Motivation and Emotions in a Health Literacy Game: Insights from Co-occurrence Network Analysis

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Abstract. Accumulating evidence indicates that game-based learning is emotionally charged. However, little is known about the nature of emotions in game-based learning. We extended previous game-based learning research by examining epistemic emotions and their relations to flow experience and situational interest. Sixty-eight 15–18-year-old students played the Antidote COVID-19 game for 25 min. Epistemic emotions, flow, and situational interest were measured after the playing session. These measures indicated that the game engaged students. Students reported significantly higher intensity levels of positive epistemic emotions (excitement, surprise, and curiosity) than negative epistemic emotions (boredom, anxiety, frustration, and confusion). The co-occurrence network analyses provided insights into the relationship between flow and situational interest. We found an asymmetrical pattern of the "situational interest-flow" co-occurrence. When situational interest occurred, the flow was always co-occurring. This co-occurrence suggests that situational interest could be a prerequisite or a potential trigger for flow experience but not an adequate state ensuring a high flow experience. Further, flow and situational interest co-occurred mainly with positive epistemic emotions. The findings imply that flow and situational interest are similar constructs and share several characteristics. The study also demonstrated that epistemic emotions, flow, and situational interest can be used as proxies of engagement. Implications of the findings are discussed.

Keywords: Game-based learning · Epistemic emotions · Flow experience · Situational interest · Engagement

1 Introduction

The mechanisms of successful game-based learning processes are still poorly understood [1, 2]. A recent systematic survey [3] revealed that affective-cognitive models of learning [3, 4] had gotten little attention in the game-based learning field. This is surprising as

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/978-3-031-22124-8_15.

K. Kiili et al. (Eds.): GALA 2022, LNCS 13647, pp. 149–159, 2022.
https://doi.org/10.1007/978-3-031-22124-8_15

theories that emphasize both affective and cognitive aspects dominate contemporary multimedia learning research, and it has been hypothesized that emotional engagement may play a crucial role in game-based learning. Although recent research has indicated that game-based learning is emotionally charged [2, 6], the nature and objects of emotions in game-based learning have not been thoroughly examined. Particularly the role of emotional engagement in game-based learning is unclear.

Engagement can generally be defined as active involvement in a given learning task [7]. According to Fredricks, Filsecker, and Lawson [8], learner engagement consists of three distinct but interrelated dimensions: behavioral, emotional, and cognitive engagement dimensions. In the present study, we used two motivational constructs, flow experience, and situational interest, as proxies of engagement as suggested in [9]. Moreover, to better address students' emotional engagement in the Antidote COVID-19 health literacy game, we also measured students' epistemic emotions.

1.1 Flow and Situational Interest

Flow theory defines intrinsically-motivated behaviors resulting from immediate subjective experiences that occur when learners engage in a learning activity [10]. Flow is characterized by a holistic feeling of becoming completely absorbed in the learning activity, the merging of action and awareness, the increased focus of attention to a particular stimulus, a lack of self-awareness, and a feeling of agency over learners' own actions and the environment. Flow can only occur when learners perceive a balance between their skills and tasks. Three-channel model of flow emphasizes that flow is not a stable state. For example, a player occasionally tends to experience either boredom (too easy challenges) or anxiety (too demanding challenges), which may motivate the player to strive for the flow state to experience enjoyment again. A recent study examining the relationship between flow and emotions showed that players who experienced higher positive emotions (happiness and excitement) also experienced higher flow [11].

Because flow can be a relatively unstable state, game designers aim to design game mechanics to elicit learners' situational interest in the game, as interest is often required for learners engaging in a state of flow [12]. Situational interest is theoretically described as both a psychological and motivational state, leading to re-engagement in learning activities [13]. Situational interest emerges from interaction with the features built into the environment, for example, game elements and game mechanics in learning games. According to Kiili et al. [9] flow experience and situational interest can be used as proxies of engagement in game-based learning as these constructs explain why people engage in activities. Their study revealed that although flow experience and situational interest are strongly related, situational interest is mainly related to immersive aspects of flow and does not reflect the fluency dimension of flow.

1.2 Epistemic Emotions

Affective-cognitive models of learning [4, 5] emphasize that emotions are not only by-products but drivers of learning. In general, emotions can be defined as affective episodes that are induced by a certain stimulus and have an object. Academic emotions can be classified as achievement, topic, epistemic, and social [14]. In this paper, we

focus on epistemic emotions because epistemic emotions are directly related to the learning process [15], can motivate learners to engage in cognitive activities [14], and can influence learning outcomes and performance [16]. According to [17] knowledge and the generation of new knowledge are the objects of epistemic emotions (surprise, curiosity, enjoyment, confusion, anxiety, frustration, boredom). In contrast, the stimuli and object of achievement emotions relate to success or achievement in academic tasks. In game-based learning, players may experience topic emotions due to the content of the narrative itself, for example COVID-19 pandemic, rather than as a function of their experience of processing the earning content included in the game (epistemic emotions) or their appraisals of control or value of the game-based learning activity (achievement emotions).

Epistemic emotions can be classified according to their valence (positive/negative) and strength of physiological arousal (activating/deactivating). In general, research has indicated that positive activating emotions support learning more than negative ones [5] by facilitating, for example, elaboration and critical thinking [18]. Thus, game-based learning activities should aim to promote positive epistemic emotions (e.g., curiosity, enjoyment) and reduce negative epistemic emotions, deactivating negative emotions (boredom) in particular. It has been argued that boredom can impair the systematic use of learning strategies undermining the effectiveness of learning activities [18]. However, it is noteworthy that some negative activating emotions (e.g., confusion) and neural emotions (e.g., surprise) may facilitate learning in certain learning settings.

1.3 Present Study

The present study had two objectives: to examine student engagement in the Antidote COVID-19 game and examine the similarities and differences between flow experience and situational interest in relation to epistemic emotions. Figure 1 Summarizes the expected outcomes of the study.

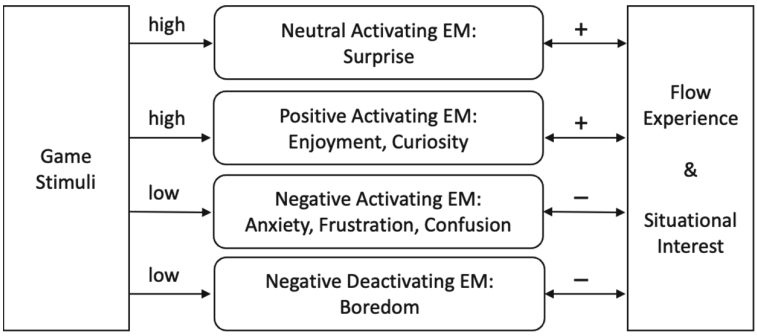

Fig. 1. The expected outcomes of the study (EM = Epistemic Emotion).

First, we examined students' engagement in the Antidote COVID-19 game. We used flow experience, situational interest, and epistemic emotions as proxies of engagement. Previous research has indicated that game-based learning engages students [2, 6]. Thus,

we expected that students report high levels of situational interest and flow. Further, we expected that students report significantly higher positive epistemic emotions than negative ones. To make reporting of the results simpler, we classified surprise as a positive emotion, although it is usually considered a neutral emotion. Second, we examined relations between flow experience, situational interest, and epistemic emotions. We expected to find a strong positive correlation between flow and situational interest, as demonstrated in [9]. The downside of correlational analyses is that it only looks for coupling between variables regardless of their magnitude. For example, a correlational analysis might yield a high relationship between flow and situational interest, although both variables might be scored towards the lower end of the used measurement scale. The co-occurrence network analysis, which we employed in this study, tackles this limitation by studying the coupling of variables only towards the higher end of measurement scales [19]. Therefore, we employed co-occurrence network analysis to describe how often different epistemic emotions are reported together with flow and situational interest within individuals. With these analyses, we aimed to answer the following research questions. How often do students report flow experience and situational interest together, and how strong is this relationship? Which specific epistemic emotions occur together with flow experience and situational interest, and how often?

2 Method

Participants. Sixty-eight 15–18-year-old (M = 16, SD = 0.78) students participated in the study. Students were recruited from two Finnish schools. There were 43 high school students and 25 9th graders. 22 of the participants were men and 40 women; six students reported their gender as "other." 60% of the participants reported playing computer games, mobile games, or console games at least a couple of times a week.

Game Description. Antidote COVID-19 is a mobile game about viruses, the human immune system, vaccines, and pandemics. PsyonGames has developed the game, and WHO has validated the game contents. Antidote COVID-19 is a tower defense game where the player tries to protect the base of the cell from a swarming danger (enemies), bacteria, and viruses (see Fig. 2). The main enemy is the coronavirus. The game tells a story about discovering the characteristics of coronavirus and learning to fight against it by developing vaccines. The story is told through messages from the laboratory and comic strips delivered during the gameplay. In each level, the player must first create a passageway that enemies must take to get to the base cell. Along that route, the player can build defense towers (white blood cells such as monocytes, macrophages etc.) that try to destroy the enemies. If too many enemies reach the base cell, the player will lose and must start the level again. By completing levels, the player earns new types of towers and RNA-points, which the player can use to upgrade vaccines that give the player certain advantages. The game gives the player feedback about performance with the health points and RNA-points. At any time, the player can use an encyclopedia to get information about different cells, enemies, and vaccines included in the game.

Measures. We measured epistemic emotions with a short version of the Epistemically-Related Emotion Scales [17] designed to measure surprise, curiosity, enjoyment, confusion, anxiety, frustration, and boredom. Each emotion was measured with a single item

by asking students to reflect on how strongly they felt the different emotions when they played the game. A five-point Likert scale with the response categories from 1 = not at all, 2 = quite a little, 3 = moderately, 4 = strongly, 5 = very strongly was used. In this short version of the scale, enjoyment is measured with the item of excitement. We measured situational interest with four items [20] (e.g., I think this topic is interesting). A 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) was used. We measured flow experience with a slightly modified 10-item version of the Flow Short Scale [21]. The statements were changed to past tense and made the activity refer to game playing [9]. A scale ranging from 1 (strongly disagree) to 5 (strongly agree) was used instead of the original 7-point scale. All the used scales were administered in Finnish.

Fig. 2. Gameplay: Coronavirus is trying to reach the base that the player is protecting with towers.

Procedure. The study was conducted during a regular school day. First, the researcher presented a video to participants that provided study details and practical instructions. Second, every participant received a randomly generated participation code (tag) that was used for logging in to digital pre-and post-questionnaires. Next, participants filled out demographics and a consent questionnaire. After pre-measures, participants played the Antidote COVID-19 game for 25-min with iPads. Finally, participants completed the questionnaire about their motivational and emotional experiences and reported the level that they reached in the game.

Co-occurrence Network Analysis. In general, correlational analyses look for coupling between variables of interest regardless of their magnitude. In co-occurrence network analysis, the magnitude is considered, and only the higher end of a measurement scale is used to coupling variables [19]. Usually, the higher end is decided based on the mid-level of the measurement scale [22]. That is, co-occurrence is manifested if both variables of interest are scored above the mid-level of the scale. Drawing on this, a dichotomous coding was applied to the epistemic emotions, situational interest, and flow scales. In the present study, we coded the responses that were above three as 1. Otherwise, the responses were coded as 0. Following, co-occurrence network analysis with louvain community detection algorithm was applied on the dichotomous scores to observe the overlaps between situational interest, flow, and epistemic emotions [23]. In the analysis,

variables are considered as nodes, and the co-occurrences between them are considered as edges (i.e., connections between the nodes). The analysis was conducted with igraph R package [24].

3 Results

3.1 Engagement

The descriptive statistics of all measures are shown in Table 1. The reliability of flow experience ($\alpha = .91$) and positive emotions were good ($\alpha = .87$), the reliability of situational interest ($\alpha = .78$) was acceptable, and the reliability of negative emotions was poor ($\alpha = .53$). Boredom, which was the only deactivating emotion on the used emotion scale lowered the reliability of the formed negative emotions construct.

Table 1. Descriptive statistics of engagement measures

	Mean	Standard deviation	Occurrence (f)
Flow experience	3.77	0.79	55
Situational interest	3.29	0.81	42
Positive epistemic emotions	3.21	0.89	–
Surprised (A)	3.12	1.09	25
Curious (A)	3.18	0.88	24
Excited (A)	3.34	1.02	34
Negative epistemic emotions	2.09	0.68	–
Confused (A)	2.79	1.17	20
Anxious (A)	1.57	0.91	4
Frustrated (A)	2.26	1.15	12
Bored (D)	1.72	0.98	4

The results indicate that the game engaged students as most reported moderate-to-high intensity of flow, situational interest, and positive epistemic emotions. Moreover, the students reported lower levels of negative epistemic emotions. Further, Paired Samples T-Test indicated that the game induced significantly higher intensity of positive epistemic emotions in students ($M = 3.21$, $SD = 0.89$) compared to negative epistemic emotions ($M = 2.09$, $SD = 0.68$), $t(67) = 7.48$, $p < .001$, $d = 0.91$. The frequency of students who experienced flow, situational interest, and each emotion are also presented in Table 1. The Occurrence column of Table 1 confirms that most students reported that they experienced flow ($f = 55$) and situational interest ($f = 42$). Excitement ($f = 34$), surprise ($f = 25$), and curiosity were the most frequently occurred epistemic emotions. However, only a small fraction of the students experienced anxiety ($f = 4$) and boredom ($f = 4$).

3.2 Relations Between Flow, Situational Interest, and Epistemic Emotions

As expected, the correlation between flow and situational interest was large, $r = .62$, $p < .001$. To examine the relation more deeply, we considered the relations between flow, situational interest, and epistemic emotions with co-occurrence network analysis. Table 2 shows the co-occurrence of epistemic emotions with flow, and Table 3 shows the co-occurrence with situational interest (note that the edge weight indicates how often two variables were reported together). It was observed that a high-intensity level of flow occurred 55 times and a high-intensity level of situational interest 42 times. The most often co-occurring epistemic emotions with flow were excitement (edge = 34; 62%), surprise (edge = 25; 46%), and curiosity (edge = 23; 42%). There was the similar trend in situational interest as the most co-occurring epistemic emotions with it were excitement (edge = 30; 71%), surprise (edge = 25; 60%), curiosity (edge = 23; 55%). Anxiety and boredom co-occurred very rarely with flow and situational interest. Further, the analyses revealed that a high-level situational interest was always accompanied with high level of flow (edge = 42; 100%).

Table 2. Co-occurrences of flow and motivation/emotion pairs

Node 1	Node 2	Edge weight	% of all edges	% of self-edge
Flow	Sit. Interest	42	20, 4	76, 4
	Excited	34	16, 5	61, 8
	Surprised	25	12, 1	45, 5
	Curious	23	11, 2	41, 8
	Confused	14	6, 8	25, 5
	Frustrated	9	4, 4	16, 4
	Anxious	3	1, 5	5, 5
	Bored	1	0, 5	1, 8

Table 3. Co-occurrences of situational interest and motivation/emotion pairs

Node 1	Node 2	Edge weight	% of all edges	% of self-edge
Sit. Interest	Flow	42	23, 6	100, 0
	Excited	30	16, 9	71, 4
	Surprised	25	14, 0	59, 5
	Curious	23	12, 9	54, 8
	Confused	9	5, 1	21, 4
	Frustrated	6	3, 4	14, 3
	Anxious	1	0, 6	2, 4
	Bored	0	0, 0	0, 0

4 Discussion

This research responds to demands to explore emotions in game-based learning [1]. We extended previous research by examining epistemic emotions, emotions that motivate learners to engage in cognitive activities, and their relation to flow experience and situational interest in a health literacy game. While most previous studies have examined relations between motivational constructs and emotions with correlational analyses, systemic research on how epistemic emotions are coupled with motivational constructs is scarce. Thus, we utilized co-occurrence network analysis to achieve a deeper understanding of whether and how emotional and motivational experiences are coupled with each other during game-based learning.

4.1 How Engaging the Game Was?

Both the motivational and emotional measures indicated that the game engaged students and induced positive emotional responses. The results are in line with previous studies indicating that game-based learning is emotionally charged [2, 6]. However, this study shed light also on nature of experienced emotions. Previous research has shown that positive activating epistemic emotions enhance engagement in learning environments [25]. For example, surprise and curiosity might facilitate greater knowledge exploration behaviors [26]. However, both negative activating and deactivating epistemic emotions were found to hinder engagement although negative activating emotions (e.g., frustration) might also facilitate short-term engagement through triggering extrinsic motivations to avoid failure [25, 27, 28]. In light of this line of research, it can be claimed that the current game-based learning environment facilitated enjoyable and engaging learning experiences since students reported higher intensity-levels of positive epistemic emotions compared to the negative epistemic emotions. Further, previous research has indicated that boredom can impair the systematic use of learning strategies which tends to undermine the effectiveness of learning activities [18]. In that sense, the used game was very successful as only four students reported experiencing boredom. Further, most participants reported high-intensity levels of flow and situational interest. The findings

imply that positive epistemic emotions might facilitate enjoyable game-based learning experiences and contribute to learning engagement.

4.2 Flow, Situational Interest, and Epistemic Emotions as Indicators of Engagement

Consistent with a recent study [9], we found a strong positive correlation between flow and situational interest. The co-occurrence network analyses provided new insights into this relationship. We found an asymmetrical pattern of the "situational interest-flow" co-occurrence. When situational interest occurred, flow was always co-occurring. However, experienced flow did not always accompany situational interest. This suggests that situational interest could be a prerequisite or a potential trigger for experiencing flow but not an adequate state ensuring high flow experience. On the other hand, flow refers to an optimal psychological state that occurs when challenges and skills are in balance [10]. It might be possible that although the topic and the game did not interest some of the students, the appropriate challenges and fluent gameplay may have facilitated the intensity of flow. In general, our findings indicate that flow can be experienced without experiencing high levels of situational interest. Thus, it seems that a moderate level of situational interest would be sufficient for some learners to experience flow.

The current study goes beyond revealing the trend of shared variation among epistemic emotions and motivational constructs with correlational analysis. It shows distinct sub-groups of both frequent and rare co-occurrences among flow, situational interest, and epistemic emotions. Overall, the current findings imply that flow and situational interest are highly coupled with each other. Further, they both mostly co-occur with epistemic emotions on the positive valence spectrum than negative. The study also demonstrated that epistemic emotions, flow, and situational interest reveal interesting qualities of game-based learning and thus it is useful to use all of them as proxies of engagement.

4.3 Limitations and Future Directions

There are some limitations in our study and the findings should be interpreted carefully. It is probable that the used retrospective questionnaire did not grasp all epistemic emotions that students experienced when they played the game. It is also possible that the emotions that students reported were not always necessarily epistemic in nature. For example, students may have reported achievement emotions based on their success in the game (e.g., enjoyment or anxiety) instead of emotions induced by the knowledge processed while playing the game. Further, the topic of the game was sensitive and may have induced topic emotions in students. However, in one think-aloud study in which epistemic emotions were measured, most of the reported emotions were epistemic in nature [18]. Nevertheless, we emphasize that questions used to measure epistemic emotions should be carefully aligned with the object of epistemic emotions in future studies. The other limitation is that we conducted a short study, and thus it was not reasonable to measure learning outcomes. In future studies, the relations between epistemic emotions and learning outcomes should be investigated. Further, for example, think-aloud studies could be conducted to explore what game elements induce epistemic emotions.

Acknowledgments. This research is funded by the Strategic Research Council (SRC).

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