Investigating Student Interest and Engagement in Game-Based Learning Environments

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Abstract. As a cognitive and affective state, interest promotes engagement, facilitates self-regulated learning, and is positively associated with learning outcomes. Research has shown that interest interacts with prior knowledge, but few studies have investigated these issues in the context of adaptive game-based learning environments. Using three subscales from the User Engagement Scale, we examine data from middle school students (N=77) who interacted with Crystal Island in their regular science class to explore the relationship between interest, knowledge, and learning. We found that interest is significantly related to performance (both knowledge assessment and game completion), suggesting that students with high interest are likely to perform better academically, but also be more engaged in the in-game objectives. These findings have implications both for designers who seek to identify students with lower interest and for those who hope to create adaptive supports.

Keywords: Interest, science learning, learning technology

1 Introduction

Interest is a construct with both cognitive and affective components [1] that has been repeatedly found to influence learning [2]. It is known to affect student attention and self-regulation [3], and it has been found to motivate student engagement with science content and practices [4].

However, more careful attention to the types of interest is needed, as these may be critical for fosternig equitable learning outcomes [5]. For example, Hidi & Renninger [4] describe a four-phase model of interest development that distinguishes between triggered situational interest, maintained situational interest (sustained over time), emerging individual interest, and well-developed individual interest (which endures regardless of context). Students who have not developed individual interest likely need more extrinsic rewards and stimulation to trigger situational interest [6]. Thus, understanding how interest emerges—and how it relates to student learning behaviors within an online system—could lead to improved learning designs and more effective adaptive systems.

This paper investigates students' situational interest and engagement in a game-based learning environment for middle school science. We combine survey measures of these constructs with student knowledge assessments and interaction logs to explore potential relationships, showing how interest is related to knowledge and engagement.

1.1 Related Literature

Interest and curiosity are both constructs that facilitate learning [7]. Both have factors related to cognition, affect, and the desire to close a knowledge gap [6]. Though not universally recognized as separate constructs (see [7]), interest measures tend to address content-related factors. Similarly, curiosity may reflect an immediate knowledge deficit (aligning with situational interest) as opposed to a long-term propensity to re-engage with the topic at hand (individual interest). Hidi & Reninger's four-phase model of interest development [7] describes two phases of situational interest and two phases of individual interest. As learners progress from Phase 1 to 4, they become increasingly motivated to re-engage with the topic without needing external support.

In science learning, interest is associated with intrinsically motivated engagement [4], and behavioral engagement with science in non-academic contexts [8]. Interested students are also more likely to engage in self-regulated learning, showing increased attention and better goal-setting abilities [3].

Dimensions of Interest. Studies grounded in different theoretical frameworks operationalize interest in different ways, leading to measures that do not always align. In general, however, researchers tend to agree that interest is driven both by cognitive and affective processes [1]. That is, even in the early stages of situational interest, students experience curiosity, or the desire to close an information gap. While this experience may sometimes be frustrating, by the time students have achieved a well-developed individual interest (i.e., [4]'s fourth phase), we might expect students to regulate their emotions well enough to maintain a flow-like state. Not surprisingly, this development coincides with increased knowledge. Zhang et al.'s study [9] of middle school science found prior knowledge slows the decline in interest and facilitates the growth of interest in more knowledgeable students. Additionally, prior knowledge interacts with interest predicting the level of conceptual change [10]. In other words, core components of individual interest are increasing curiosity (the desire to close knowledge gaps) and sustained affective engagement. Subject knowledge accumulates as students grow from situational interest into a more sustained form of interest. Yet, prior knowledge likely drives the kinds of questions a student is capable of asking and therefore is a necessary ingredient (and not just a biproduct) in the later stages of interest.

Interest in game-based learning. Previous work has sought to make connections between the research on interest and the research on student engagement [11]. In particular, researchers have considered how game-like elements trigger students' situational interest [12]. Such investigations can lead to adapting learning technologies to promote and sustain student science interest [13], which can be accomplished by personalizing questions [14] and feedback [15].

1.2 Current Study

This study investigates interest using data from an inquiry-based learning game for middle school microbiology, Crystal Island [11]. The analyses use three scales of the User Engagement Survey [16] to operationalize the cognitive and affective engagement aspects of student interest. Specifically, we examine the relationship between these scales and student performance measures (both external knowledge assessments and game completion). The findings are relevant for the design of learning technologies that can adapt to student interest.

2 Methods

Research was conducted using Crystal Island, a game-based learning environment for middle school microbiology that supplements classroom instruction by combining inquiry-based learning and direct instruction. The first-person, single-player game places students in a research camp on a remote island where a mysterious infectious disease has caused widespread illness [11]. Students play the role of a medical detective tasked with identifying the disease and its transmission source. Students must navigate the island, gather information, form hypotheses, conduct tests, and synthesize their findings to solve the mystery. As they do, they interact with non-player characters and virtual objects, including posters, research articles, and books that impart knowledge about microbiology and specific information about the mysterious disease.

2.1 Data Collection

Gameplay took place in a middle school science class in the southeastern US, as previously reported in [17], who sought to detect and prevent dialogue breakdown with an non-player characher. Interaction data was collected as 92 students used the game over three days or until they completed the game. An identical pretest and posttest on microbiology were given at the start and end of the study. To account for prior knowledge we computed normalized learning gain using the method described in [18]. Students with incomplete surveys were excluded, resulting in 77 students analyzed.

2.2 Survey Measures of Interest & Engagement

Three survey scales (collected immediately after students use the program) were used as a proxy for the related constructs of interest and engagement. These were drawn from the original version of the User Engagement Scale (UES; [19]) and a revised version (UESz, re-validated specifically in a video-game environment; [16]). We focus on the three scales (Table 1). The Novelty (NO) scale measures students' interest and curiosity in the game, while the others measure students' engagement. In fact, Focused Attention (FAz) is strongly correlated with the Flow State Scale [20], modeled after Csikszentmihalyi's original conception of flow [16]. There is a one-item overlap between the FAz and the Felt Involvement (FI) scale, which had initially been characterized as capturing the enjoyment and interest of the gameplay experience. In summary, NO appears to capture a basic measure of situational interest, FAz captures flow-like engagement, and FI might be described as the enjoyment at the intersection of those two constructs.

Table 1. UES and UESz Subscales used to operationalize student interest and engagement

Scale Name/Construct	Items
Novelty (NO): used to operationalize situational interest/curiosity	I continued to play the game out of curiosity. The content of the game incited my curiosity. I felt interested in the game.
Felt Involvement (FI): used as secondary measure of flow/engagement	I was really drawn into the game.* I felt involved in the game. The gaming experience was fun.
Focused Attention (FAz): used to operationalize flow/ engagement	I lost myself in this gaming experience. I was so involved in the game that I lost track of time. I blocked out things around me when I was playing the game. When I was playing the game, I lost track of the world around me. The time I spent playing the game just slipped away. I was absorbed in the game. During the gaming experience I let myself go. I was really drawn into the game.*

3 Results

We first examine the Spearman correlations between interest survey scales and external knowledge assessments (pretest, posttest and normalized learning gain) and then use t-tests to compare these scales to game completion. Table 2 shows 10 significant positive correlations among the knowledge assessments and the survey scales. Specifically, pretest is associated with all three survey scales, and posttest is associated with NO and FI. Learning gain was not significantly correlated with any of the survey scales and is only related to the posttest (but not the pretest).

We next considered a knowledge measure internal to the game, namely completing the game by solving the mystery. Game completion provides a holistic measure of students' in-game achievement while also demonstrating the extent to which their behavioral engagement aligned with the goals of the learning task. To solve the mystery, students must both acquire relevant science knowledge while also engaging in a series of experiments and scientific reasoning processes to derive a conclusion. As the measure was binary, Welch two sample t-test was conducted to examine any difference between each of the interest measures. Cohen's *d* was used to test the effect size [21]. Results show that students who solved the mystery (N=42) reported higher values for all three interest scales (FAz: $t(74.72) = -2.47$, $p = .016$, $d = -0.55$; NO: $t(74.68) = -2.21$, $p = .030$, $d = -0.50$; and FI: $t(75.00) = -2.59$, $p = .012$, $d = -0.58$).

Table 2. Correlations between Knowledge Assessments and Survey Measures

Variable	*Mean*	*SD*	1	2	3	4	5
1. PreTest	6.55	2.74					
2. PostTest	6.79	3.12	.73**				
3. Learning Gain	0.03	0.37	.005	.64**			
4. Focused Attention (FAz)	24.35	7.36	.26*	.16	-.03		
5. Novelty (NO)	10.34	3.01	.23*	.23*	.11	.77**	
6. Felt Involvement (FI)	10.51	3.05	.28*	.29**	.12	.83**	.89**

Note. SD = standard deviation; * = $p < .05$; ** = $p < .01$.

4 Discussion and Conclusions

Understanding the relationship between interest and behavior can help developers create additional game features to promote situational interest and tackle cognitive and behavioral disengagement. Our results suggest that future development of learning games should consider measuring interest explicitly and comparing that to real-time student patterns and feedback so that adaptive technologies can match game challenge to interest, scaffolding the latter.

Specifically, we find that interest and engagement measures are positively correlated with a student's science content knowledge. This result is in accordance with prior work showing a symbiotic relationship between interest and content knowledge. In this study, students with higher knowledge of microbiology showed higher interest in the game. While correlation cannot imply causality, this finding contributes to ongoing debates surrounding knowledge and interest's reciprocal development. Likwise, students with high interest were more likely to solve the mystery and thus complete the game. Game completion speaks both to student knowledge and also to their broader engagement, since post-test measures show improvement even among students who did not complete the game. This finding implies that those with higher interest, in addition to learning more, were more motivated/engaged to complete the objectives of the game.

Future work should consider ways in which surveys of constructs like interest align with student behaviors in other adaptive learning systems. For example, this study used retrospective UES scales to measure student interest and engagement, but measures designed to capture situational interest *in situ* or to capture interest more broadly (e.g., IMI, [22]) might produce different results. Future work should also explore new ways to connect to students' existing prior knowledge and interests. That is, this study asked specifically about the interest students have in the game they were presented with (in line with a substantial body of literature on interest and engagement), but did not ask about students' interests outside the game, a method supported by a growing body of research on the relationship between interest and prior knowledge.

As we continue to develop AI-based learning technologies, we should consider ways to adapt and respond to student assets (e.g., engagement or interest), rather than deficits (such as disengagement). Responding directly to student interest and prior knowledge appears to be a critical step in that process.

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