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An Investigation of Frustration Among Students Using Physics Playground

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Abstract. This paper investigates the phenomenon of frustration when taken alone and when part of other affective sequences. The study attempted to determine the incidence of frustration and sequences involving frustration and their relationship with student achievement. 60 high school students from a university in the Philippines were asked to use Physics Playground for 120 minutes. Human observers recorded student cognitive affective states following BROMP while the game itself logged student activity. Frustration was found to have the second highest incidence from among the other affective states. Frustration, as well as sequences involving frustration, was found to be negatively correlated to student achievement occurring more than chance.

Keywords: intelligent tutoring systems · affect sequences · frustration affect· Physics Playground

1 Introduction

Frustration is defined as the feeling of being stuck. Within learning contexts, frustration may be regarded as a non-optimal experience because it can lead some learners to a sense of resignation (Lee, Rodrigo, Baker, Sugay, and Coronel, 2011). In other contexts, however, frustration may be considered important to learning because motivation and/or perseverance through failure helps the learner overcome greater challenges and succeed (Kapoor, Burleson, and Picard, 2007). Experiencing repeated frustration can increase students' tolerance for failure and set-backs, and prepare them for higher education, or lifelong learning in general (Kai et al., n.d.).

Existing researches in affective studies and learning recognize the importance of predicting and responding to frustration (Burleson and Picard, 2004), (Graesser and Olde, 2003) and (McQuiggan, Lee, and Lester, 2001), but, individual differences have to be taken into consideration as some learners disengage when frustrated while others become more energized (D'Mello, 2012). These variations make frustration difficult to generalize as either positive or negative.

The goal of this study is to investigate frustration among students using Physics Playground (PP) by focusing on its incidence and the incidence of affect sequences punctuated by frustration and its relationship with in-game achievement.

2 Research Questions

This study aims to address the following questions:

1. What is the incidence of frustration as compared to other affective states in students using Physics Playground?
2. What are the most common affective sequences involving frustration and their relationships to the students' in-game achievement?

3 Learning Environment: Physics Playground (PP)

Physics Playground (formerly Newton's Playground) was used for this experiment/field study. PP is a two-dimensional computer-based game that was designed to help secondary school students understand qualitative physics. Figure 1 shows sample screenshots of two levels in PP that require the student to guide the green ball to the red balloon.

Data from 60 students was collected on January 2015 in two schools in the northern region of the Philippines.

The goals of the study were to assess the persistence and affect of students using an educational game for Physics, and to determine any differences among the different regional groups. The subsections that follow describe the methods and materials used to these ends.

There are eight different playgrounds for the game's different levels where the student achieves his goal by drawing ramps, pendulums, levers or springboards or by nudging and/or clicking the ball. The drawings behave according to the laws of Physics.

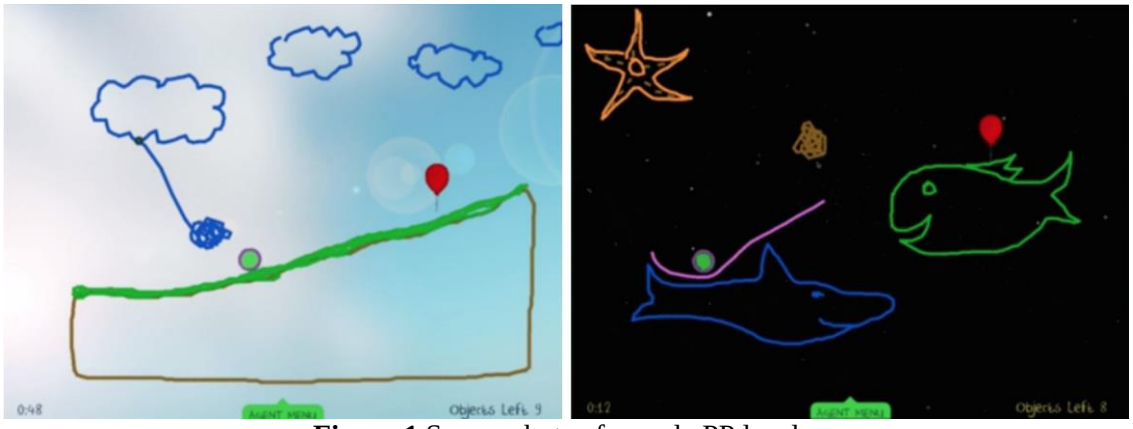

Figure.1. Screen shots of sample PP levels.

PP's log files tracks the students interaction with the software along with the students achievements while using the software.

4 Methods

4.1 Participants

The study took place in one high school in Baguio City, Philippines, under the supervision of the co-authors.

We enlisted participation from two high school classes, with a total of sixty (60) grade 8 students with ages ranging from 13 to 18. The average age is 15.68. Thirty (30) students were female and thirty-two (32) were male.

These students, in the pre-survey form, said that they watched TV more frequently than they play video games. As to academic performance, these students were average students.

4.2 Structure of the Study

The experiment/field study was comprised of an orientation and pre-test, a 120-minute session of actual PP usage in the computer laboratory, and a post-test. The students were instructed to follow the directions as they encounter in the software. The students can skip puzzles (playgrounds) that they are unable or do not want to solve.

4.3 Measures

The different data collected during the experiment were comprised of: students' profile or demographics sheet, written pre-test and post test data, system logs, and human observations.

Both pre-tests and post-tests were taken for 15 minutes and both had 16 multiple-choice questions/problems on Physics as the subject area.

The system automatically logs the student's start time, end time, levels finished, number of revisits and restarts, total time per level, and the gold, silver and no badges count and time.

For this study, the features of interest were the count of the gold badges, silver badges and no badges to depict student success or achievement in using PP.

4.4 The Baker-Rodrigo-Ocumpaugh Monitoring Protocol (BROMP)

The researchers used the Baker-Rodrigo-Ocumpaugh Monitoring Protocol (BROMP) in coding both affect and behavior of the students as they used PP. It is a protocol for quantitative field observations of student affect and engagement-related behavior (Ocumpaugh, Baker, and Rodrigo, 2012).

While there may be many affect annotation schemes, BROMP was used for this study as it allows the real-time annotation of affect for a large number of students without using the self-report method (Shute et al., n.d.). A number of affect researches investigating students while using PP has used the BROMP (Andres et al., 2014), (Andres and Rodrigo, 2014), and (Andres and Rodrigo, 2013).

The affective states of interest observed were engaged concentration, confusion, frustration, boredom, happiness, surprise, excited, and delighted. The descriptions of these affective states are:

1. Engaged Concentration is the affective state of interest resulting to total immersion to the learning task (Ocumpaugh et.al, 2012). It is manifested through actions like leaning closer to the computer, and miming solutions to the problems or learning tasks.
2. Confusion is the affective state that mirrors lack of understanding of the material and the uncertainty of not knowing what to do next (Ocumpaugh et al, 2012) and (Csikszentmihalyi, 1991). It is manifested in actions like scratching the head, viewing the same game objects and/or levels repeatedly and saying the statements "Why is this not working?" or "I don't understand." (Andres et al., n.d.).
3. Frustration is the affective state that expresses annoyance and dissatisfaction. It is manifested in actions like keyboard thumping and pulling at his hair and saying the statement "This is annoying!" or some equivalent remark (Ocumpaugh et al, 2012).
4. Boredom is the affective state that is associated with the lack of interest and motivation to perform the learning task. It is characterized by weariness and restlessness (Ocumpaugh et al, 2012) and saying the statements "This is boring!", and "Can we do something else?" (Andres et al., n.d.).
5. Happiness is the affective state that demonstrates contentment or other expressions of well-being, less intense than delight (Ocumpaugh et al., 2012).
6. Surprise is the affective state that is characterized by actions of bewilderment from unexpected results and is usually manifested by gasping.
7. Excitement is a positive affective state characterized by great enthusiasm and eagerness.
8. Delighted is the affective state that mirrors a high degree of satisfaction and amusement (Ocumpaugh et al, 2012). It is usually manifested in clapping of hands, laughing and saying "Yes!" or "I got it".

Participants were divided equally among the two BROMP-certified observers present in the entire session. The observers were able to code at least one observation for each student per minute in 5 to 8 second intervals. In cases were the student exhibited two or more distinct states during his or her respective observation period, the observers only coded the first state.

The observers recorded their observations using the Human Affect Recording Tool (HART), an Android application developed to guide researchers in conducting quantitative field observations for both affect and behavior according to BROMP. HART also allows the synchronization of BROMP data with educational software log data (Ocumpaugh et al, 2010).

4.5 Student achievement in PP

In PP's environment, a student is able to earn badges, i.e. gold and silver for every puzzle solved. The system automatically logs these badges along with the count of failed attempts which it labels as no badges.

Gold badges are earned by the student each time a level is solved efficiently or by drawing less than a certain number of objects (usually < 3) and silver badges are earned if they solve the level by drawing three or more objects (Shute, Ventura and Kim, 2013). The minimum, maximum and mean values (with standard deviation) are presented in table 1.

Table 1.Student achievement features

Feature	Minimum	**Maximum**	**Mean**	**Standard Deviation**
Gold badges	0	22	6.37	4.10
Silver badges	6	47	20.23	8.69
No badges	1	571	105.78	109.26

Student performance in terms of solving the puzzles in the different levels show that the students had more unsolved puzzles than solved puzzles and that the efficiently solved puzzles were fewer than those that were solved using any solution to a puzzle (or by drawing more than the desired number of objects).

5 Data Pre-processing

After the synchronization of the BROMP observation data from HART and the PP system logs, data normalization was achieved by computing percentages of affect (individual, 3-step sequences and 5-step sequences) occurrences per student and badges per student.

There were three affect data sets used in this study. The first data set consisted of single affect observations. The second set consisted of sequences of three consecutive affect observations (3-step affect sequences). The third data set consisted of sequences of five consecutive affect observations (5-step affect sequences).

The number of occurrences for each type of affect (single, 3-step sequence, and 5-step sequence) were counted and the percentages were computed.

6 Over-all Incidence of Affective States

The incidence of the affective states and affect sequences of interest were computed as the total count of observations per affective state (and per affect sequence) divided by the total number of observations per student. The average of the percentages is reported as the incidence as presented in Table 2. On average there were 117 observations per student, with a standard deviation of 37.

Table 2 shows that engaged concentration (78.79%) was the most commonly observed cognitive-affective state. This is consistent with the findings of Andres and Rodrigo (2014), Shute, Ventura and Kim (2013), and Rodrigo and Baker (2011).

The second most frequently observed state was frustration (7.89%). This is surprising as there were no observations at all of frustration in (Rodrigo and Baker, 2011).

Confusion (6.13%) was the third most commonly observed state. This does not follow the findings in (Rodrigo et al. 2007) and (Andres and Rodrigo, n.d.) where the incidence of confusion was higher than the incidence of frustration.

Students exhibited boredom and happiness, 3.88% and 3.09% of the time respectively. Surprised (0.18%) and excited (0.03%) were relatively rare and delight was not observed at all.

Table 2. Incidence of cognitive-affective states of students while using PP

Affective State	Percentage
Engaged Concentration	78.79
Frustration	7.89
Confusion	6.13
Boredom	3.88
Happiness	3.09
Surprise	0.18
Excited	0.03
Delighted	0.00

As with the previous studies of Andres and Rodrigo (2014) and Andres et al. (n.d.), frustration, confusion and boredom were the three more commonly observed affective states, excluding engaged concentration. In (Andres et al., n.d.) boredom was conflated with frustration observations.

7 Affect and their relationships with Student Achievement

7.1 Single Affect and Student Achievement Relationships

The incidence of each affective state per student was correlated to each of the count of badges, i.e. gold and silver, including the count for no badges.

After performing bivariate correlations only the following relationships involving frustration have been found to occur more than chance: Frustration and Gold Badges ($r = -0.312$, $p = 0.016$), Frustration and Silver Badges ($r = -0.376$, $p = 0.003$), Frustration and No Badges ($r = 0.394$, $p = 0.002$).

The analysis shows that Frustration and Achievement are negatively correlated, i.e. the higher the level of frustration of the student, the lower his/her achievement is.

7.2 3-step Affect Sequences and Student Achievement Relationships

Three (3) affect observations occurring in sequence comprise a 3-step affect sequence. We counted the number of times that a student exhibited each of the 3-step affect sequences and then computed for the incidence of each sequence per student.

Table 3. Incidence of 3-step cognitive-affective sequences and correlation results that occur more than chance

Affective Sequence	Percentage	Correlation Results (more than chance)			
		Silver Badges		No Badges	
		r	p	r	p
NNF	2.32	-0.298	0.023	0.308	0.019
FNN	2.19	-0.281	0.033	0.293	0.026
NFN	2.13	-0.274	0.037	0.278	0.035

The ten (10) most common 3-step affect sequences were correlated with the badges, i.e. gold, silver and no badges.

Table 3 presents the relationships occurring more than chance (95% confidence level) and sequences involving frustration.

From Table 3, it can be noted that, as with single affect and achievement correlation results (cf. Section 7.1), 3-step sequences punctuated with single frustration occurrences were negatively correlated with achievement.

The negative consequence of frustration still holds with affect sequences or three affect observations punctuated with one frustration observation.

7.3 5-step Affect Sequences and Student Achievement Relationships

The most common 5-step affect sequences were correlated to the badges, i.e. gold, silver and no badges and resulted to only one statistically significant relationship involving frustration, i.e. Not Frustrated - Not Frustrated - Not Frustrated - Not Frustrated - Frustrated(NNNNF) Sequence AND No Badges ($p = 0.256$, $r = 0.048$) with an incidence of 1.18%.

The 5-step affect sequence and achievement relationship that has been found to occur more than chance revealed that even in a longer sequence of non-frustration, punctuated with a single frustration affect, a student still has low achievement, i.e. the more NNNNF sequences occur, the more failed attempts the student had.

As with three-step affect sequences, the negative consequence of frustration is still observed with aggregates of observations involving 5 affective states punctuated with a single frustration affect.

8 Summary of Contributions and Future Work

Frustration, second only to engaged concentration, was observed to have high overall incidence among the affective states observed in this study. Also, frustration was the only affective state that has a more than chance relationship to student achievement.

From the analysis of the overall incidence of frustration as well as the bivariate correlations performed between 3-step and 5-step affect sequences and student achievement while using PP, we found that frustration and any sequence involving frustration has a negative relationship with student achievement using PP.

This contrasts sharply with the findings about confusion. Resolved confusion has been found to have a positive relationship with student achievement (Lee et al., 2011). This was not the case with frustration.

Although frustration was relatively infrequent, frustration was definitely negative in the context studied here.

This study contributes in several ways:

1. In the introduction, we mentioned that literature cites both positive and negative aspects to frustration. We wanted to investigate whether this was true in the context of PP. We found that, in this context, frustration is only negative.
2. In the development of learning systems, more and more consideration is given to creating systems that are personalized and adaptive. These findings give designers some understanding of what the student maybe experiencing at an affective level when confronted with failure. These insights may help designers design adaptations and interventions to either remediate any knowledge gaps, redirect the student to learning-oriented activities, or provide meta-affective scaffolding to help the student cope with these negative feelings.

We flag that our source data is drawn from a non-Western student group. Hence, any conclusions might not generalize to a larger, more diverse population. Indeed, the group of Valerie Shute reported incidences of enjoyment (Shute et al., 2013) that we did not observe in our own study group.

That said, these findings also provide a different experience of PP, one that may vary dramatically from previous experiences in other contexts.

The data therefore provides insight that may benefit the design of systems, adaptations, and interventions for a variety cultural contexts.

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