


Investigating the impact of a gamified learning analytics dashboard: Student experiences and academic achievement

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Abstract

Background: The substantial growth in gamification research has connected gamified learning to enhanced engagement, improved performance, and greater motivation. Similar to gamification, personalized learning analytics dashboards can enhance student engagement.

Objectives: This study explores the student experiences and academic achievements using a gamified dashboard in a large, introductory STEM course.

Methods: We examined two groups of students enrolled in different sections of a one-semester-long physical geology course with a total enrollment of 223 students. The only difference between the groups was that one had access to the dashboard. The data collection included students' assignments, overall performances, and exam scores. Students in both sections completed a Science Literacy Concept Inventory survey at the beginning and end of the term. Additionally, students completed an end-of-term survey containing open-ended questions on their experience and interactions with specific elements.

Results: Students shared mostly positive comments about their experience with the dashboard, and the final grade of students with access to the dashboard was 13% higher, on average, compared to their peers in the non-dashboard section.

Conclusion: With low costs and little time invested, gamified dashboards could have a significant impact on student performance in large STEM lecture courses.

KEYWORDS

21st century abilities, games, human-computer interface, post-secondary education, teaching/learning strategies

1 | INTRODUCTION

A wide array of curricula, interventions, and programming have been introduced in undergraduate education to foster engagement and participation in science, technology, engineering, and math (STEM)

courses (Successful K-12 STEM Education, 2011). One instructional method, gamification, shows considerable promise in transforming teaching and learning in higher education (Çakıroğlu et al., 2017; Díaz-Ramírez, 2020). Gamification, or the addition of games-like experiences in learning environments, can have a powerful impact on

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academic achievement and behavioural engagement (Granic et al., 2014). The considerable growth in gamification research in the past decade has connected gamified learning to increased engagement (Morschheuser et al., 2018), improved performance (Chu & Chang, 2014), enhanced motivation (Hwang et al., 2014), and an overall more enjoyable experience (Liu et al., 2017). Building on these potential affordances for learners, a growing number of researchers have suggested gamification as a useful tool to positively impact students' learning in STEM education (Li & Tsai, 2013), including in geoscience education (Reuss & Gardulski, 2001). STEM subjects are intrinsically rich with abstract theories and complex problems, for which students might develop anxiety and experience challenges in learning (Alam & Gleason, 2022a; Cheng et al., 2014). Given the potential uses of gamification in STEM education, research that utilizes validated instruments and focus on student variables is needed (Ortiz et al., 2016).

Similar to gamification, personalized learning analytics dashboards have the potential to increase student engagement, but the focus on real-time data strongly supports student self-regulation (Aljohani et al., 2019; Brown et al., 2019). In learning analytics dashboards, students can reflect on learning and change behaviours through the visualization of progress (Park & Jo, 2019). Although gaining in popularity, these digital instructional supports may struggle with lack of use (Alam & Gleason, 2022b; Bodily et al., 2018), failure to provide meaningful feedback (Teasley, 2017), and inability to target student subgroups (Sansom et al., 2020).

By combining personalized learning in dashboards and the motivating experience of gamification, instructors may sustain student interest, resulting in increased academic achievement. In addition, understanding how and why students engage with a gamified dashboard can help target interventions for different learners. The purpose of this study is to (1) investigate the differences in academic performance between students with and without access to a gamified learning dashboard and (2) examine how and why students engage with the tool. It is hoped that findings from this study will assist future researchers in determining effective interventions for maintaining student interest, which may lead to better academic performance in the future.

2 | RELATED WORK

Researchers have explored creating full educational games for the classroom (Kangas et al., 2016) and integrating gameful design into instructional activities (Orhan Gökşün & Gürsoy, 2019). The use of specific game mechanics in non-game contexts, such as gamification, is a convenient method for tapping into gaming's motivational affordances without developing a complete game (Deterding et al., 2011). The term *gamification* is used frequently when a learning experience is, at the core, unchanged, except for the addition of individual game mechanics (Deterding et al., 2011). For example, gamification occurs when the course content and assignments remain the same, but the instructor adds badges and a leaderboard to increase motivation

(Plass et al., 2015). As the research on gamified systems has grown, there is a critical need for more scholarly research on longitudinal and individual effects on motivation and increased diversity of content areas (Nacke & Deterding, 2017; Nadolny & Gleason, 2018; Nadolny et al., 2022; van Roy & Zaman, 2018). For example, while at least 30 studies have examined gamification in higher education STEM courses, a focus on geoscience education is uncommon (Ortiz et al., 2016).

In the geosciences, research on games and gamification primarily includes studies on non-digital games or games designed for K-12 students (Chen et al., 2016; Gates & Kalczynski, 2016). For example, Reuss and Gardulski (2001) created a life-size board game for students to practice and self-assess knowledge of historical geology. The game resulted in extremely positive student motivation and learning, so much so that they chose not to include a control group in future semesters. In a different study, the researchers found the board game *Taphonomy: Dead and fossilized* (Martindale & Weiss, 2020) to be a successful and challenging addition to a high school Earth science course. Survey results suggested that students and teachers responded positively to the game, asserting that it was fun and helped them learn or improve their knowledge of fossilization. Other games included card games (Spandler, 2016) and role-playing games (Kluver et al., 2018), with generally positive results.

While non-digital game research shows overwhelmingly positive results, the research on digital gamification requires more study. The application of gamification in education can have notable results, even with small changes to the learning experience. For example, students using game-like quizzes were more motivated and engaged (Li & Tsai, 2013). Also, learning performance was significantly higher in a course with leaderboards (Ortiz-Rojas et al., 2019). de Freitas et al. (2017) reviewed three gamified learning analytics dashboards in development in the UK, Belgium, and Australia, and the review highlighted the benefits of combining the engaging elements of gamification with data analytics visualization. In one case study within a geoscience course, the use of points and leaderboards resulted in increased motivation, but the study's design limited generalizability (Hasan et al., 2017). Although many studies are associated with positive outcomes, in some cases, gamification can be a detriment to learning. A study by Hanus and Fox (2015) implemented leaderboards, badges, and competition in a communication course. The results indicated a negative impact on motivation and exam scores, potentially due to the specific combination of gamification mechanics having a negative impact on motivation.

Despite the growing literature on gamification's impact on engagement and academic achievement, few research studies apply these techniques to learning analytics dashboards. In a review of research on learning dashboards (Schwendimann et al., 2017), most studies were conceptual, and only a few were actually evaluated in real classroom settings. (Schwendimann et al., 2017) argued that real classrooms need to be measured against real student learning gains, and the authors noted a severe deficit in studies evaluating student learning gains: 'learning impact is probably the most important yet under-explored aspect of research regarding learning dashboards'. One of the limitations of the learning dashboard is that student

engagement has been difficult to quantify, for instance, by determining how much time students used the gamified elements.

There is a critical need for research that applies rigorous methodologies to determine how and when gamification is most effective for learning (Bodnar et al., 2016; Nacke & Deterding, 2017; Nadolny et al., 2021; Ortiz et al., 2016). In this study, we build upon prior work on the impacts of gamified learning dashboards. Our methodological design included validated instruments, a comparison group, data on user characteristics and science literacy, and data collection over 4 months (one semester of instruction). Combined with qualitative data to provide a rich context, this study examines the student experience and resulting academic achievement using gamified learning dashboards.

3 | MATERIALS AND METHODS

3.1 | Study design

This study is part of an ongoing project exploring gamification dashboards in high enrollment undergraduate courses using an educational design research (EDR) lens. EDR contributes to theory while solving problems in practice, including cycles of design and evaluation. In this case, we apply complementary methods in the evaluation of a maturing intervention towards developing theoretical understanding (McKenney & Reeves, 2012). In this study, we examined the use of a gamification dashboard in two sections of a one-semester geology course using complementary methods. The use of open-ended survey responses serves a complementary role in clarifying and elaborating on the results of the online user data (Bryman, 2006; Clark & Ivankova, 2016).

Within our research design, we employed a mixed-methods approach to our data collection and analysis. In mixed methods, the combination of both qualitative and quantitative data enhances the complexity and completeness of research results. We collected the multiple data points sequentially, with greater weighting applied to the quantitative data supported by the qualitative insights (Ivankova & Creswell, 2009). This explanatory design included an open-ended survey at the end of the semester to support interpretation and elaboration of results (Creswell et al., 2003). Methods for data collection and analysis for each source of data are discussed in Section 3.4.

This study was approved by the Iowa State University Institutional Research Board for human subjects approval. Each participant was assigned an anonymous study ID once survey data was matched to academic performance.

3.2 | Course description and participants

Participants included students in an introductory physical geology course offered at a research-intensive, doctoral-granting institution in the U.S. Midwest. The course met three times a week for 50-min periods over 15 weeks. Two sections of the course were offered, at 11 AM and 1 PM, and the same tenured instructor taught both.

We selected this course for our intervention as most students enrol in the course to fulfil the general education science requirement for their major, leading to a broad representation of majors in the student population. The main learning objectives for this kind of science course is for students to achieve scientific literacy and become familiar with the main processes that affect our planet from human to geologic time scales.

Since 2015, the instructor has implemented a student-centered pedagogy using a hybrid format where students complete assigned textbook readings and associated online homework graded for correctness and accessed through the course's learning management system (LMS) before coming to class. Class periods consist of reading reflections, ConcepTest problems graded for completion and correctness (McConnell et al., 2006) and brief lectures on challenging topics identified based on the homework results. The gamification dashboard was introduced to the students enrolled in the treatment section only during the first class period. The instructor did not refer to it throughout the course or further encouraged students to utilize it.

Enrollment in the morning section (#1, treatment section) was 137 students; there were 86 students in the afternoon section (#2, comparison section). Out of the course enrollment, 59 students in the treatment section and 44 in the control section completed the pretest Science Literacy Concept Inventory (SLCI) survey. Demographic information on the students was collected as part of the SLCI survey (Table 1).

We noticed some slight variations between the two sections. Students with access to the dashboard viewed the LMS more often, on average, when compared to the control group (1022 vs. 748.19). There was a larger number of science majors in the morning section (38.8% vs. 18.18%), although students in the comparison section had higher average SLCI scores (Table 1). Only the difference between LMS page views by section was statistically significant when subjected to a t-test. As in all observational research, there is potential selection bias, although we believe the

TABLE 1 Descriptive statistics for survey sample.

	Dashboard access (n = 137)	No dashboard access (n = 86)
LMS page views (average)	1011 (509.81)	748.19 (262.72)
Women	47.46%	40.91%
First generation college student	32.20%	34.09%
First year	27.12%	31.82%
Second year	52.45%	45.45%
Third year	11.86%	15.91%
Fourth year	8.47%	6.82%
SLCI pre-test (average)	56.56 (30.51)	61.90 (27.6)
Science major	38.98%	18.18%
Academic performance (out of 100 points)	78.24 (16.00)	76.12 (13.02)

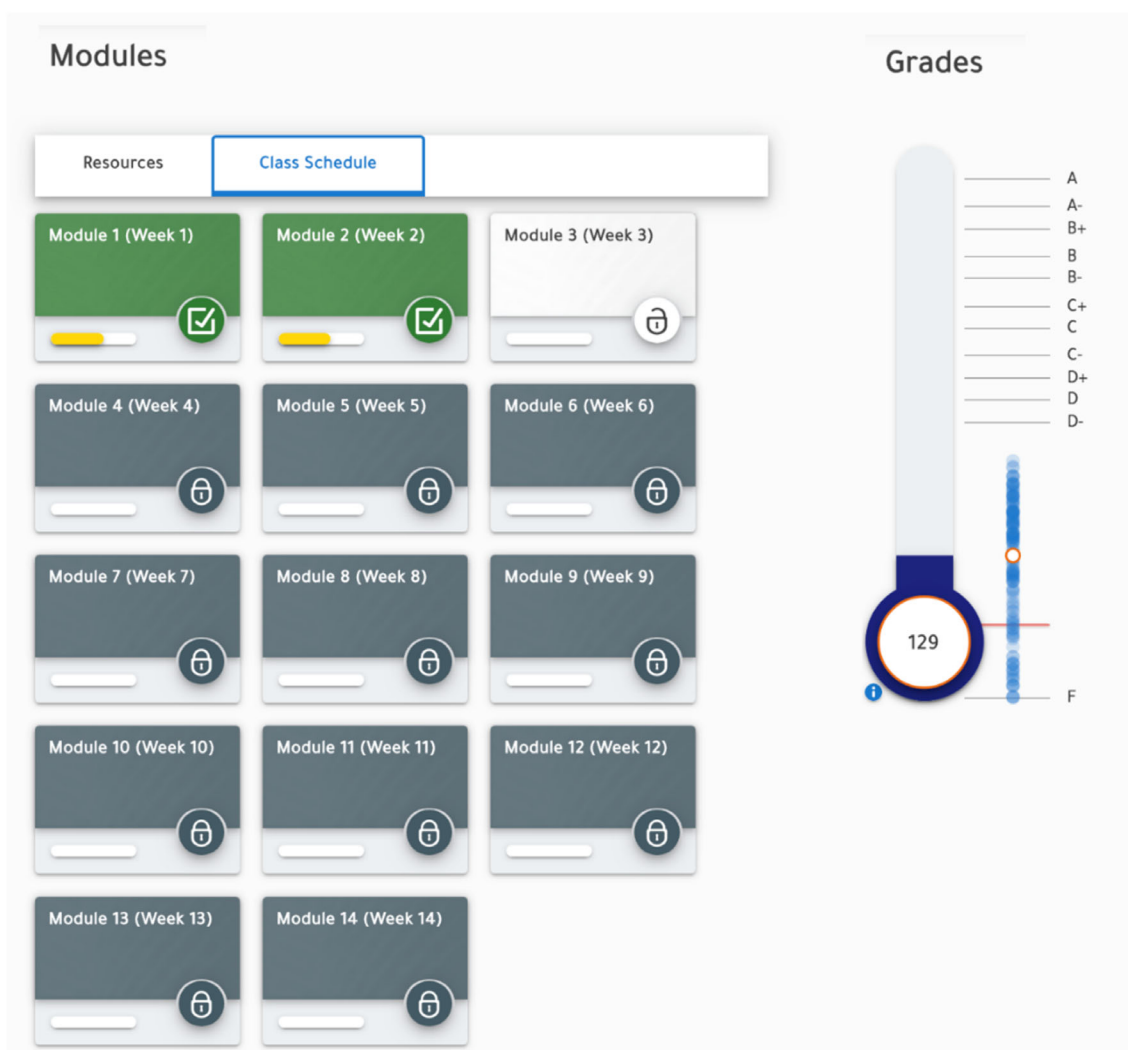


FIGURE 1 Dashboard modules map (left) and progress tracker (right).

two groups are sufficiently similar to allow for reasonable inferences (if not generalization).

3.3 | Gamified performance dashboard

Delphinium is a plugin designed for the Canvas LMS. It uses elements of gaming for improved motivation among students. This gamified system offers individual users engagement and instrumental goals to motivate them through course content organized in learning modules. This platform includes some of the most widely used components in gamification research, such as progress trackers, badges, rewards, and leaderboards (Alaswad & Nadolny, 2015; Arnab et al., 2015). For instance, badges can be earned through scoring specific points or a percentage of grades in one or multiple assignments, and rewards can be achieved by completing quizzes or obtaining certain points. The leaderboard displays the top-performing participants using pen names. All of these features can be customized. In Delphinium, the research team incorporated items that track progress through the course and

items that reward students for points earned. Each element of the dashboard is introduced below.

3.3.1 | Module map

The module map is a representation of the modules found in the LMS. Delphinium synchronized the content materials from Canvas into a visualization of weekly modules. The course design included a linear, weekly progression, and the module map was structured accordingly (Figure 1).

3.3.2 | Progress tracker

Leaderboards and other displays of points (see Figure 1, right) rank students against one another in scores or other achievements, typically anonymously to protect identities. These tools assist in students' comprehension of their relative performance with the motivating

reward of moving up the scale. However, using a competitive element based on grades can have negative results for learners (Scott, 2012), particularly if they remain at the bottom for an extended period. The thermometer-shaped visualization in this project addressed these concerns through a combination of individual metrics (i.e. earning up points) and competitive metrics (i.e. dots to represent other students' scores).

3.3.3 | Health tracker

Similar to the progress tracker, the health tracker represented overall performance, with the addition of the average score of the last 10 assignments. This feature assists students in predicting their final score and encourages them to adjust course strategies throughout the semester (Figure 2).



FIGURE 2 Dashboard health tracker showing performance in the last 10 assignments (left) and overall performance quality (right).

3.3.4 | Rewards

Rewards are extrinsic motivators that can increase participation when systematically and consistently provided to learners (Aldemir et al., 2018). Rewards support immediate feedback and a positive experience in a gamified classroom (le Maire et al., 2018). Rewards must be tightly connected to meaningful course activities, or they can have a negative effect on academic performance (Hanus & Fox, 2015). The rewards icons activate when a student meets the points threshold for that particular reward. Selecting the reward box initiates a browser animation (Figure 3).

3.3.5 | The avatar

Avatars are a popular gaming feature connected to identity development and presence in games (Chae et al., 2016; Meadows, 2008). The avatar feature in Delphinium is customizable, which positively influences learner presence and engagement (Chen et al., 2019). In the Delphinium system, students can add avatar features as they earn points in the course (Figure 4).

3.4 | Data collection

3.4.1 | User data

Participants' user data from the LMS included the number of times students accessed the dashboard and the number of pages viewed by students. The LMS also stored the scores for each assignment and each student's overall performance, including exam scores.

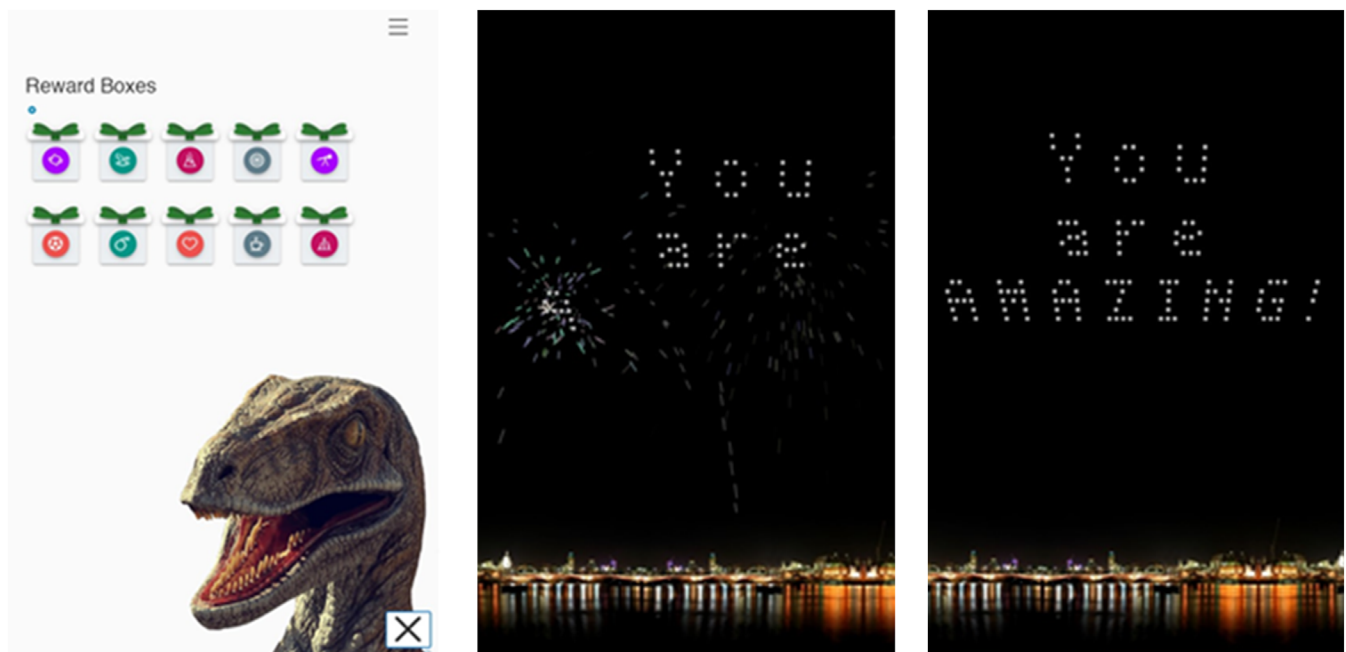


FIGURE 3 Dashboard rewards and animation.

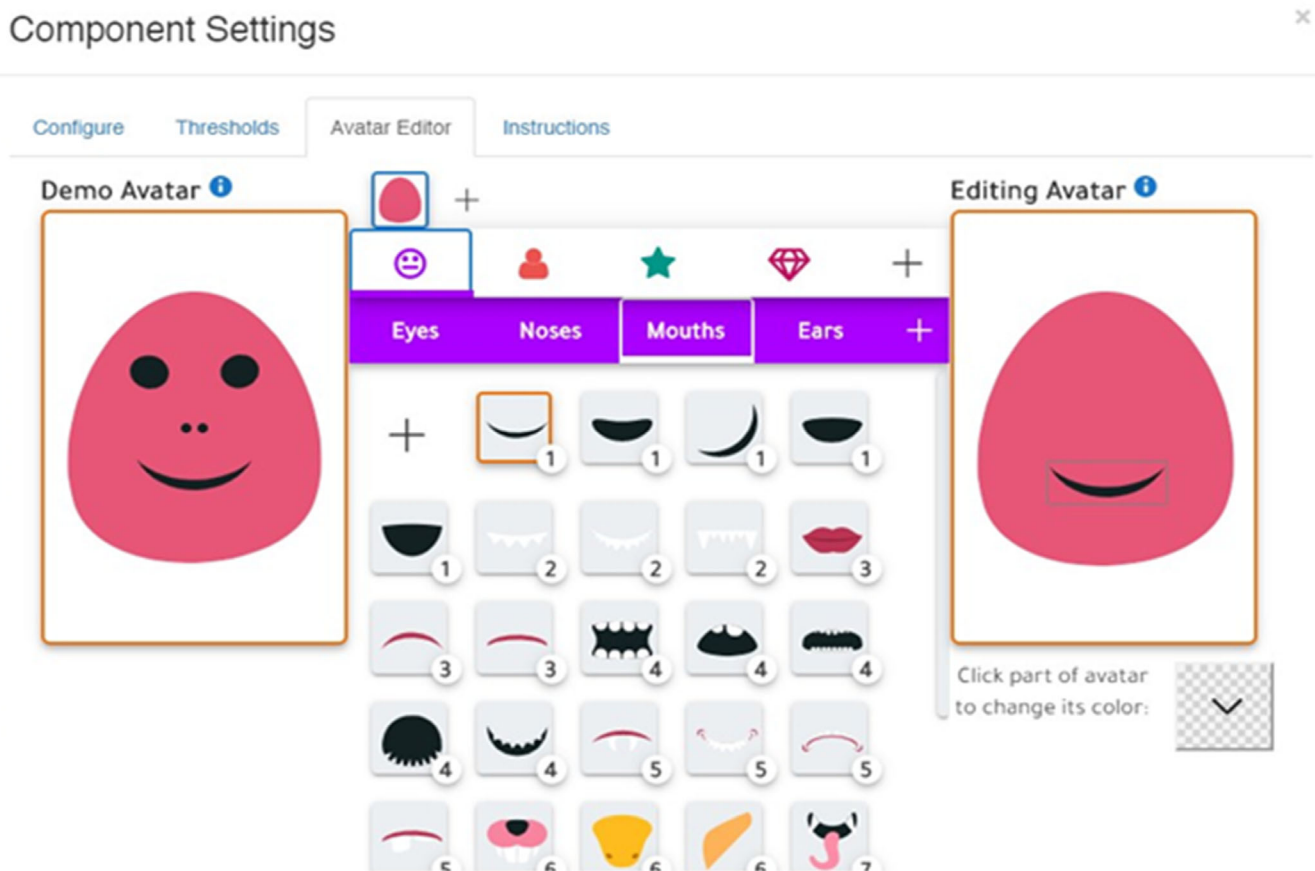


FIGURE 4 Dashboard editable avatar.

Exams included an individual and a group component following a collaborative, or pyramid-style, format (Zipp, 2007). The last author is the course instructor and has been using this exam format each fall semester since 2005. The instructor created the exams using questions pulled from an extensive test bank assembled over 20 years of teaching the course. Each exam consisted of 30 multiple-choice questions, and the exam was administered on paper and graded using scantrons. Students would spend 25 min completing the exam independently and then hand in a completed scantron before retaking the exam with one or more of their peers.

Both sections received different versions of the same exam that covered the following topics: plate tectonics, earthquakes, Earth's interior, minerals, igneous rocks and processes (exam 1–4); volcanoes, weathering and erosion, sedimentary rocks, surficial processes, streams, floods and groundwater (exam 2–4); metamorphic rocks, geologic time, rock deformation, oceanic crust and divergent boundaries, continental crust and convergent boundaries (exam 3–4); deserts, glaciers, coastal processes, climate change, mineral and energy resources (exam 4). Exams were cumulative, meaning exams included questions on all the material covered up to that time and in previous exams, but the exam did not ask the same questions. For this study, we included the score in the individual portion of the exam in our user data.

3.4.2 | Survey administration

At the beginning and end of the term, students in both sections completed a science literacy survey. Both surveys contained the Science Literacy Concept Inventory (SLCI), a 25-item concept inventory that maps onto 12 literacy principles. The SLCI was created by a cross-disciplinary team of scientists and science educators using extensive literature reviews and their combined multidisciplinary experiences (41). It touches on all three of (36) definitions of science literacy: (a) understanding of norms and methods of science (i.e. the nature of science); (b) understanding of key scientific terms and concepts; and (c) understanding of the impact of science and technology on society (Miller, 1983). The SLCI administered to the students in this course was version 7 (2019). Compared to earlier versions, it included a global predicted and postdicted self-assessment rating, and students could choose to receive an online feedback letter, including their scores and an essay on the value of self-assessment for learning. The survey was administered during the first and last 2 weeks of the semester. Since the instrument is designed to assess citizen-level science literacy, the test is not timed; students usually take about 30 min to complete it. This study utilized the pre-test scores in data analysis. Cronbach's Alpha for the SLCI was 0.88, Kuder–Richardson KR20 = 0.88, KR21 = 0.86, Spearman–Brown Prophecy = 0.90.

Additionally, students in the treatment section completed an end-of-term survey containing open-ended questions on their experiences with the dashboard (e.g. What do you think about seeing your grade and other rewards in the Delphinium tab? How did you feel about completing the learning modules in this course through the Delphinium tab?), including their perceptions, feelings, and interactions with specific elements.

3.5 | Data analysis

3.5.1 | Quantitative data analysis

To answer our research question about the potential impact of access to the dashboard on the students' end-of-course performance, we used the ordinary least squares regression method. We controlled for significant differences in the end-of-term performance between the section with access to the dashboard and the section without access. Additionally, we include a term for students' gender, whether they were the child of a college graduate, whether they majored in a STEM discipline, their academic year, whether they were a native English speaker, and their score on the SLCI instrument. We included an interaction between students' course section and the numbers of page views in the LMS as students in the gamified section had significantly higher page views than students in the comparison section ($x = 916$, $p < 0.01$). There also appears to be a nonlinearity in the relationship between final grade and page views (see Appendix A), so we include an interaction term for the relationship between Dashboard Access and total LMS page views.

Additionally, we estimate a second model for the relationship between the dashboard use and the final grade. In this case, we limited the sample to just students with access to the dashboard. We controlled for the number of page views of the dashboard instead of overall engagement with the LMS. Since all of the sample had access to the dashboard (and had used it at least once), we believed observing variation in dashboard use could provide insight into whether the frequency of use explained significant differences in outcomes. All of our models performed well on the global validation of linear model assumptions (GVLMA) tests (Pena & Slate, 2014). The GVLMA package runs assumptions checks for kurtosis, skewness, linearity, and heteroskedasticity (Pena & Slate, 2014).

3.5.2 | Qualitative data analysis

The qualitative data included responses to an open-ended survey asking students to reflect on the different components of the dashboard, including use and perceptions of the tool. We used the qualitative data analysis method to identify patterns in students' experiences with the dashboard (Miles et al., 2018). First-cycle coding was applied using both deductive coding based on the research literature and inductive coding grounded in the student responses. Second-cycle coding revealed patterns in responses displayed in both numerical and narrative formats. The open-ended survey completion rate was 84% (115) of students in

the treatment section. The third and fourth authors engaged in first and second-cycle coding together, and negotiated emergent meaning and themes as they worked. Because their work was a dialogic process, we did not calculate inter-rater reliability for the second phase of coding.

4 | RESULTS

4.1 | Academic performance

4.1.1 | Dashboard access

The vast majority of the students adopted the tool early in the semester. All students who had access to the dashboard used the system at least a few times throughout the semester. Less than 10% of users accessed the tool for the first time after the first exam, 5 weeks into the course.

Students who accessed the dashboard did so an average of 27.4 times, with a standard deviation of 27.54 views (Figure 5). A handful of users accessed the dashboard more than 100 times. Although the precise timing and distribution of how and when students accessed the dashboard varied, we anticipate that most 'users' (i.e. students who logged on more than once) did so weekly.

4.1.2 | Academic achievement

Students with access to the dashboard performed about 13 points higher out of 100, on average, when compared to their peers in the non-dashboard section ($p < 0.05$) (Table 2). Additionally, students who were the children of college graduates outperformed their peers who were first-generation college students by 4.49 points, on average. No other factors in the model explained significant differences in end-of-term performance.

Students who accessed Canvas more regularly performed better in the class, regardless of the gamified component (Figure 6). Therefore, the dashboard's benefit may not require as frequent engagement as other tools in the LMS to produce an end-of-term grade benefit, although the interaction of these terms was not significant.

4.1.3 | Factors influencing academic achievement

There does not appear to be a significant relationship between frequency of dashboard use and end-of-term academic performance (Table 3) when we look at just students who used the dashboard at least once. We observe more significant differences in end-of-term performance within our control variables among students with access to the dashboard. Children of college graduates outperformed first-generation college students. First-year students did significantly better at the end of term than sophomores and seniors, on average. These factors and their intersection with motivation merit further investigation in the context of gamified courses.

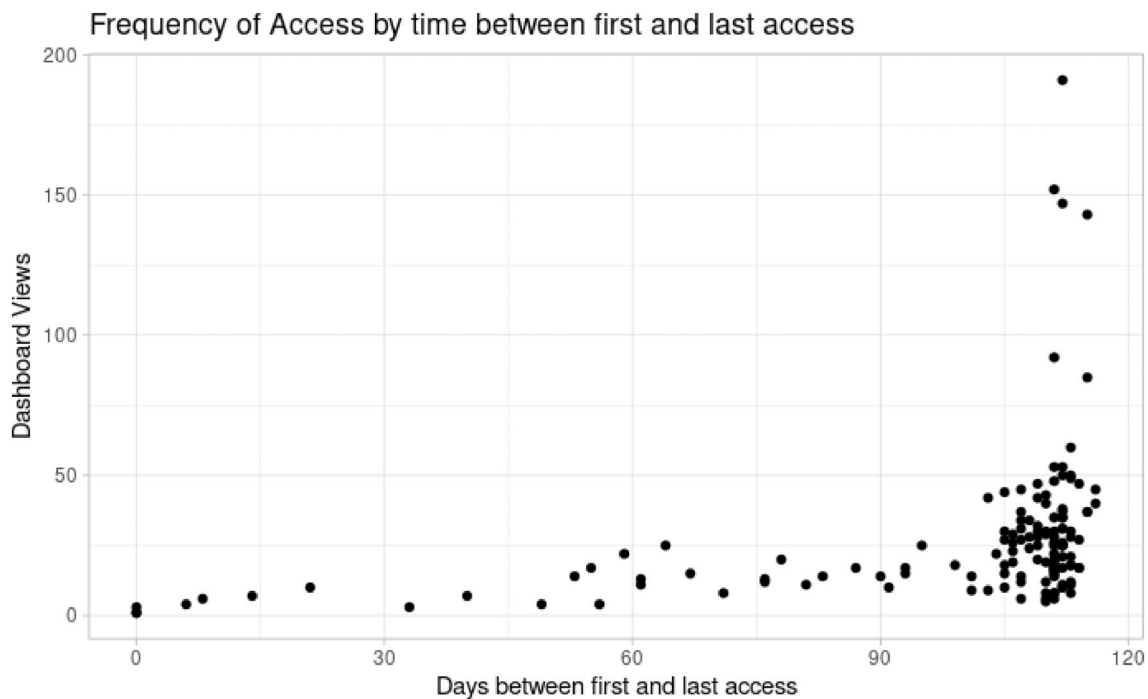


FIGURE 5 Number of students accessing the dashboard for the first time by date.

TABLE 2 Ordinary least squares regression model for end-of-term academic performance (final grade out of 100, $n = 103$).

	Estimate(standard error)	95% confidence interval
Intercept	76.9 (5.97)	[65.02, 88.76]
Men ^a	0.51 (2.11)	[−3.67, 4.7]
Children of college graduate ^b	4.49 (2.19)**	[0.14, 8.83]
Non-science major ^c	−1.827 (2.26)	[−6.32, 2.67]
Sophomore/2nd year ^d	−3.26 (2.44)	[−7.93, 1.41]
Junior/3rd year ^d	2.89 (3.21)	[−3.49, 9.27]
Senior/4th year ^d	−1.65 (4.01)	[−9.62, 6.31]
Non-native English speaker ^f	3.45 (4.64)	[−5.78, 12.67]
SLCI score	0.04 (0.04)	[−0.02, 0.11]
Non-gamified section ^g	−13.48 (6.69)**	[−26.76, −0.19]
LMS page views	0.01 (0.004)	[−0.004, 0.01]
Interaction: dashboard access X LMS page views	0.01 (0.01)	[−0.002, 0.03]

Note: Multiple R -squared: 0.2092, adjusted R -squared: 0.1232; F -statistic: 2.434 on 10 and 92 df , p -value: 0.01274. Reference category:

^aWomen.

^bFirst-generation college student.

^cScience majors.

^dFreshman/first year.

^fNative English speaker.

^gGamified section.

* $p = 0.10$;

** $p = 0.05$; *** $p = 0.01$.

4.2 | Open-ended survey results

4.2.1 | Ease of use

Students appreciated the gamified dashboard's ease of use and simple interface. They frequently mentioned accessing study guides in the learning modules through the dashboard to support test preparation. Students were motivated by upcoming exams to visit the dashboard and review concepts to 'poke around on it before every test, [and] watched a few recommended videos'. One student who did not frequently use the dashboard shared that 'the study guides on [the dashboard] helped a lot. Other than that, I didn't really use it'.

In addition to test preparation, the students appreciated the course content's presentation in one easy-to-access location and that 'it was very easy to complete the homework and learning modules through [the dashboard] because all of the assignments were in order and said the due date. I could also get them done before class much quicker'. As currently designed, learning management systems distribute functions such as grading and learning materials on different pages, and, in contrast, the gamified dashboard allows students to visit one location for multiple tasks.

4.2.2 | Organization and access

Students indicated that the organization of the dashboard helped them understand the layout of the course and their progress through course materials. Students noted that the grades presented on the modules, progress tracker, and health tracker were a helpful addition.

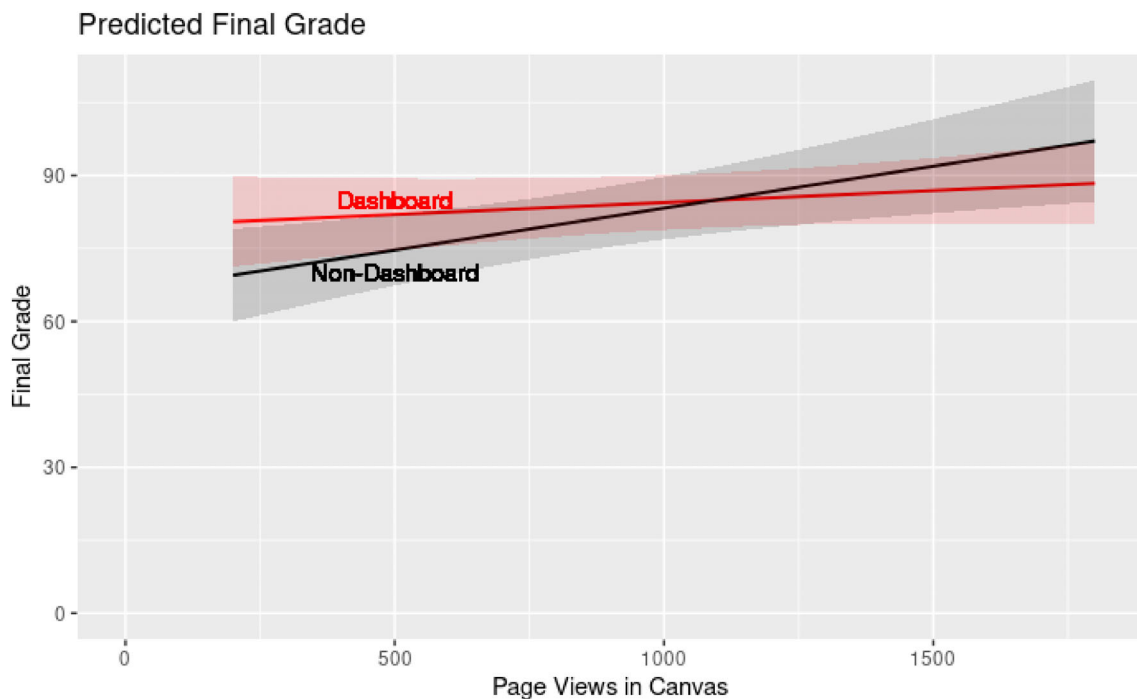


FIGURE 6 Performance difference and page views in the Canvas LMS.

TABLE 3 Ordinary least squares regression model for dashboard users (End of term grade out of 100).

	Estimate (standard error)	95% confidence interval
Intercept	75.87 (11.00)	[53.83, 97.91]
LMS page views	−0.06 (0.05)	[−0.17, 0.05]
Men ^a	3.56 (2.46)	[−1.39, 8.51]
Children of college graduates ^b	7.50 (2.50) ***	[2.47, 12.53]
Non-science major ^c	−4.53 (2.55)	[−9.66, 0.60]
Sophomore/2nd year ^d	−8.63 (2.87) ***	[−14.40, −2.87]
Junior/3rd year ^d	−4.05 (4.27)	[−12.63, 4.53]
Senior/4th year ^d	−8.23 (4.60)	[−17.47, 1.02]
Non-native English speaker ^e	5.63 (5.68)	[−5.79, 17.04]
SLCI score	0.01 (0.04)	[−0.07, 0.09]

Note: Multiple R-squared: 0.1946, F-statistic: 1.289 on 9 and 48 df, p-value: 0.2677. Reference category:

^aWomen.

^bFirst-generation college student.

^cScience majors.

^dFreshman/first year.

^eNative English speaker.

* $p = 0.10$; ** $p = 0.05$;

*** $p = 0.01$.

Of the students who enjoyed the visualization of course data, there was a split between which specific dashboard element benefited learning. For about half of these students, the course module map was the tool of choice, and they used Canvas to check their grades.

The other half preferred looking at the grade and rewards tools to visualize how far they had progressed in the class. One student mentioned that they 'like how it shows how your points grow as the semester goes on because it's more rewarding', while another specifically mentioned that they 'sort of like seeing my grade as a thermometer, that was new and exciting'. This thematic finding brings to the forefront the organization of materials in LMS and the challenges of a rigid or linear content structure.

4.2.3 | Performance and progress

It is worth noting that although students were particularly motivated to see their rank in the course, the same feature was demotivating for some students. For some, the leaderboard feature (i.e. dots representing rank) integrated within the thermometer was a rewarding experience, and 'seeing my grade in the [dashboard] tab was a good way of showing how I ranked in comparison to other students in my class'. Conversely, this also provided a source of anxiety or other negative emotions for a small number of students, such as 'when you start off at 0 points and have to climb up the thermometer it's disheartening when you sit at an F for half the class'. The design of the grade progression on the thermometer, with an extended time before moving from F to D, resulted in mixed emotions from students in the course.

4.2.4 | Confusion

The dashboard presented course information and grades in a non-traditional format and was a novel experience for most students.

Although the tool was introduced to students during one of the first classes of the semester, some did not recollect learning how to use the tool. One student requested that 'it needs to be better explained at the beginning of the semester because I still have no idea how to use it'. Others found the dashboard to be a source of confusion, notably 'because it differs from my grade in the grade book'. The dashboard's earning-up points strategy does not always align with the average score presented in the LMS grade book. Some confused students also had a favourable view of the tool. One student stated that if 'I had known about it earlier on as I think it would have helped me stay better organized'. There was a need for more clarity and communication between the faculty member and students on the dashboard's benefits and application.

4.2.5 | Infrequent use

Approximately one-third of the survey respondents indicated that they infrequently used the dashboard or did not use it at all. This observation is also supported by the dashboard access data (see Figure 5). In this course, students could access materials through the dashboard or circumvent the tool by going directly to the course digital textbook to complete assignments. The reasons for lack of use included a preference for traditional Canvas tools, quicker access to the textbook, and a lack of awareness of the dashboard and its affordances. As with the Confusion category, several students noted a positive view of the tool but chose the alternative. One student remarked that they 'did most of the assignments through the MyLab and Mastering tab, not through [the dashboard], but [the dashboard] is definitely more organized', and another thought, 'it's cool; however, I forgot it was there most of the time'. When provided the choice in the type of access to materials, some students infrequently used the dashboard because they intentionally used more familiar methods, and others overlooked the dashboard completely.

4.2.6 | Technical issues

A small number of students encountered technical issues that influenced emotions and overall perceptions of the usefulness of the dashboard. The platform's load time was the most frequently mentioned technical issue, resulting in student frustration and leading some students to abandon the tool. The students remarked that it 'wouldn't always load so that's a bit frustrating' and that 'it always took forever to load no matter where or what kind of device (iPhone, desktop, laptop) I used to access it'.

5 | DISCUSSION

Access to the gamified dashboard provided a significant and early benefit for student academic achievement. The final grades of the students who used the dashboard were, on average, over one letter

grade higher than the grades of students who did not have access to the dashboard, a finding reflected in the qualitative results. Based on the survey feedback, students attributed their success in the course to the dashboard features that gave them easy access to assignments, highlighted resources, including study guides, and clear organization of course materials. The performance gap between high engagement LMS users and low engagement users narrowed when students had access to the dashboard. This implies that the dashboard may provide student performance benefits that carry through the term, which helped students orient their time and study strategies.

When accounting for access to the dashboard, we observed very few demographic differences among students in their end-of-term performance. Only students who were the children of college graduates significantly outperformed their peers whose parents did not have a post-secondary degree (see Figure A1). The children of college graduates traditionally have higher persistence and retention rates compared to students who are the first generation in their family to attend college (Pascarella et al., 2004). First-generation students are one-third of the higher education population, and difficulties they experience during the first-year transition might complicate their pathways to academic success (Ives & Castillo-Montoya, 2020). Although not surprising, future research should investigate the potential benefits of gamification for first-generation students, especially in courses where significant differences in performance are persistent. Although tools like gamified dashboards may help this population of students navigate course material, their impact may be increased by connecting game elements with prior experience and cultural background (Ives & Castillo-Montoya, 2020).

The frequency of dashboard use was not associated with improved performance. We take this to be a promising albeit apparently contradictory finding. While their frequency of engagement with other LMS tools was a significant predictor of improved academic performance in the course section without the dashboard, it does not appear that substantially higher levels of use are required to receive a benefit (Figure A2). This conclusion is based on the observation that all students who had access to the dashboard accessed it at least a handful of times, and most of this access was spread throughout the semester. Although more data are needed to confirm this conclusion, this finding suggests that dashboard users may not need to spend significant time engaging with the tool to benefit from its use. In this way, the gamification dashboard is a low-cost intervention for both students and instructors. Other studies examining the impacts of gamification elements on the academic performance show that small changes in course design can result in large impacts on learners (Çakıroğlu et al., 2017; Díaz-Ramírez, 2020; Ortiz-Rojas et al., 2019).

It is known that dashboards provide customization and personalization for learning (Brown et al., 2006; Mohd et al., 2010). The dashboard should also include motivating features to encourage students to engage, as participation can be an issue in a virtual environment (Bodily et al., 2018). In this study, the combination of dashboard and gamification addressed some issues with learning analytics dashboards. Delphinium provides a blueprint for the inclusion of gamification in these systems. The combination of course data visualization

and motivating elements were associated with a significant difference in final grades, with users potentially benefiting from personalized information.

In this study, we focused on students' initial academic preparation for the course, but future studies should also consider students' motivations for taking the course. Differences in goal motivation might explain some differences we observed in behavioural engagement over the term and when students adopt the course tools. Future research should be conducted to further narrow the performance gap between highly engaged and moderate- to low- engagement students.

The relationship between first-generation and non-first-generation students and their use of the gamification dashboard should be further considered. It may be that, as students benefit from access to the dashboard, they would benefit even more from tools that reinforce course concepts. Similarly, by recording the motivational states that students enter the course with and how those states change over multiple semesters, we could better trace both the dashboards' motivational affordances and trends in student engagement. These observations will more broadly explain access patterns for the dashboard tool.

There is a need for additional research in the field of gamification to investigate whether any specific element of gamified dashboards has demotivational impacts on students. As some participating students indicate anxiety or other negative emotions associated with the gamified dashboard, a careful study is needed to examine the exact cause of negative emotions and find a solution to this challenge. Special attention should also be paid to the dashboard's competitive elements and the investigation of other components beyond leaderboards, badges, and points. Moreover, this study only focused on a specific STEM course, introductory physical geology. A similar study can be done to examine the gamification of learning analytics dashboards in other STEM courses like physics, biology, or more abstract subjects like mathematics.

6 | LIMITATIONS

There are a few limitations to this dataset and study that should be noted. Students were required to use Canvas for the course, and they could not avoid it or choose different online tools. However, it is possible that not all student clicks were captured in our data. Canvas records the total number of clicks within the course page but does not record clicks within the dashboard, so our trace data indicates when a student clicked on the dashboard, but not which features they accessed or how frequently. Furthermore, students could access the homework platform directly through the link provided by the textbook publisher when they registered for it, a link also available through Canvas, and without going through Delphinium.

This study was conducted over a single semester, and it is unlikely that it will be possible to fully reproduce its design given changes in student population and overall adjustments (e.g. subsequent semesters of this course were offered only online in 2020 and 2021 because of COVID-19 restrictions). The distribution of students in the two sections was not random, which is typical in educational research. We did not observe systematic bias in the distribution of students across the two

courses by demographics or in their pre-course attributes (like the SLCI score).

Further limitations were present in the instructional design. Students were not asked to reflect on their learning experience, and more specifically on their experience with the dashboard. Reflective experiences allow students to regulate their thoughts and behaviours, and to monitor their learning and academic success.

We did observe a significant difference between sections in the frequency of Canvas use. While we only wanted to measure the outcome impacts of a Canvas-only section vs. a gamification treatment section, the gamified section utilized Canvas far more than the Canvas-only section. The dashboard section used Canvas more frequently, which makes intuitive sense as they had more features to access than the control group.

7 | CONCLUSIONS

This study identifies the potential benefits of using gamified dashboards in introductory STEM courses to address engagement and academic performance. Our findings suggest that when students have access to a gamified dashboard in their introductory geology course, they receive a significant end-of-term academic performance benefit of one grade level.

Students appreciated the ability to monitor their progress through course tasks and in accruing grade points, although a few students did express reservations about the demotivational effect of slow changes in their total grades. Students were engaged by the personalized grades and visualization of assignments, adopted the tool early in the semester, and used it throughout the duration of the course, albeit with varying frequency. Accounting for their incoming scientific literacy, major, and other demographic factors, we observed a narrowing of the performance gap between highly engaged and moderate- to low-engaged students. Considering that the dashboard represents a low-cost, low-time investment intervention to help students cultivate study strategies, narrowing the performance gap is encouraging. Even if this effect is small or moderate, relative to the costs, gamified dashboards in large introductory STEM lecture courses could have a significant impact on student performance.

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PEER REVIEW

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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REFERENCES

- Alam, M., & Gleason, B. (2022a). An augmented reality-based learning experience for teacher candidates. In T. Bastiaens (Ed.), *Proceedings of EdMedia + Innovate Learning* (pp. 381–387). Association for the Advancement of Computing in Education (AACE). Retrieved July 19, 2023 from <https://www.learntechlib.org/primary/p/221316/>
- Alam, M., & Gleason, B. (2022b). Teacher candidates' opinions about augmented reality as a supplemental educational tool. In E. Langran (Ed.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 1750–1754). Association for the Advancement of Computing in Education (AACE). Retrieved July 19, 2023 from <https://www.learntechlib.org/primary/p/220945/>
- Alaswad, Z., & Nadolny, L. (2015). Designing for game-based learning: The effective integration of technology to support learning. *Journal of Educational Technology Systems*, 43(4), 389–402. <https://doi.org/10.1177/0047239515588164>
- Aldemir, T., Celik, B., & Kaplan, G. (2018). A qualitative investigation of student perceptions of game elements in a gamified course. *Computers in Human Behavior*, 78, 235–254. <https://doi.org/10.1016/j.chb.2017.10.001>
- Alojhani, N. R., Daud, A., Abbasi, R. A., Alowibdi, J. S., Basher, M., & Aslam, M. A. (2019). An integrated framework for course adapted student learning analytics dashboard. *Computers in Human Behavior*, 92, 679–690. <https://doi.org/10.1016/j.chb.2018.03.035>
- Arnab, S., Lim, T., Carvalho, M. B., Bellotti, F., de Freitas, S., Louchart, S., Suttie, N., Berta, R., & De Gloria, A. (2015). Mapping learning and game mechanics for serious games analysis: Mapping learning and game mechanics. *British Journal of Educational Technology*, 46(2), 391–411. <https://doi.org/10.1111/bjjet.12113>
- Bodily, R., Ikahihifo, T. K., Mackley, B., & Graham, C. R. (2018). The design, development, and implementation of student-facing learning analytics dashboards. *Journal of Computing in Higher Education*, 30(3), 572–598. <https://doi.org/10.1007/s12528-018-9186-0>
- Bodnar, C. A., Anastasio, D., Enszer, J. A., & Burkey, D. D. (2016). Engineers at play: Games as teaching tools for undergraduate engineering students: Research review: Games as teaching tools in engineering. *Journal of Engineering Education*, 105(1), 147–200. <https://doi.org/10.1002/jee.20106>
- Brown, M. G., Schiltz, J., Derry, H., & Holman, C. (2019). Implementing online personalized social comparison nudges in a web-enabled coaching system. *The Internet and Higher Education*, 43, 100691. <https://doi.org/10.1016/j.iheduc.2019.100691>
- Brown, W. E., Lovett, M., Bajzek, D., & Burnette, J. M. (2006). Improving the feedback cycle to improve learning in introductory biology using the digital dashboard. In *E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education* (pp. 1030–1035). Association for the Advancement of Computing in Education (AACE).
- Bryman, A. (2006). Integrating quantitative and qualitative research: How is it done? *Qualitative Research*, 6(1), 97–113. <https://doi.org/10.1177/1468794106058877>
- Çakıroğlu, Ü., Başbüyük, B., Güler, M., Atabay, M., & Yılmaz Memiş, B. (2017). Gamifying an ICT course: Influences on engagement and academic performance. *Computers in Human Behavior*, 69, 98–107. <https://doi.org/10.1016/j.chb.2016.12.018>
- Chae, S. W., Lee, K. C., & Seo, Y. W. (2016). Exploring the effect of avatar trust on learners' perceived participation intentions in an e-learning environment. *International Journal of Human-Computer Interaction*, 32(5), 373–393. <https://doi.org/10.1080/10447318.2016.1150643>
- Chen, C.-L. D., Yeh, T.-K., & Chang, C.-Y. (2016). The effects of game-based learning and anticipation of a test on the learning outcomes of 10th grade geology students. *EURASIA Journal of Mathematics, Science and Technology Education*, 12(5), 1379–1388. <https://doi.org/10.12973/eurasia.2016.1519a>
- Chen, Z.-H., Lu, H.-D., & Lu, C.-H. (2019). The effects of human factors on the use of avatars in game-based learning: Customization vs. non-customization. *International Journal of Human-Computer Interaction*, 35(4–5), 384–394. <https://doi.org/10.1080/10447318.2018.1543090>
- Cheng, M.-T., Su, T., Huang, W.-Y., & Chen, J.-H. (2014). An educational game for learning human immunology: What do students learn and how do they perceive?: Using educational games for learning immunology. *British Journal of Educational Technology*, 45(5), 820–833. <https://doi.org/10.1111/bjjet.12098>
- Chu, H.-C., & Chang, S.-C. (2014). Developing an educational computer game for migratory bird identification based on a two-tier test approach. *Educational Technology Research and Development*, 62(2), 147–161. <https://doi.org/10.1007/s11423-013-9323-4>
- Clark, V. L. P., & Ivankova, N. V. (2016). *Mixed methods research: A guide to the field*. SAGE Publications Inc. <https://doi.org/10.4135/9781483398341>
- Creswell, J. W., Plano Clark, V. L., Gutmann, M. L., & Hanson, W. E. (2003). Advanced mixed methods research designs. *Handbook of Mixed Methods in Social and Behavioral Research*, 209(240), 209–240.
- de Freitas, S., Gibson, D., Alvarez, V., Irving, L., Star, K., Charleer, S., & Verbert, K. (2017). How to use gamified dashboards and learning analytics for providing immediate student feedback and performance tracking in higher education. In *Proceedings of the 26th international conference on World Wide Web Companion—WWW '17 Companion* (pp. 429–434). International World Wide Web Conference Committee. <https://doi.org/10.1145/3041021.3054175>
- Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). *From game design elements to gamefulness: Defining 'amification'* (pp. 9–15).
- Díaz-Ramírez, J. (2020). Gamification in engineering education – An empirical assessment on learning and game performance. *Heliyon*, 6(9), e04972. <https://doi.org/10.1016/j.heliyon.2020.e04972>
- Gates, A. E., & Kalczyński, M. J. (2016). The oil game: Generating enthusiasm for geosciences in urban youth in Newark, NJ. *Journal of Geoscience Education*, 64(1), 17–23. <https://doi.org/10.5408/10-164.1>
- Granic, I., Lobel, A., & Engels, R. C. M. E. (2014). The benefits of playing video games. *American Psychologist*, 69(1), 66–78. <https://doi.org/10.1037/a0034857>
- Hanus, M. D., & Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & Education*, 80, 152–161. <https://doi.org/10.1016/j.compedu.2014.08.019>
- Hasan, M. L., Mohyaldinn, M. E., Hja Aziz, N. A., & Mohamed, M. A. (2017). Improving students' motivation to learn through gamification. In *2017 7th World Engineering Education Forum (WEEF)* (pp. 642–647). IEEE. <https://doi.org/10.1109/WEEF.2017.8467059>
- Hwang, G.-J., Hung, C.-M., & Chen, N.-S. (2014). Improving learning achievements, motivations and problem-solving skills through a peer assessment-based game development approach. *Educational Technology Research and Development*, 62(2), 129–145. <https://doi.org/10.1007/s11423-013-9320-7>
- Ivankova, N. V., & Creswell, J. W. (2009). Mixed methods. In *Qualitative research in applied linguistics: A practical introduction* (Vol. 23, pp. 135–161). Palgrave Macmillan.
- Ives, J., & Castillo-Montoya, M. (2020). First-generation college students as academic learners: A systematic review. *Review of Educational Research*, 90(2), 139–178. <https://doi.org/10.3102/0034654319899707>
- Kangas, M., Koskinen, A., & Krokfors, L. (2016). A qualitative literature review of educational games in the classroom: The teacher's pedagogical activities. *Teachers and Teaching*, 1–20, 1–20. <https://doi.org/10.1080/13540602.2016.1206523>
- Kluver, D. B., Robertson, W. M., & Agardy, R. (2018). Role playing a city's response to climate change: Engaging undergraduate geoscience

- students. *Journal of Geoscience Education*, 66(1), 25–35. <https://doi.org/10.1080/10899995.2018.1411734>
- le Maire, N. V., Verpoorten, D. P., Fauconnier, M.-L. S., & Colaux-Castillo, C. G. (2018). Clash of chemists: A gamified blog to master the concept of limiting reagent stoichiometry. *Journal of Chemical Education*, 95(3), 410–415. <https://doi.org/10.1021/acs.jchemed.7b00256>
- Li, M.-C., & Tsai, C.-C. (2013). Game-based learning in science education: A review of relevant research. *Journal of Science Education and Technology*, 22(6), 877–898. <https://doi.org/10.1007/s10956-013-9436-x>
- Liu, D., Santhanam, R., University of Oklahoma, Webster, J., & Queen's University. (2017). Toward meaningful engagement: A framework for design and research of gamified information systems. *MIS Quarterly*, 41(4), 1011–1034. <https://doi.org/10.25300/MISQ/2017/41.4.01>
- Martindale, R. C., & Weiss, A. M. (2020). 'Taphonomy: Dead and fossilized': A new board game designed to teach college undergraduate students about the process of fossilization. *Journal of Geoscience Education*, 68(3), 265–285. <https://doi.org/10.1080/10899995.2019.1693217>
- McConnell, D. A., Steer, D. N., Owens, K. D., Knott, J. R., Van Horn, S., Borowski, W., Dick, J., Foos, A., Malone, M., McGrew, H., Greer, L., & Heaney, P. J. (2006). Using conceptests to assess and improve student conceptual understanding in introductory geoscience courses. *Journal of Geoscience Education*, 54(1), 61–68. <https://doi.org/10.5408/1089-9995-54.1.61>
- McKenney, S. E., & Reeves, T. C. (2012). *Conducting educational design research*. Routledge.
- Meadows, M. S. (2008). *I, avatar: The culture and consequences of having a second life*. New Riders <http://VH7QX3XE2P.search.serialssolutions.com/?V=1.0&L=VH7QX3XE2P&S=JCS&C=TC0000493892&T=marc&tab=BOOKS>
- Miles, M. B., Huberman, A. M., & Saldaña, J. (2018). *Qualitative data analysis: A methods sourcebook* (4th ed.). SAGE.
- Miller, J. D. (1983). Scientific literacy: A conceptual and empirical review. *Daedalus*, 21, 29–48.
- Mohd, W. M. B. W., Embong, A., & Zain, J. M. (2010). A framework of dashboard system for higher education using graph-based visualization technique. In *International Conference on Networked Digital Technologies: Second International Conference, NDT 2010, Prague, Czech Republic, July 7-9, 2010. Proceedings, Part I 2* (pp. 55–69). Springer Berlin Heidelberg.
- Morschheuser, B., Hassan, L., Werder, K., & Hamari, J. (2018). How to design gamification? A method for engineering gamified software. *Information and Software Technology*, 95, 219–237. <https://doi.org/10.1016/j.infsof.2017.10.015>
- Nacke, L. E., & Deterding, S. (2017). The maturing of gamification research. *Computers in Human Behavior*, 71, 450–454. <https://doi.org/10.1016/j.chb.2016.11.062>
- Nadolny, L., Alam, M. I., Brown, M. G., & Lamm, M. H. (2021). Game Research Trends at the Annual ASEE Conference: A 15-year Content Analysis Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference. <https://peer.asee.org/37215>.
- Nadolny, L. N., & Gleason, B. W. (2018). The best of all worlds: Combining the flipped classroom, game-based learning, and learning communities in a large technology integration course. In E. Langran & J. Borup (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 1065–1067). Association for the Advancement of Computing in Education (AACE). Retrieved July 19, 2023 from <https://www.learntechlib.org/primary/p/182656/>
- Nadolny, L., Malone, L., Chapman, J., & Alam, M. (2022). Participatory gamification design: Navigating diverse perspectives. In T. Bastiaens (Ed.), *Proceedings of Ed Media+Innovate Learning* (pp. 534–540). Association for the Advancement of Computing in Education (AACE). Retrieved July 18, 2023 from <https://www.learntechlib.org/primary/p/221337/>
- Orhan Göksün, D., & Gürsoy, G. (2019). Comparing success and engagement in gamified learning experiences via Kahoot and Quizizz. *Computers & Education*, 135, 15–29. <https://doi.org/10.1016/j.compedu.2019.02.015>
- Ortiz, M., Chiluiza, K., & Valcke, M. (2016). *Gamification in higher education and stem: A systematic review of literature* (pp. 6548–6558). IATED-Int Assoc Technology Education A& Development (IATED). <https://doi.org/10.21125/edulearn.2016.0422>.
- Ortiz-Rojas, M., Chiluiza, K., & Valcke, M. (2019). Gamification through leaderboards: An empirical study in engineering education. *Computer Applications in Engineering Education*, 27(4), Article 4. <https://doi.org/10.1002/cae.12116>
- Park, Y., & Jo, I.-H. (2019). Factors that affect the success of learning analytics dashboards. *Educational Technology Research and Development*, 67(6), 1547–1571. <https://doi.org/10.1007/s11423-019-09693-0>
- Pascarella, E. T., Pierson, C. T., Wolniak, G. C., & Terenzini, P. T. (2004). First-generation college students: Additional evidence on college experiences and outcomes. *The Journal of Higher Education*, 75(3), 249–284. <https://doi.org/10.1353/jhe.2004.0016>
- Pena, E. A., & Slate, E. H. (2014). *gvlma: Global validation of linear models assumptions*. R package version 1.0.0.2.
- Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist*, 50(4), 258–283. <https://doi.org/10.1080/00461520.2015.1122533>
- Reuss, R. L., & Gardulski, A. F. (2001). An interactive game approach to learning in historical geology and paleontology. *Journal of Geoscience Education*, 49(2), 120–129. <https://doi.org/10.5408/1089-9995-49.2.120>
- Sansom, R. L., Bodily, R., Bates, C. O., & Leary, H. (2020). Increasing student use of a learner dashboard. *Journal of Science Education and Technology*, 29(3), 386–398. <https://doi.org/10.1007/s10956-020-09824-w>
- Schwendimann, B. A., Rodriguez-Triana, M. J., Vozniuk, A., Prieto, L. P., Boroujeni, M. S., Holzer, A., Gillet, D., & Dillenbourg, P. (2017). Perceiving learning at a glance: A systematic literature review of learning dashboard research. *IEEE Transactions on Learning Technologies*, 10(1), 30–41. <https://doi.org/10.1109/TLT.2016.2599522>
- Scott, N. (2012). *A user-centered theoretical framework for meaningful gamification*. Games+ Learning+ Society 8.0.
- Spandler, C. (2016). Mineral supertrumps: A new card game to assist learning of mineralogy. *Journal of Geoscience Education*, 64(2), 108–114. <https://doi.org/10.5408/15-095.1>
- Successful K-12 STEM Education. (2011). *Identifying effective approaches in science, technology, engineering, and mathematics*. National Academies Press. <https://doi.org/10.17226/13158>
- Teasley, S. D. (2017). Student facing dashboards: One size fits all? *Technology, Knowledge and Learning*, 22(3), 377–384.
- van Roy, R., & Zaman, B. (2018). Need-supporting gamification in education: An assessment of motivational effects over time. *Computers & Education*, 127, 283–297. <https://doi.org/10.1016/j.compedu.2018.08.018>
- Zipp, J. F. (2007). Learning by exams: The impact of two-stage cooperative tests. *Teaching Sociology*, 35(1), 62–76. <https://doi.org/10.1177/0092055X0703500105>

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APPENDIX A

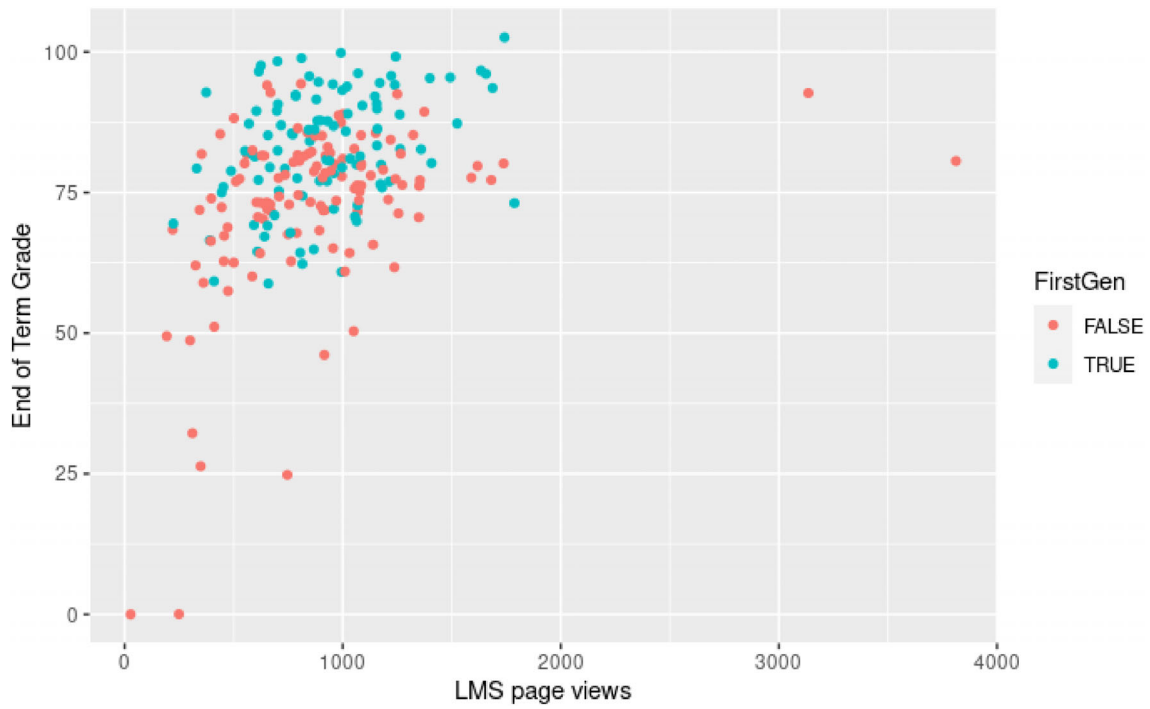


FIGURE A1 Relationship between total page views in the Canvas LMS and end of term grade for students by first generation college student status.

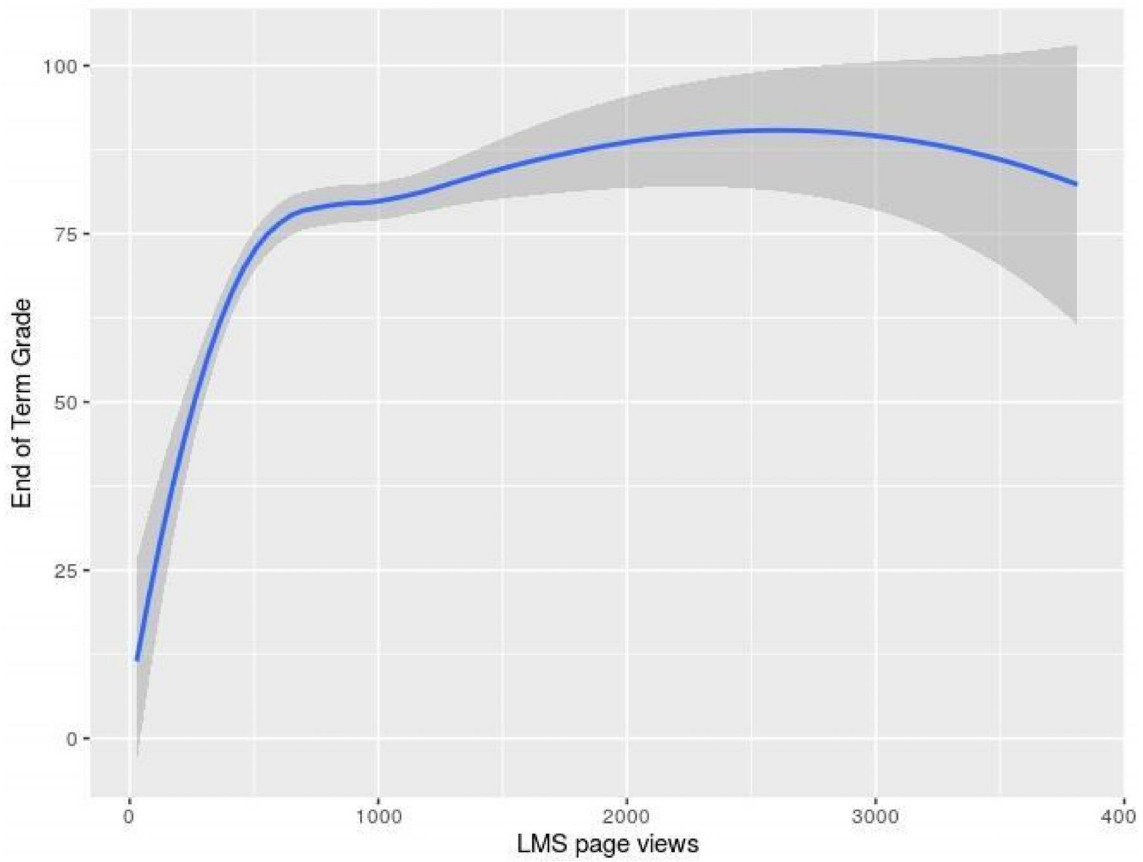


FIGURE A2 Relationship between total page views in the Canvas LMS and end of term grades for all students.