Is Student Frustration in Learning Games More Associated with Game Mechanics or Conceptual Understanding?

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Abstract: Digital games have evolved as an engaging medium for learning. This paper studies the interaction between game design and student affective experience. Data from 137 students playing a learning game was analyzed to identify the factors correlating with student frustration. Results suggest that in this well-designed game, difficulty associated with conceptual understanding is more predictive of student frustration than difficulty with the game mechanics.

Introduction

In the past couple of decades, researchers from various fields like math, science, reading, language arts, health, and physics have looked into using digital games as vehicles for learning (Ke, 2009). The cognitive-affective state of frustration plays a significant role both in the experience of students and their learning (Iepsen, Bercht, & Reategui, 2013). It is relatively poorly understood what elements in the design of games or specific levels in those games are associated with the emergence of this affective state. In this paper, we focus on examining the relationship between two keys elements of a game level - conceptual understanding and game mechanics -- and student frustration. Thus, the main research question of this paper is whether difficulty with game mechanics or conceptual understanding is more strongly associated with student frustration, in a puzzle-based learning game.

Method

Physics Playground (PP; Shute & Ventura, 2013) is a two-dimensional game which has been developed to help secondary school students understand conceptual physics. The primary physics concepts in PP include Newton's laws of motion, energy, and torque. The player creates simple machines (i.e., ramp, springboard, pendulum, and lever) to guide a green ball to hit a red balloon (goal) by using a mouse and drawing directly on the screen. The player analyzes the givens (what he/she sees on the screen) and sketches a solution by drawing new objects on the screen (see Figure 1). Each level (total of 74) in PP has been scored on two types of difficulty: Game Mechanics (GM), and Physics Understanding difficulty (PU). In simple terms, game mechanics difficulty relates to the aspects of the level that makes it harder to solve whereas physics understanding difficulty corresponds to complexity of the content-related aspects of the game.

We used rubrics developed by the PP research team (including learning science researchers, instructional designers, game developers, and physics experts) to score the game mechanics (GM) and physics understanding (PU) difficulties of each level. The GM rubric included the following aspects of the level - position of the ball (over or below the balloon), the number of obstacles between the ball and the balloon, whether a hint was given within the name of the level, whether the player needs to synchronize actions in order to solve the level, and the number of sub goals needed to solve the level. For the PU rubric, the physicists identified the primary and secondary physics concepts for each level. The rubric considers the conceptual order of the primary concept of the level (force and motion = 0, momentum and energy = 1, torque = 2), the need to either balance the forces (i.e., equilibrium or Newton's third law = +1) or conservation of energy (i.e., energy can transfer or conservation of momentum = +1), and checks if primary and secondary concepts are the subtopics of same parent topic (e.g., Newton's first and second law) or of a different parent topic (e.g., Newton's first law of motion and energy can transfer)=1. Each level has been scored by two raters, and conflicts between the raters were then resolved through dialogues. The raw GM and PU scores are rescaled to 1-5.

Participants of the study consisted of 137 8th and 9th grades students (57 male, 80 female) enrolled in a public school in the southeastern U.S. They played PP in their 55-minute class period in a computer-enabled classroom over two days. Observers used the Baker Rodrigo Ocumpaugh Monitoring Protocol (BROMP 2.0) (Ocumpaugh et al., 2015) to label students' affective states while they played the PP game. Frustration was observed 11.3% of the time in this environment.

Result

Among the 74 levels in PP, tutorial levels and levels with less than 15 labeled students were filtered out to focus on levels with an adequate number of data points. In the 27 levels that remained, the mean GM and PU values are 2.10 (SD = 0.62) and 2.88 (SD = 0.99). For each level, the percentage of students who were labeled as frustrated at least once was calculated resulting in an average of 15.02% (SD = 6.56%) across the final levels.

Regression analysis was conducted to estimate the relationship between student frustration and the GM and PU individually (see Table 1). An ordinary least squares model was used for all regression analysis. The results show that PU is a significant predictor of frustration ($p < 0.05$, Cohen's $d = 0.96$). However, GM is not a significant predictor of frustration. Among the game levels included in this analysis, PU only takes values of 2 and 4. The Cohen's *d* indicates a large effect size between these two groups.

To further understand the effects of PU, the levels were analyzed based on the primary physics concept involved to solve the level. The top three concepts were energy can transfer (EcT), Newton's 1st Law (N 1st L) and properties of torque (PoT). We see that EcT as a primary concept is the most predictive of student frustration ($p < 0.01$, $d = 1.48$; see Table 2).

Table 1: Results of regression analysis on GM and PU (individual models)

Predictors	**B**	***t***	***p***	**R^2**	**Cohen's *d***
GM	0.59	0.28	0.776	0.003	-
PU	5.68	2.39	0.025^*	0.185	0.96

$^*p < 0.05$

Table 2: Results of regression analysis on the primary concepts (individual models)

Predictors	**B**	***t***	***p***	**R^2**	**Cohen's *d***
EcT	7.52	3.46	0.002^*	0.32	1.48
N 1st L	-4.66	-1.78	0.087	0.11	-
PoT	-3.38	-1.02	0.317	0.04	-

$^*p < 0.01$

Discussion

This study examined the association between student frustration and two key elements of a learning game. Our results suggest that frustration is significantly correlated with the conceptual understanding of the physics content, but not to the mechanics of the game itself. This indicates that a student is less likely to get frustrated when he/she has a conceptual understanding of the solution even when implementing it within the game itself is harder. Further, we also observed that frustration is closely related to a specific physics concept, "energy can transfer", a concept that is more complex and also involves relatively more difficult machines. It is important to understand the causes and triggers of frustration in order to design interventions that can meaningfully improve student engagement and learning. This study is a first step towards identifying how student frustration relates to the characteristics of this specific game. Further research is warranted to see if our findings generalize to other student demographics, learning game settings, and domains of study, and to understand causal relationships between elements of game design and student emotions.

References

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