342
16. I think it is important to know something about the subject of debts.	0.729		
17. I think it is important to save for big expenses.		0.608	
18. I am interested in the causes of debts.	0.819		
19. I would not know what to do to get rid of debts.			−0.393
20. I can advise someone with debt about what to do to get rid of debts.			0.751
21. I am not interested in information about debts.	−0.748		
22. I think making debts is not a problem.		−0.433	
Eigenvalues	3.134	1.961	1.734
Percentage of total variance explained	20.895	13.071	11.560

Note. Only factor loadings ≥ |0.30| are shown.

these three subscales because of low item-rest correlations. In Table 5, the descriptive statistics are presented for each of the three indicators of student immersion.

4.3.2. Team game activities

Team game activities were measured twice during the game by an online questionnaire with nine 'team activities' in which the students could be engaged (see Table 3 for the items and their descriptive statistics). Students completed this questionnaire as a team on their shared tablet. We included activities that were part of the game, such as visiting organizations, as well as other activities, such as being occupied with something other than the game. Because the students were supposed to discuss the game with each other, this approach was also an activity in the questionnaire. To determine whether the students were engaged in competition, we asked whether they looked at their scores. Each team of students rated on a five-point scale how often they had performed this activity in the past hour, with 1 = *almost never* and 5 = *almost the entire time*. We did not find any significant differences between the scores of the two time points except for the activity '*We were looking to see whether we scored better than our fellow students*' ($t(64) = -3.68$; $p < 0.001$), which had a higher score at time point 2. The average scores of time points 1 and 2 were used in the subsequent analyses. Exploratory factor analysis with varimax rotation indicated that the nine game activities could be grouped into three clusters: 1) game activities specific for this mobile game, 2) general game activities, and 3) off-task behaviour (see Table 3). As the relationships of game activities with team performance might be different for each game activity (see Admiraal et al., 2011), we used these three clusters to only structure the activities.

4.3.3. Learning outcomes

Students' learning outcomes were measured by 15 questionnaire items, which were part of both the pre-game and post-game questionnaire. All items were answered on a four-point Likert scale with *1 = completely disagree* and *4 = completely agree*. After a principal component factor analysis with varimax rotation, three factors were extracted, which explained 46% of the variance., The reliability and

Table 5
Students' immersion in the game and their perceived learning outcomes.

	Items See Tables 2 and 4	Pre-game		Post-game	
		Mean (SD)	N	Mean (SD)	N
Student immersion					
Empathize with character	1, 6			2.38 (0.83)	179
Situation similarity	2, 5			3.32 (0.74)	177
Content authenticity	3,4			2.72 (0.79)	179
Learning outcomes					
Interest in the subject ($\alpha = 0.85$)	9, 14,16, 18, 21	2.80 (0.65)	180	2.99 (0.63)	179
Subject knowledge ($\alpha = 0.77$)	10, 12, 20	2.23 (0.67)	180	2.87 (0.56)	179
Spending money wisely ($\alpha = 0.60$)	8, 11, 13, 17, 22	1.49 (0.44)	181	1.49 (0.47)	179

Note. Cronbach's α = α post-game questionnaire after lengthening to six items using the Spearman-Brown correction for test length.

Table 6
Regression analysis with the three indicators of learning outcomes as the dependent variables (student level).

	Interest in the subject N = 176			Subject knowledge N = 176			Spending money wisely N = 176		
	B (s.e.)	*β*	*Sr²*	*B (s.e.)*	*β*	*Sr²*	*B (s.e.)*	*β*	*Sr²*
Empathizing character	**−0.11 (0.04)**	**−0.14**	**0.02**	**−0.16 (0.05)**	**−0.24**	**0.05**	0.01 (0.03)	0.03	
Situation similarity	0.06 (0.04)	0.07		−0.02 (0.05)	−0.03		0.03 (0.04)	0.03	
Content authenticity	0.01 (0.04)	0.01		−0.04 (0.05)	−0.06		**−0.08 (0.04)**	**−0.14**	**0.02**
Pretest score	**0.72 (0.05)**	**0.74**	**0.52**	**0.38 (0.06)**	**0.46**	**0.18**	**0.65 (0.06)**	**0.62**	**0.36**
Gender	0.10 (0.07)	0.07		0.07 (0.08)	0.06		−0.07 (0.06)	−0.07	
Age	0.04 (0.02)	0.09		−0.01 (0.03)	−0.02		0.00 (0.02)	0.00	
Adjusted R^2	*0.57*			*0.28*			*0.41*		

Note. N = number of students included in the analyses; 's.e.' = standard error. Sr^2 = Squared semi-partial correlation. Significant fixed effects (with α = 0.05) are printed bold.

descriptive statistics of three factors that were extracted from the factor analysis on learning oucomes are included in Table 4.

The first learning outcomes is labelled *Interest in the subject* and refers to the extent in which students reported to be interested in the topic of debts. The second factor is labelled *Subject knowledge* and refers to the extent students perceived they have knowledge of the topic of debts. The third learning outcome indicator is *Spending money wisely*, which refers to the extent students reported conscious behaviour on borrowing and spending money. Two items (items 15 and 19) were not included in either one of these three subscales because of low item-rest correlations.

4.3.4. Team game performance

Each team started with a debt of €1400 (a score of minus 1400). The goal of the game was to get rid of the debt. During the game, the students had to send all of their choices (e.g., the job they chose, the options to save money and how much money these options would save) to the game master. One group had to restart because of technical problems, and this score was not included in the analyses. At the end of the game, the average debt of the teams was increased to €1665 (SD = €761); the best score was a surplus of €273.59, and the worst score was a debt of €3062.68.

4.4. Analyses

To validate the self-reported data on game activities, the first author randomly chose a team of students to observe their game activities for each of the nine times that the game was played. The self-reported data from the students concerning their activities were consistent with the researcher's observations except for technical problems, which seemed to be over-represented in the self-reported data. This over-representation was caused by the students' broad interpretations of technical problems. They indicated having technical problems when they had to switch between applications (e.g., from the map to the sheet with character information) or when they did not know where to find particular information (e.g., information on their character). Students indicated that these inconveniences were technical problems.

To examine whether the scores on the three indicators of learning outcomes have increased after playing the game (research question 1), paired sample t-tests were performed.

Student data was nested within student teams. Therefore, to answer research questions 2, a multilevel variance components model was calculated with MLwiN2.27 for the three learning outcome variables. From these models it was clear that variance at the team level did not significantly differ from 0 for *Interest in the subject* ($\sigma^2 u_{0j} = 0.00$ with a standard error of 0) and for *Subject knowledge* ($\sigma^2 u_{0j} = 0.09$ with a standard error of 0.07). For *Spending money wisely*, threshold values were reached ($\sigma^2 u_{0j} = 0.09$ with a standard error of 0.04). Therefore, to answer research question 2 linear regression analyses were performed at the student level with the three indicators of immersion and student background information as predictors, one of the three learning outcomes as dependent variable and the relevant pretest score as covariate.

Although variance at the team level did not significantly differ from 0 for two indicators of learning outcomes, we performed a series of one-to-one multilevel regression analyses with team activities as predictors, one of the three learning outcomes as dependent variable, and the relevant pre-test score as covariate to answer research question 3.

To answer research question 4 multiple regression analysis was performed at the team level with the team activities as predictors and team performance as dependent variable.

5. Results

5.1. Students' learning outcomes

In Table 5, the results for students learning outcomes are summarized. We found a significant difference between Subject knowledge before playing the game ($M = 2.23$; $SD = 0.67$) and after playing the game ($M = 2.87$; $SD = 0.56$; t(178) = -13.55, $p < 0.001$). The students showed more subject knowledge after playing the game than before. This can be understood as a large effect (Cohen's d average variance = 1.04, see Cohen, 1988).

A significant difference was also found between Interest in the subject before playing the game ($M = 2.79$; $SD = 0.64$) and after playing the game ($M = 2.98$; $SD = 0.63$; t(178) = -5.48, $p < 0.001$). The students were more interested in the subject after playing the game than prior to playing the game. This can be understood as a small to medium effect (Cohen's d average variance = 0.30, see Cohen, 1988).

No significant difference was found for Spending money wisely before and after playing the game (t(178) = 0.18; p = 0.86).

5.2. Students'immersion in the game and learning outcomes

The results of the regression analyses of students' immersion in the game and their learning outcomes (research question 2) are summarized in Table 6. For all three dependent variables, the relevant pretest and posttest scores were significantly positively related. The level students empathized with the game character showed a significant negative relationship with both *Interest in the subject* and *Subject knowledge*. This means that the more students identified with their game character, the less they were interested in the topic of the game (B = −0.11, s.e. = 0.04) and the lower their scores on self-reported subject knowledge (B = −0.16, s.e. = 0.05). For Spending money wisely, we found a significant negative effect of Content authenticity, which means that the more students perceived the game as authentic, the less they reported that they spend what is in their pocket. Effect sizes were indicated by squared semi-partial correlations (Sr^2) and can be understood as small (for Interest in the subject and Spending money wisely) and medium effects (for Subject knowledge, see Cohen, 1988).

Table 7
Regression analysis with team performance as dependent variable (team level).

	Team performance N = 68		
	B (s.e.)	*β*	*Sr²*
Game activities specific for this mobile game			
We were busy thinking how to save money.	−57.95 (105.09)	−0.09	
We were imagining ourselves as our character.	144.48 (99.38)	0.23	
We were busy looking at the route.	**−235.74 (95.09)**	**−0.38**	**0.08**
We were discussing.	−67.62 (159.89)	−0.07	
We were busy visiting organizations.	**329.43 (113.04)**	**0.46**	**0.11**
General game activities			
We were looking up information on the internet.	−72.63 (94.90)	−0.10	
We were looking to see whether we scored better than our fellow students.	60.01 (78.68)	0.10	
Off-task behaviour			
We were occupied doing something other than the game.	−8.33 (147.74)	−0.01	
We had technical problems.	−117.86 (97.16)	−0.17	
Adjusted R^2	*0.17*		

Note. N = number of teams included in the analyses; 's.e.' = standard error. Sr^2 = Squared semi-partial correlation. Significant fixed effects (with α = 0.05) are printed bold.

5.3. Team game activities and students' learning outcomes

The multilevel analyses with variance component models showed that variance at the team level did not differ from 0, for both Interest in the subject and Subject knowledge. To check whether game activities were related to either one the learning outcomes (research question 3), subsequent multilevel regression analyses were performed one by one, with one team game activity, one of the learning outcomes and its corresponding pre-test score. None of the game activities were significantly (with $\alpha = 0.05$) related to either Interest in the subject and Subject knowledge, after controlling for the pre-test scores. For Spending money wisely we found a significant positive effect of the activity Looking up information from the internet (B = 0.08; s.e. = 0.03) explaining 18% of the variance at the team level and 4% of the total variance (small to medium effect size, see Cohen, 1988).

5.4. Team game activities and team game performance

Regression analyses at team level (research question 4) showed that two team game activities were significantly (with $\alpha = 0.05$) related to team game performance (with 68 team scores, see Table 7): Visiting organizations ($B = 329.43$, $s.e. = 113.04$) and Navigating ($B = -235.74$, $s.e. = 95.09$. This means that the more student teams visited organizations and the less they looked at their navigation, the higher their team game performance. Both effects can be understood to be medium sized effects, based on their squared semi-partial correlations (c.f. Cohen, 1988).

6. Discussion

In this study, we examined whether students' learned from a mobile game. In addition, to provide insights into the relationship between students' game activities and the game outcomes, we examined whether students' immersion in the game and character and team game activities were related to learning outcomes.

Students reported being more interested in the game topic and to knew more about the topic of the game after playing the game than before. No changes were found with respect to their spending money behaviour. For both *Interest in the subject* and *Subject knowledge*, students' level of empathizing with game character was a significant predictor, but unexpectedly, it was a negative relationship. In addition, a negative relationship was also found between the perceived level of authenticity and student self-reported spending money wisely. One explanation for the negative relationships in the current study could be that students were assigned a character, which could lead to less immersion in the game and character or even to a negative influence on their learning from the game. Another explanation could be that students were distracted when they were too immersed with the game and its character, which might have prevented them from being more engaged with other game activities. Considering how important roles and (identification with) characters are deemed in games (Dickey, 2007; Soutter & Hitchens, 2016), this result merits further research.

None of the team game activities was significantly related to either students' interest in the subject or their subject knowledge. In their literature review on relationships between game attributes and learning outcomes, Wilson et al. (2009) provide an overview of studies showing significant relationships between game attributes and learning outcomes. Yet these authors also report that it was not possible to find one-to-one relationships between game attributes and learning outcomes. Yet in later studies, these one-to-one relationships have been found. For example, Admiraal et al. (2011), Ardito et al. (2012) and Hwang and Chang (2016), have found relationships between game activities during the game, more specific activities focussing on competition, and cognitive learning outcomes. Yet Nadolny et al. (2017) only found small effects of competition, compared to other game attributes such as challenging tasks and instant feedback. One explanation for our different findings with respect to game activities might be that game activities were measured during the game, and not at the end of the game including the debriefing phase. Yet the debriefing phase is understood to be an important phase in game-based learning for students (Ardito et al., 2012).One game activity was significantly negatively related to students' self-reported spending money wisely: Searching the internet for information. This outcome seems reasonable; students who are searching for more information on the internet, reported to spend more what is in their pocket. Apparently, this activity is a useful addition to the other game activities.

Two team game activities were related to team game performance (i.e., visiting organizations and navigating). Visiting organizations was positively related to team performance, which indicated that the advice the students received helped them get rid of their debts. Looking at the route showed a negative relationship with game performance. In line with the research of Admiraal et al. (2011), navigating seems to be a distractive activity with a negative effect on team game performance. When designing location-based mobile games, this aspect should be taken into consideration carefully.

Our study has shown that student immersion in the game and some game activities in mobile location-based games are related to game outcomes. In our study, we measured team game activities by surveying groups of students through an online questionnaire on a tablet that the students shared. One possible route for future research is to measure students' game activities in more detail and at an individual level. In this way, more varied insights into student activities can be established.

Measuring these activities in more detail may be accomplished using GPS logs to examine exactly which organizations the students visited and when. With detailed insights into students' game activities at individual and group levels, we expect to find more relationships between game activities and game outcomes.

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