Exploring characteristics of students' emotions, flow and motivation in a math game competition

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Abstract: The overall objective of the present study was to investigate associations between emotions, flow experience, intrinsic motivation, and playing performance in a math game competition. Finnish 3rd – 6th graders (n = 251) participated in a math game competition relying on intra-classroom cooperation and inter-classroom competition. During a three-week competition period, students were allowed to freely play a digital rational number game founded on number line estimation task mechanics. An online questionnaire was used to collect students' experiences after the competition. The results indicated that students who experienced higher positive emotions in the competition also experienced higher levels of flow. Findings also showed that intrinsically motivated students experienced more positive emotions and higher flow as well as indicated a higher willingness to participate in math game competitions again as compared to low intrinsically motivated students. Moreover, current results provided some evidence that game based competitions might engage also lower performing students.

1. Introduction

Devlin (2013) has argued that video games can provide new interfaces to learn mathematics that are far easier and more natural to use than symbolic expressions that we have used to employ in conventional education. Game-based interfaces have the potential to provide means to develop effective ways of training mathematics that may also motivate persons who are anxious about mathematics. In fact, some recent studies have shown that the use of games in mathematics education can be beneficial for both cognitive (e.g. Kiili, Moeller & Ninaus, 2018; ter Vrugte, et al., 2017) as well as affective outcomes (e.g. Kiili & Ketamo, 2017; Ke, 2008). On a more general level, a recent meta-analysis of the cognitive and motivational effects of serious games demonstrated that serious games were more effective in terms of learning and retention than conventional instructional methods (Wouters et al., 2013). However, surprisingly, the analysis revealed that serious games were not more motivating than conventional instructional methods. The authors argued that motivation in serious games might be undermined by a limited sense of control of using such a game. That is, contrary to entertainment games, which are played on users own will, serious games are usually used within an instructional context and thus, the decision on the type of game and when to play the game is made by educators and not the players. In this context, the self-determination theory (Ryan & Deci, 2000; Deci & Ryan) argues that conditions which limit the sense of freedom of action or control may undermine intrinsic motivation. This is particularly interesting, because intrinsic motivation seems to be associated with positive emotional experiences (e.g., Koestner & Losier, 2002) and improved learning performance (e.g., Ninaus, Moeller, McMullen, & Kiili, 2017). Therefore, the current study examines the affective and cognitive outcomes of a math game competition in which users themselves decided if and when they wanted to participate in such an instructional intervention with a game.

Individuals partaking in a competitive game may experience an array of different emotions. Importantly, emotions experienced in competitive educational settings influence outcomes of an educational intervention. For instance, Plass and colleagues (2013) found out that a competitive math game mode enhanced game performance compared to individual play. Their study also indicated that both competitive and collaborative game modes increased enjoyment compared to individual play. In line with these results, a study by Cagiltay, Ozcelik, and Ozcelik (2015) showed that competitive aspects in a serious game significantly improved motivation and learning outcomes. However, very little is known about emotions that students experience in competitive game-based learning settings and how domain specific intrinsic motivation is related to experienced emotions in a competitive game. Importantly, though, previous studies have identified (math) self-efficacy and (math) interest as important predecessors and determinants of intrinsic motivation (Campbell & Hackett, 1986; Pajares & Miller, 1994; Ryan & Deci, 2000; Skaalvik et al., 2015).

Positive emotional experience in gameplay or even everyday life is often related to the experience of flow. For instance, flow and enjoyment are usually highly correlated (Landhäußer & Keller, 2012) and thus, flow might even be described as a special form of enjoyment (Baumann, Lürig, & Engeser, 2016). But of course, enjoyable experiences are not always related to flow. Landhäußer and Keller (2012) have argued that it is important to note that flow is not the same as having fun, but a combination of concentration, a merging of action and awareness, reduced self-consciousness, a sense of control, a transformation of time, and a intrinsically rewarding activity makes experiencing flow possible. For instance, enjoying the sunset at the beach is most likely not related to flow experience. Thus, it is necessary to measure emotions and flow independently (Baumann et al., 2016).

2. Present study and hypotheses

In the current study, we added a competitive aspect to a non-competitive math game by organizing a competition around the game with online scoring boards based on players' highscores achieved in the game. The overall objective of the present study was to investigate the associations between affect, flow, performance, and intrinsic motivation during a math game competition. Therefore, we formulated the following three main hypotheses.

Hypothesis 1: According to Abuhamdeh (2012) flow theory is relevant for predicting enjoyment (see also Baumann, Lürig, & Engeser, 2016; Landhäußer & Keller, 2012). Therefore, we expect that there is significant positive relation between flow experience and pleasant emotions experienced during the game competition.

Hypothesis 2: On the one hand, self-efficacy and interest – predecessors and determinants of intrinsic motivation (Campbell & Hackett, 1986; Pajares & Miller, 1994; Ryan & Deci, 2000;

Skaalvik et al., 2015) – are usually related to more positive emotional experiences (e.g., Koestner & Losier, 2002). On the other hand, flow itself is considered to be positive emotional state (Baumann et al., 2016; Landhäußer & Keller, 2012). Based on this, we expect that students with high intrinsic math motivation (self-efficacy and interest) like the competition more, are more willing to participate in game competitions again, as well as experience higher flow and more positive feelings during the competition than students with low intrinsic math motivation.

3. Method

1.1. Participants

The participants of the current game competition were Finnish students. Altogether approximately 1500 students participated in the competition from which 258 filled in the digital questionnaire and managed to complete the competition level at least once. According to Meade and Craig (2011) careless, partially random, or otherwise inattentive survey responses should be identified and removed from the data set. Thus, we utilized following strategies to exclude inattentive and careless survey responses from the analyses. First, participation to the survey was voluntary and responses were anonymoys. Second, the survey instructions emphasized that only the participants who carefully responded to all questions were included in the movie tickets lottery after the competition. Third, we removed four participants whose overal response time was too fast indicating that these participants did not read the questions of the survey at all. Fourth, we removed three participants who used a clear response pattern (all likert scale responses were on the beginning or on the end of the scale). Finally, we carried out an outlier analysis with the most important sum variables used in the analyses (flow experience, positive emotions, intrinsic math motivation, participation willingness, and liking of the competition). Based on this analysis we did not find any extreme outliers. Consequently, 251 participants were included in the analyses of this paper. Four of the participants were 3rd graders, 69 were 4th graders, 24 were 5th graders, and 154 were 6th graders. Of these participants, 104 were females, and 147 were males. Participants were 9-13 years old with a mean (SD) of 11.63 years (1.02 years). Following the Finnish classification scheme, in which 10 reflects the best and 4 the lowest grade, the mean math grade (SD) of the participants was 8.58 (1.10). 84.5% of the participants reported that they play digital games at least once in a week.

2.1. Description of the competition

The competition was open for all Finnish 3-6 graders. In the competition, students had the opportunity to play a number line based rational number game during a three-week period.

The competition was organized around one game level that included fourteen randomly selected number line estimation tasks. The goal of the competition was to motivate students to play the level several times in order to optimize their playing strategies, increase understanding of rational numbers, and share effective playing strategies with their peers. In order to support collaboration between peers each participating class formed a team that competed against other teams. Furthermore, municipalities competed among each other. The web-page of the competition included leaderboards for both teams and municipalities. Two best teams, best municipality, most hard-working student, and a randomly selected player who answered to the research questionnaire at the end of the competition were awarded with movie tickets.

We used our rational number game engine, Semideus, to develop a digital game for the competition (see examples of studies using the same engine: Ninaus, Kiili, McMullen, & Moeller, 2017; Kiili, Moeller, & Ninaus, 2018). In the game, the player had to estimate either fraction or decimal number magnitudes on a number line ranging from zero to one (Figure 1). The tasks of the game could include also traps and enemies, time limits, mysteryboxes, and health kits. To assist the player, some of the tasks contained visual landmarks, such as sequentially placed torches that divided the number line according to the denominator of the fraction to be estimated or revealed the midpoint of the number line.

Figure 1. An example of a number line estimation task in which the player should dig up a coin cache at the location reflecting point 4/7. In this task the player should avoid the trap located at point 0.7 and the purple enemy walking around. The player has activated the partition skill and as a consequence the birds have divided the number line into seven parts.

The game also included specific skills that players could activate by using in-game currency, i.e. diamonds. The player began each game with 10 diamonds with the possibility to acquire maximally 15 extra diamonds by smashing enemies, avoiding traps, and collecting mystery boxes. Some of these skills made the solving of mathematical tasks easier and some just helped the player to survive in the game. Altogether, five different skills were available:

- The player could ask help fom the tutor. When the tutor skill was activated, a goat showed the approximate location of the coin cache to the player. The tutor skill was always available (cost: 8 diamonds).

- The partition skill visually divides the number line to as many parts as the denominator of the task. Specifically, if the skill is activated, birds fly onto the number line in a sequence of unit fractions. That is, players could easily get an accurate answer as long as they understood the partitioning of the number line based on these visual markers (see Figure 1). The partition skill was available if the denominator of the fraction to be estimated was below 11 (cost: 6 diamonds).

- The player could use the bomb skill to destroy all the enemies from the task (cost: 6 diamonds).

- The player could locate traps of the task with the trap finder skill (cost: 4 diamonds).
- Some tasks featured a time limit. In these tasks the player could remove the limit with the time manipulation skill (cost: 2 diamonds).

Appendix A provides details of the tasks that were included in the competition. It also shows the logic of the task randomization that was used. Moreover, the video of the game competition tutorial clarifies the gameplay of the used game (https://youtu.be/mNCQ5dgOaMg).

3.1. Measures and analyses

Students *playing performance* (e.g. highscore) was logged in order to assess students' rational number estimation accuracy. At the end of the competition students had to fill in a questionnaire to determine flow experience, intrinsic math motivation, positive and negative emotions, how much students liked the game, and students' willingness to participate in future game competitions.

Flow experience was measured using the 9-item short flow scale (adopted from Martin & Jackson, 2008). We translated the short flow scale to Finnish and contextualized it to address game playing. A 7-point Likert-type response format (1 = strongly disagree to 7 = strongly agree) was used.

Intrinsic math motivation was measured with self-reported measures of math interest and math self-efficacy. The three items used to measure math interest and the three items used to measure math self-efficacy were adopted from (Berger & Karabenick, 2011). A 5-point Likert-type response format (1 = strongly disagree to 5 = strongly agree) was used.

The measurement of *positive and negative emotions* was derived from items of the Sport Emotion Questionnaire (Jones, et al., 2005). For positive emotions (scale 0-4) happiness (pleased + happy) and Excitement (excited + energetic), and for negative emotions (scale 0-4) anxiety (uneasy + anxious), anger (irritated + angry), and dejection (sad + dejected) were used.

In addition, the questionnaire included one item to explore how much students *liked the game competition*, and one item to explore students' *willingness to participate* in math game competitions in the future. A 5-point Likert-type response format (1 = strongly disagree to 5 = strongly agree) was used. Moreover, students had to report their digital game playing frequency on a 4-point scale (Rarely - Once a week – Couple times a week – Almost daily).

The average scores of all flow items, emotion items, and intrinsic math motivation items were used in the analyses. Statistical analysis was performed in IBM SPSS Statistics, version 25.

4. Results

Descriptive statistics (means, medians, and standard deviations) of variables used to investigate students' experiences about the competition and math motivation are presented in Table 1. The flow construct (α = .84), pleasant emotion construct (α = .87), unpleasant emotion construct (α = .83), and the intrinsic math construct (α = .92) had a high level of internal consistency, as determined by Cronbach's alpha.

Table 1. Descriptive statistics about students' experiences and math motivation

	Mean	Median	SD	Scale
Flow experience	4.83	5	1.15	1-7 (α = .84)
Positive emotions	1.89	2	1.11	0-4 (α = .87)
Negative emotions	0.40	0.17	0.65	0-4 (α = .83)
Intrinsic math motivation	3.66	3.83	1.04	1-5 (α = .92)
Liked the game competition	3.54	4	1.16	1-5
Willingness to participate again	3.24	3	1.36	1-5
Highscore (performance)	55.13	56	23.18	0-100

Hypothesis 1: As expected, the correlation analysis yielded a strong positive relation between flow experience and positive emotions supporting Hypothesis 1, $r = .62$, $p < .001$. In a linear regression flow (unstandardized $\beta = .599$, standardized $\beta = .623$, p < .001) accounted for 39% in variance of experienced positive emotions [$F(1,249) = 157.70$, $p < .001$, $R^2 = .39$].

Hypothesis 2: T-test was run to determine whether there were differences in the experienced positive emotions, experienced flow level, and willingness to participate in game competitions again between students whose intrinsic math motivation was high and students whose intrinsic math motivation was low, using median split. There were statistically significant differences in the mean scores of experienced positive emotions ($M._{\text{high}} = 2.28$, $M._{\text{low}} = 1.47$, $t = 6.224$, $p < .001$), experienced flow ($M._{\text{high}} = 5.33$, $M._{\text{low}} = 4.31$, $t = 7.842$, $p < .001$), liking of the competition ($M._{\text{high}} = 4.02$, $M._{\text{low}} = 3.04$, $t = 7.319$, $p < .001$), and willingness to participate in game competitions again ($M._{\text{high}} = 3.74$, $M._{\text{low}} = 2.70$, $t = 6.473$, $p < .001$) between high and low motivation groups, supporting hypothesis 2.

Table 2. Correlations between students' experiences, motivation, and highscore

	1	2	3	4	5	6	7
1 Flow experience	1						
2 Positive emotions	.62**	1					
3 Negative emotions	-.22**	-.18**	1				
4 Liked the game competition	.66**	.62**	-.27**	1			
5 Willingness to participate again	.67**	.59**	-.23**	.67**	1		
6 Intrinsic math motivation	.54**	.42**	-.12	.48**	.44**	1	
7 Highscore	.38**	.27**	.02	.36**	.27**	.16*	1

Note. ** $p < .001$; * $p < .05$

5. Discussion and conclusion

The current study investigated the relationship between intrinsic motivation, flow, performance, and emotions in a math game competition. Students experiencing higher positive emotions also experienced higher levels of flow. Moreover, students categorized as highly intrinsically motivated, i.e. high math interest and high math self-efficacy, experienced more positive emotions and flow and indicated a higher willingness to participate in math game competitions in the future as compared to low intrinsically motivated students.

Current results underline the tight coupling of intrinsic motivation, positive emotion, flow, and performance. Therefore, we were able to show similar results with a math game competition as in non-competitive and non-game based learning environments. The independent measurement of flow and emotional experience supports general findings of flow being considered as a positive emotional state (e.g., Landhäußer & Keller, 2012) and its relation to intrinsic motivation (e.g., Koestner & Losier, 2002). Importantly, almost 40% in variance of experienced positive emotions was predicted by flow, which clearly underlines the tight link between flow and positive emotions or more generally the interdependence of cognition and emotion.

In the context of math game competition, students' willingness to participate again was highly related to flow, positive emotions, and the overall liking of the game competition (see Table 2). Importantly, though, the correlation between actual performance and students' willingness to participate again in a game competition was rather small (see Table 2). This might indicate that the game-based competitions might not only be interesting for high performing students but low performing students as well. However, this implication needs to be treated carefully and examined in future studies, which might also use more advanced performance measures than mere highscore. To conclude, the results provide some evidence regarding the educational potential of game-based math competitions. However, in order to better understand the usefulness of game competitions as an instructional method, more research focusing also on learning gains in game competitions and the meaning of different kind of game mechanics and user interfaces is needed.

Overall, the present study yielded promising results regarding the use of a math game competition that relies on intra-classroom cooperation and inter-classroom competition. However, there are some limitations that should be considered in future studies. First, better and more detailed metrics about students performance might improve our understanding of underlying processes in emotion and motivation when employing (math) game competitions in educational settings. Second, students could choose on their own when they answered the employed questionnaire as we were hoping to achive a higher response rate. Thus, some students might have answered immediately after their last playing session while others waited longer, which may have led to inaccurate recall. Third, in spite of flexible response schedule, response rate were rather low. Nevertheless, responders' ranks in the competition varied a lot while the median rank was 286. This indicates that the results presented in this paper are not based only on the experiences of the top players of the competition, but reflect students' experiences about the competition more generally.

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Appendix A. Details about the tasks used in the competition level

Target	Trap	Enemies	Time limit	Landmarks	Collectible	Start	Probability
1/3	-	-	-	Denominator	-	0	14%
2/3	-	-	-	Denominator	-	0	14%
3/4	-	-	-	Denominator	-	0	14%
1/4	-	-	-	Denominator	-	0	14%
0.25	-	-	-	Denominator	-	0	14%
0.8	-	-	-	Denominator	-	0	14%
5/9	-	-	-	Denominator	-	0	14%
2/5	0.2	-	-	-	-	0	14%
3/5	0.4	-	-	-	-	0	14%
4/10	0.2	-	-	-	-	0	14%
6/10	0.4	-	-	-	-	0	14%
0.600	2/5	-	-	-	-	0	14%
0.099	1/4	-	-	-	-	0.5	14%
0.400	3/5	-	-	-	-	0	14%
0.75	-	1	-	-	-	0	50%
0.21	-	1	-	-	-	0	50%
0.6250	-	1	-	-	-	0	50%
0.3750	-	1	-	-	-	0	50%
3/9 (dots)	-	-	-	Denominator	-	0	25%
6/9 (dots)	-	-	-	Denominator	-	0	25%
4/6 (dots)	-	-	-	Denominator	-	0	25%
2/6 (dots)	-	-	-	Denominator	-	0	25%
3/8	-	1	-	Midpoint	-	0	33%
5/8	0.75	1	-	Midpoint	-	0.3	33%
4/7	0.7	1	-	Midpoint	-	0.3	33%
4/9	-	1	-	Midpoint	-	0	33%
5/9	0.7	1	-	Midpoint	-	0.3	33%
3/7	-	1	-	Midpoint	-	0	33%
1/6	-	-	-	-	Health	0.5	33%
1/5	-	1	-	-	Health	0.5	33%
1/4	-	1	-	-	Health	0.5	33%
23/45	-	-	10s	-	-	0	25%
19/37	-	-	10s	-	-	0	25%
27/50	-	-	10s	-	-	0	25%
15/45	-	-	10s	-	-	0	25%
3/10 + 1/5	0.3	1	-	-	-	0	25%
1/4 + 2/4	0.25	-	-	-	-	0	25%
2/3 – 2/6	0.66	-	-	-	-	1	25%
6/8 – 2/8	0.75	-	-	-	-	1	25%
0.65	-	3	-	-	-	0	50%
3/4	-	3	-	-	-	0	50%
8/9	-	-	-	-	Health/Diam.	0.5	20%
5/6	-	-	-	-	Health/Diam.	0.5	20%
7/8	-	-	-	-	Health/Diam.	0.5	20%

0.089	-	-	-	-	Health/Diam.	0	20%
7/9	-	-	-	-	Health/Diam.	0.5	20%
8/9	3/9	2	-	-	Health	0.5	50%
7/9	0.4	2	-	-	Health	0.5	50%
0.9511	0.6	1	-	-	-	0	33%
0.6	0.25	1	-	-	-	0	33%
0.45	0.55	1	-	-	-	0.5	33%

Column explanations

Target: Value to estimate

Trap: Value to avoid

Enemies: Number of enemies

Time limit: Player lost energy, if he or she did not manage to estimate the target value within the time limit.

Landmarks: Visual markers that divide the number line into sections. Denominator: For example, if the target number is 1/3 the markers divide the number line into three sections. Midpoint: The marker was in the middle of the number line

Collectible: A mystery box that the player was able to pick up to gain a reward. Either Health or Diamonds.

Start: Player’s starting position on the number line

Propability: How likely this particular task is to feature in one run of the game. The horizontal lines on the table separate task groups. For example from the first group, one task was selected from seven possible, resulting in about 14% appearance chance for a single task. From some groups, two tasks were selected instead of one.