Ogata, H. et al. (Eds.) (2015). Proceedings of the 23rd International Conference on Computers in Education. China: Asia-Pacific Society for Computers in Education

An investigation of eureka and the affective states surrounding eureka moments

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Abstract: This paper continues prior work conducted on the analysis of moments of student learning in Physics Playground, a learning environment for qualitative physics. The study analyzed data from 60 tenth-grade students who used Physics Playground for 90 minutes. We detected spikes of student learning, or "eureka" moments, while solving physics problem. We then related these moments of insight to affective states labeled according to the BROMP protocol. Our hypothesis was that students would be confused before eureka moments, and experience delight afterwards. Contrary to this hypothesis, we found that eureka moments and the periods surrounding them were associated with a decrease in all affective states. No significant differences were found in comparing the affective profiles of students who experienced eureka and those who did not.

Keywords: Affect incidence, moment of learning, eureka, Physics Playground, open-ended learning environment

1. Introduction

"Eureka" is the name given to the insight experience. It is a moment within learning in which a learner suddenly grasps what he or she is trying to learn (Lindstrom and Gulz, 2008). When engaged in a difficult learning task, a learner might reach an impasse followed by an "aha!" moment in which the answer becomes clear (Graesser and D'Mello, 2012). Although much prior work identified eureka as an affective state in itself (Anderson, 2011), we attempt to deconstruct the eureka phenomenon into components by examining the affective states that flank as well as overlap with eureka moments.

Our research questions are:

1) What affective states occur before, during, and after eureka periods?
2) How do the incidences of these states compare with the baseline incidences of affect?

Our working hypothesis is that eureka moments should occur as described in Graesser and D'Mello (2012), i.e., students should experience confusion followed by delight, and that proportions of confusion and delight should be higher than baseline around eureka moments.

2. Methodology

Physics Playground (PP; formerly Newton's Playground) is a computer game for physics that was designed to help secondary school students understand qualitative physics (Shute, Ventura, and Kim, 2013). Using simple machines such as levers and ramps, students must guide a green ball to a red balloon. Each level is assigned a par value corresponding to the minimum number of objects needed in order to execute the level's optimal solution. If players are able to solve the level under or equal to the par value, they receive a gold badge. PP is described in detail in Shute, Ventura, and Kim (2013).

The study collected data from 62 tenth grade students across two schools from Baguio City, Philippines. For the entire sample, student age ranged from 13 to 18 years old, with an average age of 15.7 years old. 52% of the participants were male, and 48% were female.

The Baker-Rodrigo-Ocumpaugh Monitoring Protocol (BROMP) was utilized in the observation of manifested affective states. It is a protocol designed for quantitative field observations of

student affect and engagement-related behavior, described in detail in (Ocumpaugh, Baker, and Rodrigo, 2012). The affective states observed within this study were limited to engaged concentration, confusion, frustration, boredom, happiness, and delight.

3. Results

Of the 62 participants, data from 2 students were lost due to faulty data capture and corrupted log files. Only 60 students had complete observations and logs. Of these students, only an average of 29 students exhibited eureka throughout the observation period. The analyses that follow are limited to these students.

Attempts preceding gold-badge attempts were flagged as eureka moments for analysis. In order to account for the affect surrounding eureka, attempts before, during, and after eureka moments were tagged as $Gold_{-2}$, $Gold_{-1}$, and Gold, respectively. The $Gold_{-2}$ label refers to the period before eureka, demonstrated in the unsuccessful attempt to attain a gold badge, which thereby leads to the incidence of eureka, labeled as $Gold_{-1}$. The Gold label consequently refers to the attempt after the moment of eureka has occurred, characterized by the earning of a gold badge. In such cases that a student earns a gold badge on their first attempt, no eureka is recorded for that attempt.

Using timestamps from both the PP logs and HART affect logs, we tallied the affective states the students exhibited during each level attempt. There were a total of 193 eureka moments among the 60 participants. Only observed affective states during these attempts and the attempts directly preceding and following them were used to calculate for incidence of affect during, before, and after eureka moments, respectively.

We also divided the total 90-minute observation period into three 30-minute periods because exploratory analyses of the dataset showed that the baseline incidences of affective states change over time. Baseline incidences of affect were calculated per 30- minute time slice, using the incidences surrounding only the eureka moments that occurred in each period in question. Each period's respective comparison can be found in Table 1.

Table 1: Baseline incidence of affect, and incidence of affect before, during, and after eureka moments of students flagged for eureka during the 1st, 2nd and 3rd period. All values are percentages.

	First Period				Second Period				Third Period			
Affective State	B	G_{-2}	G_{-1}	G	B	G_{-2}	G_{-1}	G	B	G_{-2}	G_{-1}	G
Bored	5	5	5	5	20	17	20	13	8	11	8	12
Concentrating	95	98	95	98	90	96	90	91	96	93	96	92
Confused	39	39	39	38	35	35	35	26	19	22	19	24
Delight	17	17	17	15	10	4	10	9	4	4	4	4
Frustrated	24	22	24	20	30	39	30	39	15	11	15	12
Happy	27	27	27	25	10	9	10	13	8	7	8	8

Within only the population of students who had experienced eureka, affect surrounding each incidence varies only marginally in comparison to the baseline values. The portion examining the first period illustrates that the affective states of delight, and happiness are observed 2% less, and frustration, 4% less than each of their corresponding baselines after eureka moments within this time period. Frustration has also been observed to be 2% less than the baseline before the incidence of eureka. The incidence of boredom has been found to be at its lowest within this time period. Table 1 shows that boredom is exhibited most by the participants in the second period of observation; Whereas, both the baseline incidence and incidence around eureka of concentration, and happiness greatly decline.

Found in the third period, the durations before and after an incidence of eureka, affective states of boredom, and confusion have been observed to manifest higher in the population than the established baseline value. Boredom is increased by 3% and 4%, before and after occurrences of eureka, while confusion is increased by 3% and 5%, respectively. Frustration, on the other hand, exhibits a decreased occurrence of 4% and 3% from its baseline in periods before and after eureka. This third period of

observation exhibits the highest incidence for concentration, and the least incidences for the affective states: confusion, delight, frustration and happiness, across all time periods.

This work raises questions about the nature of eureka moments and their interplay with affect. The observed patterns of affect around eureka moments were not in accord with our hypotheses or what is generally described in the literature (Graesser and D'Mello, 2012). It is possible that our identification of eureka moments from the interaction logs or that our read of student affect is imperfect. Understanding why students do not appear to exhibit, at least to our trained coders, the affective states theory says they should, is the first question this work prompts.

There are several other ways in which this work can be continued. Getting more precise data about when a eureka moment occurs would be very helpful. Furthermore, this paper first identified eureka moments in the activity logs and then examined the affective states surrounding these moments. It would be interesting to examine the data from the other directions—to search for affective patterns that are assumed to characterize eureka moments and then see whether indeed a eureka moment occurs in the activity logs.

Acknowledgements

We thank Jessica Sugay, Thelma Palaoag, Pen Dela Cruz, Michelle Banawan, Yancy Paredes, the officials at University of the Cordilleras Laboratory High School and Bakakeng National High School, Drs. Jaclyn Ocumpaugh and Luc Paquette of Teachers College, Columbia University, and Drs. Valerie Shute, Matthew Ventura, and Matthew Small of Florida State University. This study was made possible through a grant from the Philippines' Department of Science and Technology Philippine Council for Industry, Energy and Emerging Technology Research and Development entitled "Stealth assessment of student conscientiousness, cognitive-affective states, and learning using an educational game for Physics.

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