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Article

Demystifying the Relations of Motivation and Emotions in Game-Based Learning: Insights from Co-Occurrence Network Analysis

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Abstract

Accumulating evidence indicates that game-based learning is emotionally engaging. 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 motivational constructs. One-hundred-thirty-one (n=131) 15–18-year-old students played the Antidote COVID-19 game for 25 minutes. Data were collected on their epistemic emotions, flow experience, situational interest, and satisfaction that were measured after the game-playing session. Learners reported significantly higher intensity levels of positive epistemic emotions (excitement, surprise, and curiosity) than negative ones (boredom, anxiety, frustration, and confusion). The co-occurrence network analyses provided new insights into the relationships between motivational and emotional states, where high-intensity flow experience, situational interest, and satisfaction co-occurred the most often with positive epistemic emotions. Results also revealed that a high-intensity flow can be experienced without high levels of situational interest in the topic. That is, gameplay can engage learners even though the learning topic does not interest them. This highlights the importance of intrinsically integrating the learning content with core game mechanics, ensuring the processing of the learning content. The study demonstrated that epistemic emotions, flow experience, satisfaction, and situational interest reveal different qualities of game-based learning. The results suggest that at least flow, situational interest, and epistemic emotions should be measured to understand different dimensions of engagement in game-based learning. Overall, the study advances prior research by clarifying relationships between epistemic emotions and motivational constructs.

1. Introduction

A growing body of evidence indicates that gamified learning [1] and game-based learning [2]–[4] can enhance cognitive, motivational, and affective outcomes that contribute more to learning when compared to non-game learning tasks. In other words, the promise of using games for learning purposes relies upon the engaging nature of games. Engagement can generally be defined as active involvement in a learning task [5]. Nevertheless, regardless of continuously increasing scientific outputs, the underlying mechanisms and characteristics of successful game-based learning processes are still poorly understood [6][7]. Particularly, the role of emotional engagement, and emotions' relationship with motivation in game-based learning, is unclear.

Game-based learning entails redesigning a learning task by utilizing the unique affordances of games (beyond the mere implementation of reward systems) to create learning experiences that are more meaningful, interesting, and effective than either a nongame or a gamified learning task [8]. In contrast to game-based learning, gamification refers to a design approach in which specific game elements, mainly reward systems and narratives, are added to an existing learning environment (without changing the learning task remarkably) to motivate learners [8]. In this paper, we focus on game-based learning. A recent systematic survey [9] revealed that over 100 theories have been used to explain the design and effects of serious games, gamified learning, and game-based learning. Self-determination, flow, and experiential learning theories were the most commonly used. This systematic survey revealed that affective-cognitive models of learning [9]–[12] had gotten little attention in the game-based learning field. This is surprising, given the recent emphasis on emotional design in contemporary multimedia learning research [13]. Furthermore, it has been hypothesized that emotional engagement may play a critical role in game-based learning [14][15]. Although recent experiments have indicated that game-based learning is emotionally charged [7][15][16], the nature and objects of emotions in game-based learning have not been thoroughly examined. In fact, a recent meta-analysis highlights a clear need for more systematic research on emotions in different kinds of technology-based learning environments [17].

In this paper, we emphasize the role of motivation and emotions in engaging learners in gameplay. "Motivation can be defined as the processes that drive, select and direct voluntary behaviors towards specific goals or desired states" [18, pp. 5]. According to [19], motivation energizes and directs behavior, which can also be experienced as interest. Schunk [20] emphasized that motivation processes include both cognition and emotion aspects; thus, cognition and emotions are theorized to interact which energizes and sustains motivation during learning. According to [11], instructional design may evoke and support specific combinations of emotions and cognitions, which in turn serve as motivating forces that influence when and how learners interact with a learning environment or whether they disengage from the learning activities totally.

Regarding the game-based learning context, the Game-Based Learning Engagement (GBLE) model (Fig. 1) illustrates the close and reciprocal relations between cognition, motivation, and emotions triggered by game-based learning. Furthermore, this proposed model states that motivation, cognition, and emotions reflect engagement in game-based learning. The GBLE model partly aligns with Ke and colleagues' [21] findings suggesting that "game-based learning engagement is an integrated and continuing process that advances from affective engagement driven by optimal challenge, cognitive engagement situated in playfulness, to potentially game-action-based content engagement". Playful cognitive engagement and game-action-based content engagement can be linked to intrinsic integration. Intrinsic integration refers to the educational game design approach that expects a clear intrinsic association between the game's core mechanics (main interactions) and the learning content or learning mechanics [22]. That is, while interacting with game mechanics, the learner is required to also process the learning content of the game.

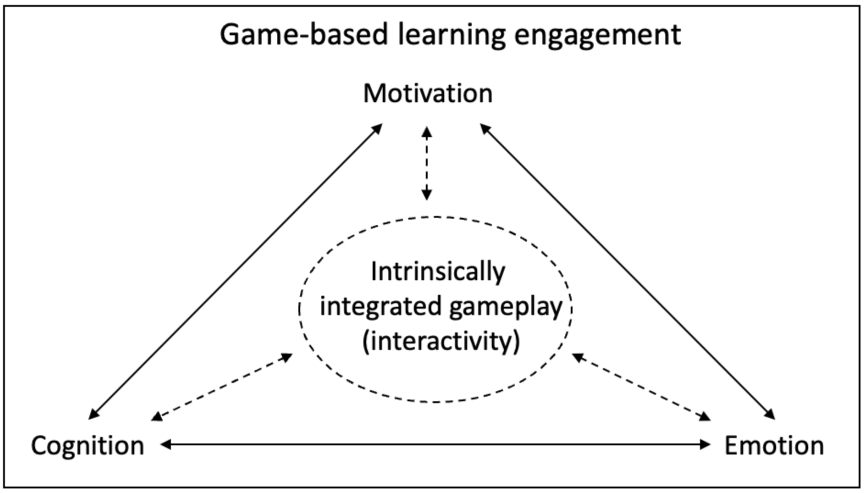

Figure 1. Game-Based Learning Engagement model (GBLE model)

In the present study, we examined game-based learning engagement in an intrinsically integrated health literacy game. We used two motivational constructs, flow experience, and situational interest, as proxies of engagement, as suggested in [23]. Moreover, to address emotional engagement, we measured students' epistemic emotions and perceived satisfaction. According to Schunk [20], satisfaction can be considered an emotion that maintains motivation. We focused on epistemic emotions because they involve cognitive and affective processes that deal with the knowledge-related qualities of information processing [24], that give rise to emotional engagement.

1.1 Flow and situational interest

Flow experience is one of the most common motivational constructs to describe the playing experience [25]. Flow theory explains that intrinsically-motivated behaviors resulting from immediate subjective experiences occur when learners engage in a learning activity [26]. Flow, also referred to as optimal experience, is characterized by a holistic feeling of becoming completely absorbed in the learning activity, where action and awareness merge as one, and the resulting increased focus of attention to a particular stimulus, contributes to a lack of self-awareness and a feeling of agency over actions and the environment [27]. However, flow only occurs when learners perceive a delicate balance between their skill level and task demands (e.g., level of difficulty). The three-channel model of flow emphasizes that flow is not a stable state. For example, a learner occasionally tends to experience either boredom (challenges that are too easy) or anxiety (challenges that are too demanding), falling outside of the flow zone, which may motivate them to strive for the flow state to experience enjoyment again [27]. A recent study examining the relationship between flow and emotions showed that learners who experienced higher positive emotions (happiness and excitement) also experienced more flow [28].

Because flow can be a relatively unstable state, game designers aim to build game mechanics to elicit learners' situational interest during gameplay, as interest is often required for learners to engage in a state of flow [29]. Situational interest is theoretically described as both a psychological and motivational state while engaging with learning content, leading to re-engagement in learning activities [30], emerging from interactions with the features built into the environment (e.g., game elements and game mechanics) [31]. According to [32], situational interest is defined as a motivational factor that engages learners with new information, but some scholars consider it more simply as a positive attitudinal response to specific learning activities. Despite this viewpoint, the mobilization of situational interest is an important instructional goal as it is an essential state in developing more stable and sustainable individual interest toward the learning topic [30]. According to Kiili et al. [23], flow experience and situational interest can be used as proxies of engagement in game-based learning, as these constructs may explain why people engage in game-based learning activities. Their study revealed that although flow experience and situational interest were strongly related, situational interest was mainly related to immersive aspects of flow experience and did not reflect the fluency dimension of flow experience. In the current study, we operationalize situational interest to reflect learners' engagement in the topic of the game, i.e., as a motivational factor that engages learners with new information that the health literacy game provides.

1.2 Epistemic Emotions

Affective-cognitive models of learning [11][12] 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 [33]. According to [24], epistemic emotions are produced by cognitive features and processing of task information. In this paper, we focus on epistemic emotions since they deal with the knowledge-related qualities of information during learning tasks. Epistemic emotions are directly related to the learning process [34], can motivate learners to engage in cognitive activities [33], and can influence learning outcomes and performance [35]. According to [36], knowledge and the generation of new knowledge are the objects of epistemic emotions (i.e., surprise, curiosity, enjoyment, confusion, anxiety, frustration, and boredom). In contrast, the stimuli and object of achievement emotions relate to success or achievement in academic tasks. In game-based learning, players may also experience topic emotions due to the content of the narrative itself, for example, the COVID-19 pandemic, rather than as a function of their experience of processing the learning 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 [12] by facilitating, for example, elaboration and critical thinking [37]. 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 [37]. However, neutral emotions (e.g., surprise) and some negative activating emotions (e.g., confusion) may facilitate learning in specific learning settings. It is also noteworthy that confusion is central to problem-solving [38], and thus it may occur relatively often in specific games, for example, puzzle and strategy games. It is argued that confusion can enhance learning because it can motivate learners to solve problems and finally resolve confusion [17]. Resolved confusion, in turn, can lead to an experience of enjoyment and increase engagement [35][38]. On the other hand, long-lasting and unresolved confusion can induce frustration and eventually lead to boredom [38].

1.3 Objectives and Hypotheses

The present study aims to shed light on the relations depicted in the proposed Game-Based Learning Engagement model. We distinguished two main objectives: to examine student engagement in the Antidote COVID-19 game and to examine the similarities and differences between flow experience, situational interest, and perceived satisfaction with the learning game in relation to epistemic emotions. Figure 2. summarizes the expected outcomes of the study.

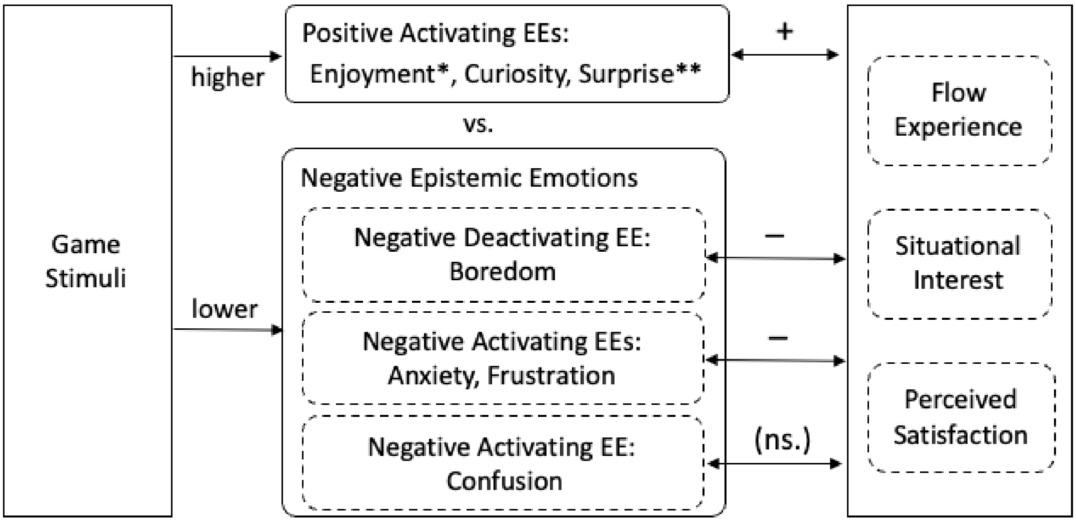

Figure 2. The expected outcomes of the study (EE = Epistemic Emotion; ns. = not significant; *Enjoyment was operationalized as excitement; **Usually surprise is classified as neutral emotion)

First, we focused on learners' playing experiences by examining how engaging the Antidote COVID-19 game was. We collected data on flow experience, situational interest, perceived satisfaction, and epistemic emotions as proxies of engagement. Previous research has indicated that game-based learning engages learners [7][16][39]. Thus, we expected that learners would report relatively high levels of flow experience, situational interest, and satisfaction. According to a recent meta-analysis, GBL often increases learners' positive achievement emotions and decreases their negative achievement emotions [40]. Against this background, we expected that learners would report significantly higher positive epistemic emotions than negative epistemic emotions measured after the game-based learning session (***Hypothesis 1***). To make reporting the results simpler, we classified surprise as a positive emotion, although it is often considered a neutral emotion [37].

Second, we examined relations between flow experience, situational interest, perceived satisfaction, and epistemic emotions. We expected to find a strong positive correlation between flow experience and situational interest (***Hypothesis 2a***). In times of flow, students experience a psychological state in which they get detached from the actual world and fully immersed in task-driven activity [27]. This is reflected as the cognitive and affective processes of the learner are fully allocated to the task at hand. In this regard, it can be argued that flow is accompanied with heightened situational interest during gameplay. In line with our assumption, previous research has found that flow and situational interest are positively associated in game-based learning environments [23]. Further, we expected that perceived satisfaction has a significant positive relationship with situational interest (***Hypothesis 2b***) and flow experience (***Hypothesis 2c***). According to the previous literature, flow experience and situational interest predict perceived satisfaction in games [41] and learning environments [42]. Based on such findings, it can be argued that owing to features such as novelty, cognitive incongruity, and cognitive activation, game-based learning environments yield positive experiences (e.g., situational interest and flow) among the learners that are reflected as enjoyment and satisfaction [43].

Regarding epistemic emotions, we expected that positive epistemic emotions (enjoyment, curiosity, and surprise) correlate positively with flow experience, situational interest, and perceived satisfaction (***Hypothesis 3***). In contrast, we expected that negative deactivating epistemic emotion, boredom, correlate negatively with flow experience, situational interest, and perceived satisfaction (***Hypothesis 4a***). Further, we expected that negative activating epistemic emotions, anxiety, and frustration, correlate negatively with flow experience, situational interest, and perceived satisfaction (***Hypothesis 4b***). We made these assumptions as flow experience, situational interest, and perceived satisfaction are coined as positive psychological states in literature [20][27][43]. However, as resolved confusion can induce positive and unresolved confusion negative emotions [35], we did not expect confusion to correlate significantly with flow experience, situational interest, or perceived satisfaction (***Hypothesis 4c***).

The downside of correlational analysis 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 experience 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 [44]. Therefore, we finally employed co-occurrence network analysis to describe how often different epistemic emotions were reported together with flow experience, situational interest, and perceived satisfaction within learners. With these analyses, we aimed to answer the following research questions. How often do learners report flow experience, situational interest, and perceived satisfaction together, and how strong are these relationships? Which specific epistemic emotions occur together with flow experience, situational interest, and perceived satisfaction, and how often?

2. Method

2.1 Participants

One-hundred-thirty-one (n=131) 15–18-year-old (M = 15.72, SD = 0.89) students participated in the study. Participants were recruited from seven Finnish schools. The sample included 73 high school students and 58 9th graders. Thirty-eight of the participants were men, and 78 were women, while 15 participants reported their gender as "other." More than half of the participants (62%) reported playing computer games, mobile games, or console games at least a few of times a week.

2.2 Game description

Antidote COVID-19 is a mobile health literacy game focusing on viruses, the human immune system, vaccines, and pandemics. Psyon Games has developed the game, and WHO experts have validated the game's content. The gameplay was based on tower defense game mechanics. In tower defense games, players must strategically place defensive structures, such as towers or obstacles, into the game world, to prevent waves of enemies from reaching a certain point or objective. In the case of Antidote COVID-19, the learner tries to protect the base of the cell from bacteria and viruses (Fig. 3) by building 'defense towers', i.e., white blood cells that destroy the enemies. Sugar is an important resource that is needed to build towers. It is produced automatically, but the learner must increase the sugar production speed with a specific tower (Myeloblast). By completing levels, the learner earns new types of towers with special powers (e.g., lymphocytes, macrophages, B-cells…), and gradually better vaccines can be developed (Fig. 4). New towers introduce additional strategic options and require learners to adapt their defense strategies accordingly. Moreover, learners can combine or synergize towers to create more powerful effects. For example, if certain towers are placed in proximity to each other, their abilities can be boosted. Also, vaccines give the learner certain advantages, such as increasing the eating speed of white blood cells (e.g., eaters become 30% more effective against Corona). If the learner fails to defend the base cell and too many enemies reach it, they will lose and must start the level again.

Figure 3. Gameplay: Coronavirus is trying to reach the base the player is protecting with towers.

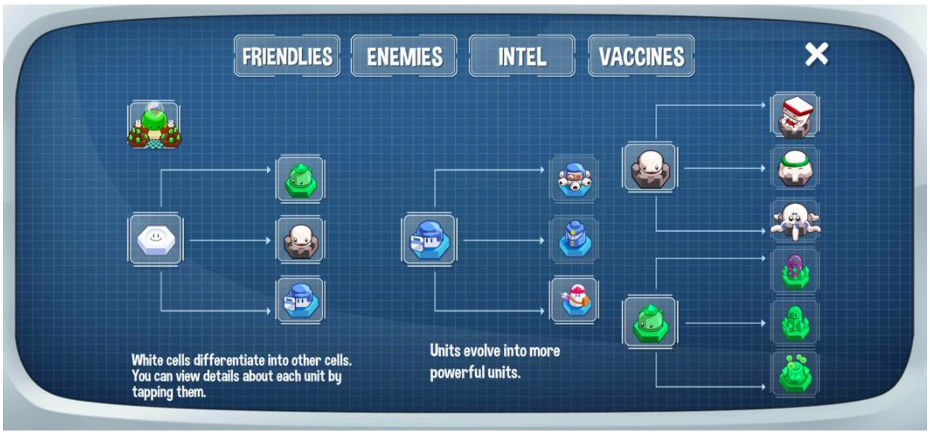

Figure 4. The evolvement of towers (one screen from the game's encyclopedia).

In general, the game tells a story about discovering the characteristics of a coronavirus and how to fight against it by developing vaccines. In addition to the core gameplay, messages from the laboratory and comic strips are used to tell the story (Fig. 5). At any time, the learner can access game's encyclopedia to gather information about different cells, enemies, and vaccines included in the game (Fig. 4 and Fig. 5) Although the encyclopedia and comic strips provide part of the health information included in the game, learner likely do not feel detached from the gameplay. Emotional design, particularly anthropomorphism [45], has been applied to game characters. Friendly characters (e.g., white blood cells) have goofy, neutral, and cute expressions, whereas enemies (e.g., viruses and bacteria) look menacing, dangerous, and angry (Fig. 6). Overall, the learning content is intrinsically integrated with the tower defense mechanics. One important aspect of the game is that it allows learners to experience the phenomena. For example, learner can experience how vaccines affect the human immune system and the coronavirus in the game, and how the behavior of coronavirus differs from other viruses included in the game.

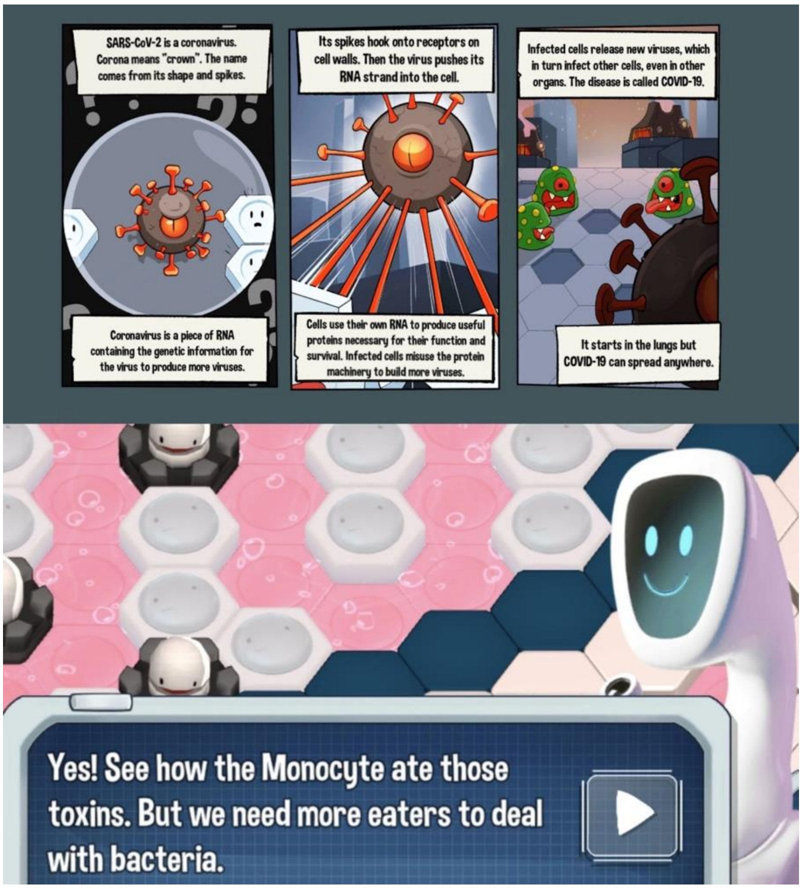

Figure 5. Part of the narrative, feedback, and guidance is delivered through comic strips and in-game dialogue.

Figure 6. Examples of emotional design of the enemies

2.3 Measures

Regarding participants' background characteristics, the game-playing frequency was measured with one question, asking, “How often do you play computer, mobile, or console games? (Almost every day", "A few times a week", "About once a month", "Hardly ever"). Epistemic emotions, including surprise, curiosity, enjoyment, confusion, anxiety, frustration, and boredom, were assessed with a short version of the Epistemically-Related Emotion Scales [36]. Each emotion was measured with a single item by asking learners to reflect on how strongly they felt the different emotions when they played the game. A five-point Likert scale with response categories ranging from 1 = not at all, 2 = quite a little, 3 = moderately, 4 = strongly, to 5 = very strongly was employed. In this short version of the scale, enjoyment was measured with the item of excitement. Situational interest was measured using a four-item scale [32]. Participants indicated their level of interest in the topic by responding to statements such as "I think this topic was interesting." A 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree) was used. In a previous study [32], the coefficient H of the scale was .84 indicating good reliability. Flow experience was measured with a slightly modified 10-item version of the Flow Short Scale [46]. The statements were adjusted to the past tense and referred specifically to game-playing [23]. A scale ranging from 1 (strongly disagree) to 5 (strongly agree) was employed, replacing the original 7-point scale. In a previous study [23], Cronbach's alpha of the scale was .87 indicating good reliability. To assess participants' perceived satisfaction with the learning material, a single 7-point Likert question was adopted from [47], asking, "How much did you like the learning material?" All the scales were administered in Finnish.

2.4 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 into digital questionnaires. Third, participants filled out demographics and a consent questionnaire. Next, participants played the Antidote COVID-19 game for 25 minutes with iPads. Finally, participants completed the questionnaire about their motivational and emotional experiences and reported the level that they reached in the game.

2.5 Analyses

Cronbach's alpha was used to consider the internal consistency of the following sum variables: flow experience, situational interest, positive epistemic emotions, and negative epistemic emotions. The labels of the game-playing frequency measurement were coded as follows: Almost every day = 3, A few times a week = 2, About once a month = 1, Hardly ever = 0. Based on skewness and kurtosis values, data were not normally distributed for flow experience, satisfaction, anxiety, frustration, boredom, and negative emotions variables. Due to non-normal distribution violations and the use of ordinal one-item measurement scales (discrete epistemic emotions and satisfaction), Related-Samples Wilcoxon Signed Rank Test was used to examine differences in positive and negative epistemic emotions. Similarly, a non-parametric Spearman's rho was used to calculate correlation analyses, and a Rank Biserial correlation (r_{rb}) was used as an effect size statistic.

In general, correlational analyses look for coupling between variables of interest regardless of their magnitude. Thus, we employed co-occurrence network analysis. In co-occurrence network analysis, the magnitude is considered, where only the higher end of a measurement scale is used in coupling variables [44]. Usually, the higher end is decided based on the mid-level of the measurement scale [48]. 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, perceived satisfaction, and flow scales. In the present study, on 5-point Likert scales we coded the responses that were at least 4 as 1, and on the 7-point Likert scale, we coded the responses that were at least 6 as 1. Otherwise, the responses were coded as 0. Following, co-occurrence network analysis with louvain community detection algorithm was applied to the dichotomous scores to observe the overlaps between flow experience, situational interest, perceived satisfaction, and epistemic emotions [49]. In the co-occurrence 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 [50].

3. Results

3.1 Descriptive statistics, reliability, and emotional engagement

On average the learners reached level five in the game (*M* = 4.86, *SD* = 1.68). The descriptive statistics of all measures are shown in Table 1. The reliability of flow experience (α = .91), situational interest (α = .81), and positive epistemic emotions (α = .85) were satisfactory. The reliability of negative epistemic emotions was poor (α = .50). Boredom, which was the only deactivating emotion on the used emotion scale, lowered the reliability of the negative emotions construct. However, even if boredom was excluded from reliability analyses, the reliability remained quite poor overall (α = .58). Therefore, we decided to use the construct that also included the boredom item in the analyses.

Table 1. Descriptive statistics of engagement measures (*n* = 131)

	Mean	Standard Deviation	Occurrence (f)
Flow Experience	3.81	0.81	62
Situational Interest	3.29	0.90	36
Perceived satisfaction	4.91	1.60	88
Positive Epistemic Emotions	3.23	0.95	-
Surprise (A)*	3.08	1.10	50
Curious (A)	3.21	1.04	54
Excitement (A)	3.40	1.13	69
Negative Epistemic Emotions	2.19	0.60	-
Confusion (A)	2.82	1.15	42
Anxiety (A)	1.72	1.08	13
Frustration (A)	2.34	1.18	23
Boredom (D)	1.85	1.06	13

Note. The scale of perceived satisfaction was 1-7; The scale of other measures was 1-5. * We classified surprise as a positive emotion even if it is sometimes considered a neutral emotion. Letter A refers to activating and D to deactivating.

The frequency of learners who experienced high-intensity flow experience, situational interest, perceived satisfaction, and each emotion is also presented in Table 1 (occurrence column). Perceived satisfaction (*f* = 88) and flow experience (*f* = 62) occurred more often than situational interest (*f* = 36). Excitement (*f* = 69), curiosity (*f* = 54), surprise (*f* = 50), and confusion (*f* = 42) were the most frequently occurring epistemic emotions. Only a relatively small proportion of the students experienced frustration (*f* = 23), anxiety (*f* = 13), and boredom (*f* = 13). Regarding emotional engagement, a Related-Samples Wilcoxon Signed Rank Test indicated that the game induced significantly higher intensity of positive epistemic emotions in students (*Mdn* = 3.33) compared to negative epistemic emotions (*Mdn* = 2), $p < .001$, r_{rb} = 0.77, which supports ***Hypothesis 1***.

3.2 Results of correlation analyses

The correlations between measured variables are listed in the table included in Appendix 1. The correlation between flow experience and situational interest was strong, *r* = .59, *p* <.001, as was the correlation between situational interest and perceived satisfaction, *r* = .58, *p* <.001, supporting ***Hypotheses 2a and 2b***. However, students' flow experience was correlated with perceived satisfaction even more strongly, *r* = .76, *p* <.001, confirming ***Hypothesis 2c***. Appendix 1 shows that flow experience, situational interest, and satisfaction have similar relationships with epistemic emotions. In line with ***Hypothesis 3***, the discrete positive activating epistemic emotions (curiosity, enjoyment, surprise) were positively related to flow experience, situational interest, and perceived satisfaction (*r* = .52 – .71, *p* <.001). Negative deactivating epistemic emotion, boredom, showed the expected strong, negative relationship with the flow experience (r = -.61, p <.001), situational interest (r = -.55, p <.001), and perceived satisfaction (r = -.67, p <.001), supporting ***Hypotheses 4a***. Aligned with ***Hypothesis 4c***, confusion did not correlate with flow experience, situational interest, and perceived satisfaction. From other negative activating epistemic emotions (anxiety, frustration), surprisingly, only frustration correlated negatively with situational interest (r = -.24, p =.005), but not with the flow experience or perceived satisfaction (*ps* > .05). Further, as we did not find a statistically significant negative correlation between frustration and flow experience, situational interest, or perceived satisfaction (*ps* > .05), ***Hypothesis 4b*** was rejected. Regarding students' game-playing frequency (how often they play digital games), the analyses revealed that game-playing frequency correlated significantly only with flow experience (r = -.20, p = .02). To support the interpretation of this finding, we explored the correlation between game-playing frequency and learners' self-reported progress in the game. This analysis showed that game-playing frequency and game progress correlated significantly (r = .33, p < .001).

3.3 Results of co-occurrence network analyses

To examine the found relationships more deeply, we examined the relations between flow experience, situational interest, perceived satisfaction, and epistemic emotions with co-occurrence network analysis. Table 2 shows the co-occurrence of epistemic emotions with flow experience, Table 3 shows the co-occurrence with situational interest, and Table 4 shows the co-occurrence with perceived satisfaction (note that the edge weight indicates how often two variables were reported together).

Almost all learners who experienced high-intensity flow (f = 62) or situational interest (f = 36) were also satisfied with the learning material (93.6% and 91.7%, respectively). However, satisfaction did not guarantee that learners experienced high-intensity flow experience or situational interest. In fact, only 65.9% of the satisfied students experienced high-intensity flow experience and 37.5% high-intensity situational interest. Epistemic emotions co-occurred the most often with situational interest, specifically with excitement (80.6%), surprise (72.2%), and curiosity (72.2%). Similarly, flow experience co-occurred with excitement (75.8%), surprise (61.3%), and curiosity (59.7%). In addition, perceived satisfaction co-occurred with excitement (72.7%), curiosity (55.7%), and surprise (48.9%). The self-edge percentages reveal that these emotions co-occurred more frequently with situational interest than with flow experience and perceived satisfaction. This is not surprising as the self-edge of situational interest (36) was smaller than self-edge percentages of flow experience (62) and perceived satisfaction (88).

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

Node 1	Node 2	Edge weight	% of all edges	% of self-edge
Flow				
	Satisfaction	58	18.77	93.55
	Excitement	47	15.21	75.81
	Surprise	38	12.30	61.29
	Curiosity	37	11.97	59.68
	Interest	30	9.71	48.39
	Confusion	18	5.83	29.03
	Frustration	11	3.56	17.74
	Anxiety	6	1.94	9.68
	Boredom	2	0.65	3.23

Note. The number of flow self-edge was 62.

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

Node 1	Node 2	Edge weight	% of all edges	% of self-edge
Interest				
	Satisfaction	33	16.5	91.7
	Flow	30	15.0	83.3
	Excitement	29	14.5	80.6
	Curiosity	26	13.0	72.2
	Surprise	26	13.0	72.2
	Confusion	9	4.5	25.0
	Frustration	6	3.0	16.7
	Anxiety	4	2.0	11.1
	Boredom	1	0.5	2.8

Note. The number of situational interest self-edge was 36.

Table 4. Co-occurrences of satisfaction and motivation/emotion pairs

Node 1	Node 2	Edge weight	% of all edges	% of self-edge
Satisfaction				
	Excitement	64	16.8	72.7
	Flow	58	15.2	65.9
	Curiosity	49	12.9	55.7
	Surprise	43	11.3	48.9
	Interest	33	8.7	37.5
	Confusion	25	6.6	28.4
	Frustration	13	3.4	14.8
	Anxiety	7	1.8	8.0
	Boredom	1	0.3	1.1

Note. The number of satisfaction self-edge was 88.

4. Discussion

This research responds to demands to explore emotions that game-based learning induces [6] and to clarify the relations between emotions and motivational constructs [51]. We extended previous research by examining epistemic emotions, emotions that influence how learners engage in cognitive activities and information processing, and their relation to learners' flow experience, situational interest, and perceived satisfaction 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 couple with motivational constructs has been scarce. Thus, we utilized co-occurrence network analysis to achieve a deeper understanding of whether and how emotional and motivational experiences co-occur in game-based learning.

4.1 How well the game engaged learners?

The results indicated that the game-based learning environment, Antidote COVID-19, engaged learners, as a large proportion of them reported moderate-to-high intensity flow experience, perceived satisfaction, and positive epistemic emotions after game-based learning. Our findings are aligned with previous studies showing that game-based learning is engaging and emotionally charged [7][16][39]. However, the results revealed that the topic of the game (e.g., health literacy) may have triggered high situational interest, but only for a relatively small number of learners (27%). This indicates that gameplay can be engaging, despite the topic of the game, highlighting the importance of well-implemented game mechanics and intrinsic integration [22]. Although, it is important to note that if the situational interest measure had been operationalized to measure learners' interest in the game, rather than their interest in learning about the topic presented in the game, the results might have been different.

The study also sheds light on the nature of epistemic emotions with game-based learning environments. Previous research has shown that positive activating emotions tend to enhance engagement in learning environments [17] including game-based environments [40][52]. For example, surprise and curiosity might facilitate greater knowledge exploration behaviors [53]. There is also evidence that most negative activating and negative deactivating epistemic emotions tend to hinder engagement and learning [17][52][54]. Considering this line of research, our results suggest that the Antidote COVID-19 game facilitated enjoyable and engaging learning experiences as learners reported higher intensity levels of positive epistemic emotions than negative epistemic emotions, as we expected (Hypothesis 1). This is consistent with recent meta-analyses indicating that GBL often increases students' positive achievement emotions and decreases negative achievement emotions [40]. Further, previous research has indicated that boredom can impair the systematic use of learning strategies which tends to undermine the effectiveness of learning activities [37]. In that sense, the Antidote COVID-19 game was successful as only 13 of 131 learners reported experiencing high-intensity boredom (deactivating emotion). This finding is aligned with Schwartz and Plass [55] who have emphasized the active role of learner in game-based learning. Overall, the findings imply that gameplay that triggers positive epistemic emotions might facilitate enjoyable game-based learning experiences and contribute to learning engagement.

4.2 Relations between flow, situational interest, satisfaction, and epistemic emotions

This study clarified the relationships between epistemic emotions and motivational constructs in game-based learning. Table 5 shows that only one of the set hypotheses (H4b) was rejected.

Table 5. Summary of hypotheses testing

	Variables of the correlation analyses	Expected relations	Confirmed
H2a	Flow with situational interest	+	Yes
H2b	Flow with satisfaction	+	Yes
H2c	Situational interest with satisfaction	+	Yes
H3	Excitement, curiosity, and surprise (positive activating epistemic emotions) with flow, interest, and satisfaction	+	Yes
H4a	Boredom (negative deactivating epistemic emotion) with flow, interest, and satisfaction	–	Yes
H4b	Anxiety and frustration (negative activating epistemic emotions) with flow, interest, and satisfaction	–	No
H4c	Confusion (negative activating epistemic emotion) with flow, interest, and satisfaction	ns.	Yes

Findings concerning anxiety and frustration did not support our hypotheses, possibly because the playing time was short (only 25 minutes), and in the beginning, the game provided support for learners by introducing and explaining new game mechanics and features. It is, therefore, understandable that high-intensity anxiety and frustration were not frequent and did not undermine learners' motivation. For example, if learners had played for a longer period of time, it may have affected their emotional experience, since as the game progresses, it becomes increasingly more difficult. In fact, a recent meta-analysis [40] revealed that the duration of game-based learning interventions affects the level of emotional engagement. Furthermore, regarding learners' background characteristics, our findings showed that learners' game-playing frequency was associated only with flow experience. We can only speculate on the possible reasons for this positive association. Maybe the game was too easy for learners who play games more frequently. The positive association between the game-playing frequency and learners' progress in the Antidote COVID-19 game is aligned with this interpretation. Nevertheless, it is possible that longer playing intervention could have influenced learners' experiences. Thus, the findings of this study should be interpreted cautiously, and further research is needed.

The co-occurrence network analyses provided new insights into relationships found with correlation analyses. Most learners who reported high-intensity situational interest also reported satisfaction with the learning material and high-intensity flow experience. However, the results revealed that flow may be experienced without experiencing high levels of situational interest. It might be possible that, while the topic of the game did not interest some of the learners, the game mechanics which provided appropriate challenges, immediate feedback, and fluent gameplay may have facilitated the intensity of flow. In general, the results suggest that situational interest could be only one antecedent or potential trigger for promoting flow but may not be an adequate state ensuring a high-intensity flow experience. Furthermore, learners who reported satisfaction did not necessarily report flow or situational interest.

Regarding emotional engagement, the co-occurrence network analyses showed that high-intensity flow experience, situational interest, and perceived satisfaction mostly co-occurred with high-intensity epistemic emotions on the positive valence spectrum rather than negative, providing more support for Hypothesis 3. Confusion was the most common of the experienced negative activating emotions. It co-occurred relatively often with flow experience (≈ 29%), perceived satisfaction (≈ 28%), and situational interest (≈ 25%). This is unsurprising as confusion is central to problem-solving [38], which was required in order for learners to progress through the game played in this study. Nevertheless, as expected, confusion did not correlate significantly with flow experience, perceived satisfaction, or situational interest.

Overall, our study uniquely contributes to the game-based learning field as it goes beyond revealing only trends of shared variation among epistemic emotions and motivational constructs. We managed to reveal distinct sub-groups of both frequent and rare co-occurrences among flow experience, situational interest, perceived satisfaction, and epistemic emotions. In general, it seems that flow may best represent the other used engagement measures, as learners who reported flow also reported high intensity of satisfaction (≈ 94%), excitement (≈ 76%), surprise (≈ 61%), curiosity (≈ 60%), and situational interest (≈ 48%), and rarely high-intensity boredom (≈ 3%). Therefore, it is understandable that flow has been one of the most used engagement measures in game-based learning [25].

All in all, the co-occurrence network analyses provided support for the proposed Game-Based Learning Engagement model (see Fig. 1) by showing that motivational and emotional states co-occur during game-based learning. Although we did not directly measure cognitive engagement, the measured epistemic emotions may represent cognitive dimensions of the model since they deal with cognitive information processing. Furthermore, the study demonstrated that epistemic emotions, flow experience, perceived satisfaction, and situational interest reveal different qualities of game-based learning, and thus it is useful to leverage all of them or combinations of them when measuring engagement in game-based learning. While the results implied that flow experience best represented the other used engagement measures (situational interest, perceived satisfaction, and epistemic emotions), it does not reveal the whole picture of learners' engagement. Therefore, we recommend that measuring situational interest may be necessary to better grasp learners' engagement in learning about the topic of the game, in addition to their epistemic emotions to better grasp emotional engagement.

Our study has several implications for the game-based learning field. First, our findings highlighted that high-intensity flow experience, situational interest, and perceived satisfaction often accompany positive epistemic emotions. This finding underlines the challenge of designing educational games from a holistic perspective. That is, educational games should foster a productive synergy among learners' cognition, motivation, and emotions rather than aiming to trigger them independently from each other during gameplay. Second, the current study showed that high-intensity flow is not necessarily accompanied with high-intensity situational interest in game-based learning. Our findings suggest that the game's mechanics, challenges, and design features may be sufficient for fostering flow regardless of the content domain presented in the game. This finding underlines that learners might still enjoy playing a specific game even though they are not necessarily interested in the domain knowledge included in the game. Thus, educational games can engage learners in subject domains that might only interest some learners. Moreover, educators could use games to spark learners' curiosity and interest in the topic, fostering the development of individual interest [30]. However, further research is necessary to support these arguments.

4.3 Limitations and Future Directions

There are some limitations in our study, and thus the findings should be interpreted carefully. It is probable that the retrospective questionnaire used did not grasp all epistemic emotions that students experienced when they played the game. However, it is important to note that collecting the subjective experiences of emotions after game-based learning has some unique advantages. Learners can reflect on their emotional experiences during game-based learning, and thus their emotional experience may become clearer after the game has ended, providing a more holistic evaluation of the entire game-based learning experience. Future research should aim to administer an emotion scale both before, during, and after game-based learning to collect a more holistic evaluation of the emotional states with games. 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., excitement 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 [37].

Another limitation is that we did not measure cognitive engagement, and thus, we could not exhaustively examine all dimensions of engagement and their relations. Moreover, the study was relatively short, and thus it was not reasonable to measure learning outcomes. In future studies, the relationship between epistemic emotions, motivation, and learning outcomes should be investigated to better understand the role of motivation and emotions in game-based learning. Finally, as we used only retrospective measurement and one specific game, and the playing time of the study was short, the generalization of the results should be exercised with caution. Previous research has shown that players' age, role of competition and social interaction, playing time, and topic of the game can influence emotional engagement [40]. Thus, future research should aim to generalize these preliminary results in different kinds of game-based learning environments and research settings. Furthermore, more research is needed to create robust methods to capture the highly dynamic, fluctuating, and context-dependent nature of engagement in game-based learning environments.

It is also worth noting that the co-occurrence network analysis utilized in this study might carry a significant limitation in terms of the dichotomous coding of variables. There is no ground truth for deciding the threshold for high- and low-intensity experience for the variables captured in this study. Different studies might apply different threshold limits. Thus, our findings might not be generalizable to samples with different characteristics. Finally, our findings might not be generalizable to other game contexts. The theme of the health literacy game utilized in this study is related to one of the most widespread epidemics worldwide. Thus, the emotions captured after the game-playing session might not relate solely to the participants' gameplay. The reported emotions might unconsciously reflect learners' experiences and memories from the pandemic time.

5. Conclusions

The current study is not a trivial step in the game-based learning research field as it demonstrated the usefulness of using co-occurrence network analysis in engagement research. It clarified the relationships between epistemic emotions and motivational constructs in game-based learning. Our results showed that motivational and emotional states co-occur in game-based learning, supporting the proposed game-based learning engagement model. The findings implied that high-intensity flow experience, situational interest, and perceived satisfaction mostly co-occurred with high-intensity positive epistemic emotions. Moreover, the results revealed that the gameplay can engage learners even though the topic of the game does not interest them. This highlights the importance of integrating the essential learning content with appropriate and engaging game mechanics. Such intrinsic integration is one of the crucial aspects of game-based learning design, as it aims to ensure that learners process the essential learning content while playing the game. The study also demonstrated that epistemic emotions, flow experience, perceived satisfaction, and situational interest reveal different qualities of game-based learning. Consequently, researchers and game designers should measure at least flow experience, situational interest, and epistemic emotions to understand different dimensions of engagement in game-based learning. The relevance of this finding is obvious, given the complexity of game-based learning environments. However, the results should be carefully interpreted as only one game was used in the study, learners played the game only for 25 minutes, and engagement was measured after the playing session. Overall, the results strengthen previous research by showing that game-based learning is engaging and emotionally charged.

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Conflicts of interest

The authors declare no conflicts of interest.

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Appendix 1

Correlations between flow experience, situational interest, perceived satisfaction, and epistemic emotions

	1	2	3	4	5	6	7	8	9	10	11
1 Flow experience	1										
2 Situational interest	.59**	1									
3 Perceived satisfaction	.76**	.58**	1								
4 Surprise	.59**	.52**	.54**	1							
5 Curiosity	.60**	.71**	.70**	.61**	1						
6 Excitement	.57**	.60**	.69**	.56**	.69**	1					
7 Confusion	-.01	-.06	.07	.27**	.15	.15	1				
8 Anxiety	.09	.00	.06	.20*	.13	.17	.14	1			
9 Frustration	-.06	-.24**	-.08	.02	-.08	.01	.31**	.50**	1		
10 Boredom	-.61**	-.55**	-.67**	-.44**	-.57**	-.58**	-.02	-.01	.20*	1	
11 Game-playing frequency	-.20*	-.01	-.10	-.09	-.04	.03	.06	.06	.02	.00	1

Note. * p < .05, ** p < .001