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Gamification of Chemical Engineering Pathways: Evidence from Introductory Courses

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Abstract

Despite significant interest in the use of gamification in the engineering classroom, only a few studies have rigorously evaluated how gamification elements impact students' outcomes in engineering coursework. We report initial results from a longitudinal design based research (DBR) study of gamification in courses along the pathway to Chemical Engineering majors. We observe a small benefit to end of term performance among students in the treatment group who had access to the dashboard. However, we did not observe significant differences by initial motivational beliefs, engineering identity scales, demographics, or students' estimates on the amount of time spent preparing for class. We identify next steps for analysis, design, and implementation of gamification in large introductory engineering pathway courses.

Introduction

The retention of students pursuing chemical engineering degrees is essential to the future science, technology, engineering, and mathematics (STEM) workforce, but failure in introductory chemistry coursework is a barrier to degree persistence and completion. Despite the positive research on impact of gamification on engagement and academic achievement, only a small number of gamification studies focus on large enrollment STEM courses like those taken by chemical engineers early in their major program, and few incorporate robust measures to rigorously and systematically assess students' behavioral, cognitive, and affective changes. The goal of this study is to establish effective strategies for the application of gamification in courses that appear early in the chemical engineering curriculum, supporting the retention of students in the major and the graduation of chemical engineers. This was achieved through the development of a chemistry and chemical engineering focused dashboard that is integrated within an online learning management system that includes gamification tools (i.e., leaderboard, badges, and rewards).

We report the results of a design-based research study of the dashboard in the introductory chemistry sequence for chemical engineers at a large research university. Students were provided access to the dashboard as part of the learning management system. The dashboard was designed to align to course content. As part of ABET accreditation, chemical engineering majors complete a progress assessment in their second year before progressing in the major. The badges provided to students in the system were based on concepts from the course that would appear on a progress

assessment, and provide students an indication of their proficiency on the topic based on their performance in the course. Students were also provided a visualization of tasks to complete within each week, a 'health' monitor that provides them their average score on recent assignments by type (homework, exam, lab quizzes), and interactive rewards that surprised students based on their performance and engagement.

Methods

This study uses a student-facing dashboard visualization to engage students in the course and encourage reflection on their study strategies (see Figure 1).

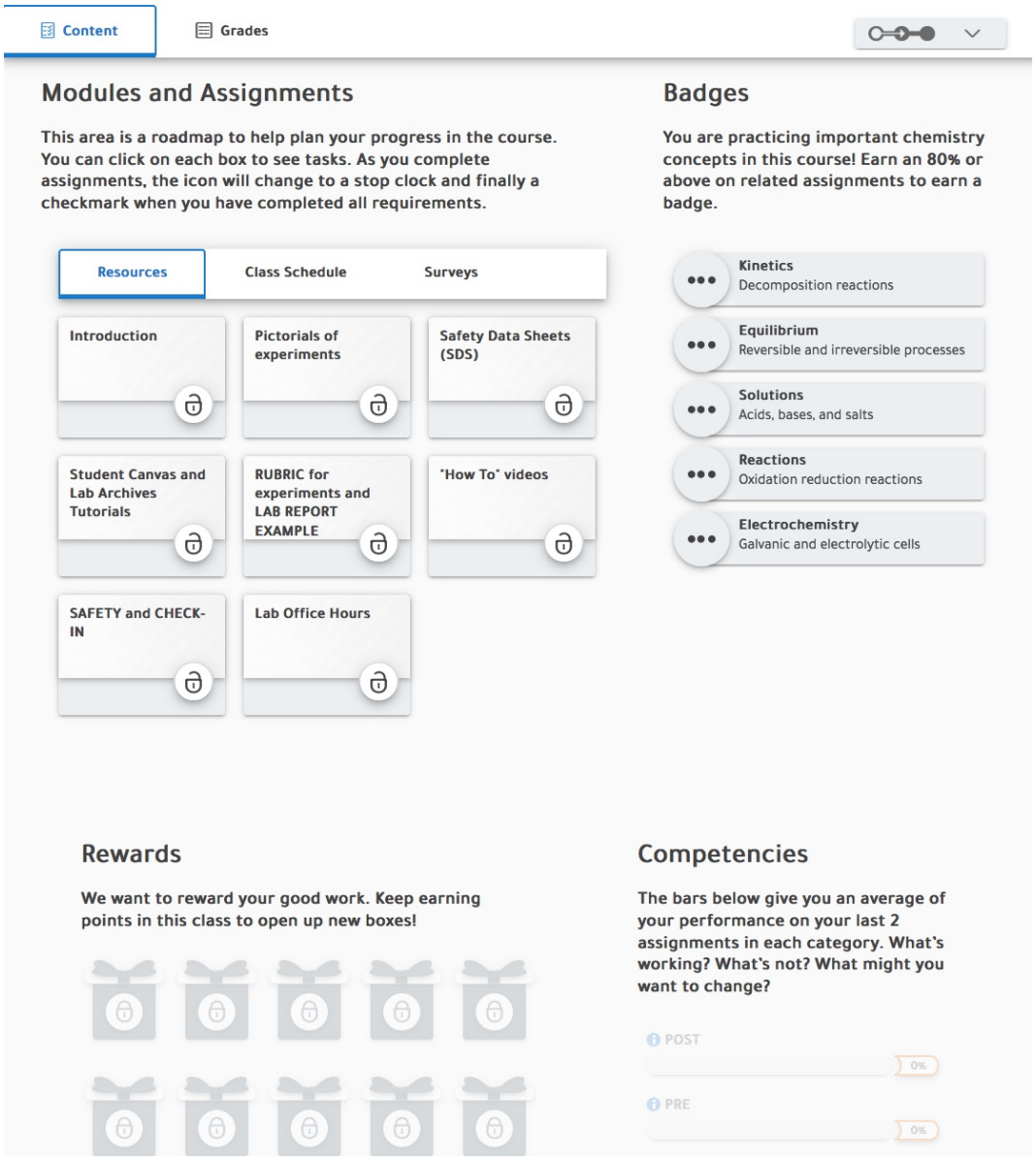

Figure 1: Example of the Delphinium Chemistry Dashboard developed for the study

The dashboard includes a visualization of course tasks and the percent completed for each task (Modules and Assignments), summary visualizations of students' performance in key knowledge domains (Badges), fun visualizations that unlock based on students engagement (Rewards), and a summary of average performance on different types of assessments (Competencies).

Our project involves complementary methods of quantitative evaluation and qualitative description of how the dashboard use impacted chemical engineering students' motivation and performance in introductory chemistry coursework. For this analysis, we report initial results of the quantitative evaluation of Fall 2020 lab courses, examining students' overall use of the dashboard. We conduct a multi-variate linear regression model to predict students' academic performance given their use of the student facing dashboard (n=548/578). We control for

- Initial measures of expectancy value based on Perez's adaptation of Eccles' expectancy value scale for goal oriented behavior[1]
- Godwin's engineering identity scale[2]
- Student level demographics
- Self reported time spent preparing for class
- Total views of the learning management system

We use the Global Validations of Linear Assumptions test to determine if our model met the requirements of linear regression.

Results

Our initial findings suggest that students benefit from using the dashboard as part of their engagement with course resources, such that as students' engagement with the dashboard (as measured in accumulated page views) increases, their end of term grade increases (B=5.8 points on final grade out of 100, p=0.000).

Table 1. Partial results of linear model for Academic Performance

Term	Estimate	Standard Error	Lower CI	Upper CI
Intercept	98.14	6.235	86.00	110.83
Delphinium Dashboard Access	6.23	1.51	3.22	9.24
Pre-Lab Prep	0.07	0.012	−0.01	0.03
Engineering ID	−0.05	0.12	−0.30	0.21
Expectations for Success	−0.00	0.17	−0.33	0.33

Initial findings also suggest that students with access to the gamified dashboard may need to use the Learning Management System less frequently than comparable users without access. The dashboard provides a significant amount of information about preparing for the course as well as students' progress. It may be that access to the dashboard simplifies students' time management and study skill strategy development.

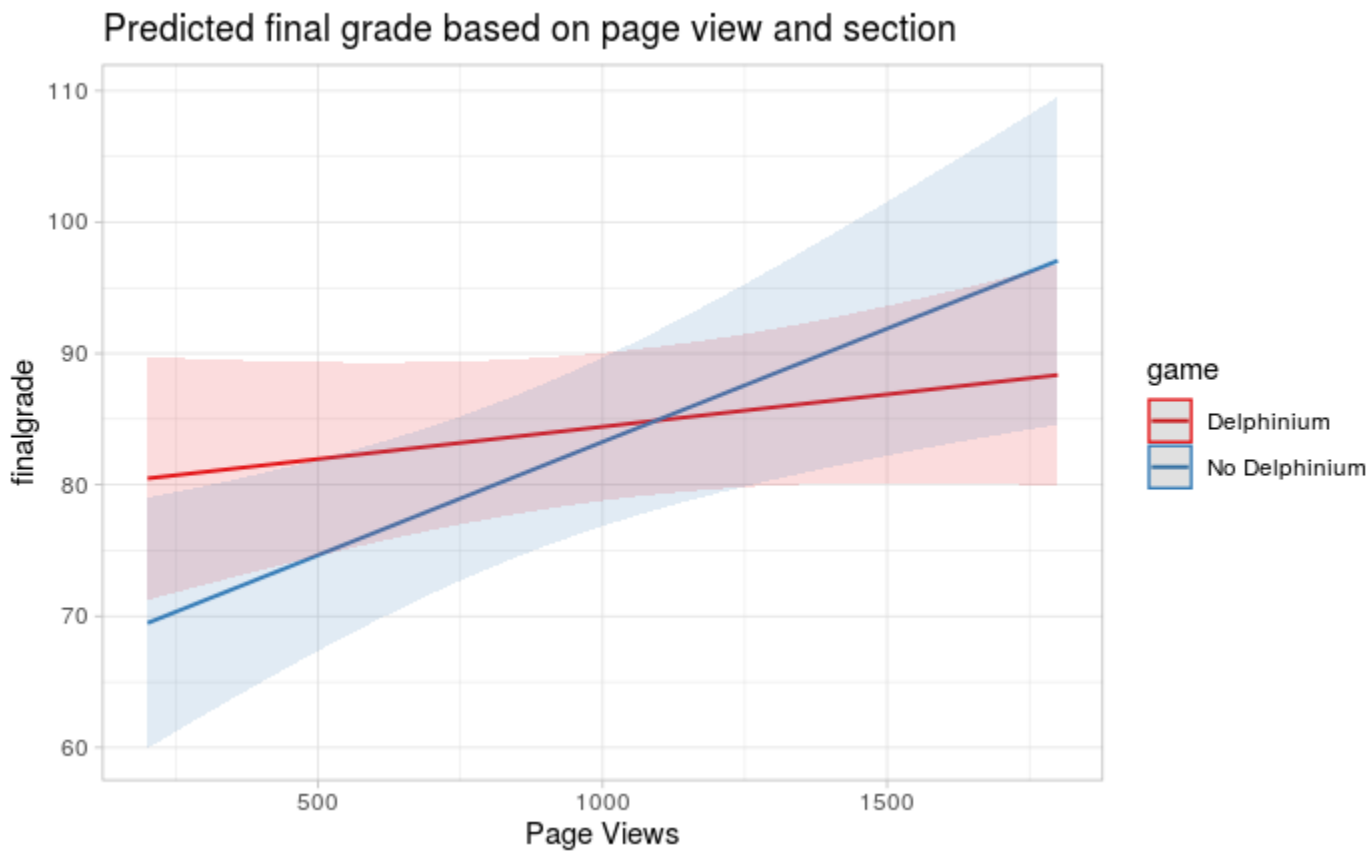

Figure 2: Final Grade by Access to the Delphinium Dashboard

Discussion and Future Directions

Our study reinforces the existing literature on gamification which suggests students benefit from tools that foster motivation and engagement. Our initial analysis identifies a significant grade bump for dashboard access- students performed nearly half a grade in terms of final performance. Many of the outcomes that we expected to be significantly related to end of courses performance- specifically students' emerging engineering identities and their expectations for success in the course- were not. As a next step, we hope to identify the potential influence on the dashboard on these socio-cognitive influences, if any.

Although students were assigned to experimental conditions, we are still left with the unresolved question of why some students adopt the dashboard and some do not. The next phase of our evaluation study involves qualitative interviews with students to unpack some of the findings we observed in our initial analysis. We observed that while students may academically benefit from the intervention- and given the low cost nature of the intervention in terms of resources and time that may be sufficient- its unclear if students who would already be successful are simply adopting the tool or if the tool changes something about students' approach to the course. Additionally, we hope to better understand the adoption process through interviews and focus groups with students (both users and non-users).

References

[1] Tony Perez, Stephanie V Wormington, Michael M Barger, Rochelle D Schwartz-Bloom, You-kyung Lee, and Lisa Linnenbrink-Garcia. Science expectancy, value, and cost profiles and their proximal and distal relations to undergraduate science, technology, engineering, and math persistence. *Science education*, 103(2):264–286, 2019.

[2] Allison Godwin. The development of a measure of engineering identity. In *ASEE Annual Conference & Exposition*, 2016.