Using eye tracking to measure the development of undergraduate students' chemistry problem-solving abilities and perceptions of self-regulation in a blended learning environment

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ABSTRACT

Eye tracking has been used as a tool to gain deeper insights into student cognition while engaged in science and mathematics learning and problem solving. Eye-tracking data show learning attention, cognitive load and cognitive processing. Measurement of eye movements provides insight into the cognitive strategies that students use for solving multiple-choice science problems. Several studies show that analyzing students' gaze and fixation informs an understanding of where students focus their attention while solving problems. An initial study was conducted to objectively measure chemistry students' problem-solving abilities while engaged in a blended learning environment.

STATEMENT OF THE PROBLEM

Chemistry educators have attempted to increase students' engagement and focus in chemistry for years. However, researchers have not discussed the aspects within blended learning classrooms that increase students' focus. The discourse is often about using these pedagogical strategies to improve students' performance in chemistry classrooms. Therefore, the question not yet examined with objective measurement resources is, *how do blended instructional strategies improve chemistry performance?* Unobtrusive measures of students' engagement and attentional focus in blended learning environments with online learning opportunities has not been thoroughly explored as a method to improve online learning and engagement, even though universities spend billions of dollars for online or e-learning experiences. Few universities use objective eye-tracking data to improve blended learning environments or online learning management systems, learners' online experiences, and engagement with difficult to grasp subject matter or concepts.

BACKGROUND

Eye tracking is a measurement of real-time eye movement used to study visual attention. Eye tracking tools are efficient in displaying the spatial and temporal features of eye movements and also provide information about eye fixations – how often a gaze is maintained on a certain location – and the rapid movements between these fixations. This is done with the use of heat maps, aggregations of gaze points and fixations. Data are organized in the order of the users' gaze with the amount of time they spent looking at a specific point (Barlinn, Kozak, Kunka, Kosikowski, 2016). In educational research, eye tracking is used to detect student perception and interpretation of certain topics.

Self-regulation is the control that students have over their own learning (Zimmerman 2000). This includes their abilities to plan ahead and set goals, stay on task and persevere through challenges. Behavior and emotions both play a role in students' self-regulation, meaning that when students feel positively about the work and can relate the material to their personal lives, they are more likely to better allocate their time and will self-reflect (Zimmerman 2000). Learning is most successful when students play an active role in their own learning.

RESEARCH QUESTION

What is the impact of blended instruction on students' chemistry problem-solving skills and perceptions of self-regulation skills?

HYPOTHESIS

Students in the experimental group (those within the hybrid blended classrooms inclusive of an online learning environment) will have increased fixation duration in appropriate areas of interest, increased engagement in chemistry classes, perform better on chemistry exams and have increased critical thinking, problem solving, and self-regulatory skills than students in traditional lecture based courses. The null hypothesis is that blended learning classrooms that incorporate online problem solving activities will have no effect on students.

METHODOLOGY

Eye-tracking data were collected from undergraduate students in a chemistry course at two historically black colleges. Fixation and gaze data were collected while students completed nomenclature word problems in an online environment. Students were asked to respond to two surveys. The first survey assessed their perceptions of self-regulation. The second survey assessed students' perceptions of their problem-solving approach, confidence and control.

Figure 1. Tobii pro eye-tracking glasses

Figure 2: Tobii Recording Unit

Classroom Environment	Average visits count	Average visit duration	Average fixation count	Average fixation duration
Blended learning Pre-test	4.25	13.82	947.00	18.94
Blended learning Post-test	38.13	8.37	1413.50	28.26
Traditional learning Pre-test	4.60	11.11	840.00	16.80
Traditional learning Post-test	36.78	11.44	609.17	12.80

Table 1. 2016 Cohort Average test scores by condition and time

	Traditional Lecture (control)	Blended Lecture (experimental)
Average post-test scores (percent correct)	43.3	72.2
Average pre-test scores (percent correct)	22.3	33

Table 2. 2016 Cohort Pre-post scores on chemistry nomenclature word problems

Figure 3. Eyetracking Participant

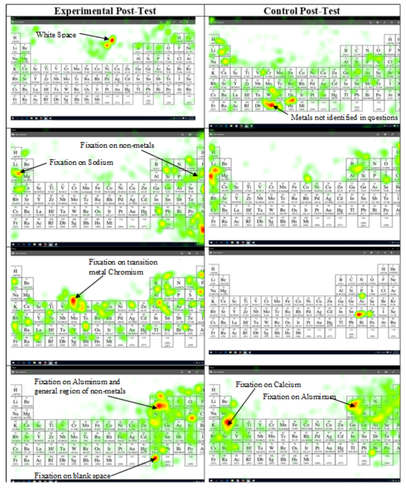

Figure 4. 2016 Cohort Generated heat map Experimental and Control groups

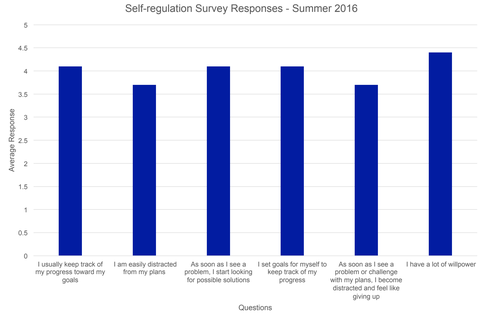

Figure 5. 2016 Cohort Self-regulation responses

RESULTS

Data presented were collected from nine students in a General Chemistry course where two conditions were measured: time and group type. Mixed ANOVA using SPSS analysis was conducted. Results show that on average, students spent slightly longer fixated on the periodic table (targeted as the area of interest) during the post-test (M = 19.81, $S.D.$ = 17.96) than in the pre-test (M = 9.34, $S.D.$ = 10.63).

There was a significant interaction between time and condition. The experimental group (blended learning) spent longer looking at the periodic table online during the post-test (M = 28.26, $S.D.$ = 21.88) than during the pre-test (M = 0.02, $S.D.$ = 0.00).

Students in the experimental cohort were more confident in their abilities to set goals and keep track of them. They were least confident in their ability to stay on task and overcome challenges. However, responses also show that students felt assured about their problem solving and critical thinking skills.

DISCUSSION

Performance on the nomenclature test revealed that the experimental group scored higher on the post-test than the control group, reflecting fixation behaviors recorded on the eye-tracking system. Students' responses revealed moderate levels of self-regulation. Self-regulation responses suggest that students are determined to achieve their goals but are often dispelled by distractions and have a hard time persevering through challenges.

Self-regulation scores did not vary by condition or by time. From the data, the experimental group scored somewhat higher than the control group, but this difference was slight. The same is true of the pre and post scores. The pre-survey scores were slightly, but not significantly higher than the post-survey scores. Overall, both groups perceive that they are prone to distractions. However, students in the experimental group appear able to override the tendency to become distracted exhibiting higher performance on the word problem quiz. The blended learning environment is able to serve as a moderator for students prone to distractions.

FUTURE WORK

These research findings have implications for chemistry education and software development to improve chemistry education. Findings from this study can be used to enhance online chemistry courses and learning management modules. The implications are that data can be used to improve online chemistry learning through infusing prompts and interactive media (video and voice) that will facilitate increased student engagement. This data can also be utilized to develop sustainable learning platforms that improve educational and psychological development.

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