GAMIFICATION IN A COREQUISITE CALCULUS SEQUENCE

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Abstract
In this paper, we will discuss Delta State University's implementation of gamification in a corequisite differential and integral calculus sequence, referred to as Calculus I and Calculus II, respectively. The template for the corequisite design emerged from the successful implementation of corequisite labs in the general education mathematics courses at Delta State. The use of gamification in the calculus sequence is defined by the inclusion of an extended, scaffolded game setting in the corequisite labs to provide immediate feedback to both student and instructor.

In fall 2016, Delta State first implemented the corequisite labs in general education mathematics courses. While each successive academic year thereafter has shown significant gains in student pass rates, the greatest gain occurred in fall 2018, after the establishment of lab-based cooperative learning groups. Based on the successes seen in the general education courses, Delta State paired all Calculus I and II sections with corequisite labs starting fall 2019. In fall 2021, the instructors of the calculus sections then introduced gamification using a combination of Kahoot! quizzes held in the weekly corequisite labs. The intention of this instructional technique was to shorten the student-instructor feedback loop, increase student engagement, and promote student self-efficacy.

Provided in this paper will be both qualitative preliminary results for the Delta State calculus sections for fall 2021 and spring 2022. From these results, we will discuss perceived success and failure, as well as future course plans, with attention given to tracking content retention throughout the calculus sequence.

Introduction
Delta State University (DSU) is a regional public university situated in the heart of the Mississippi delta which is located in the southeastern region of the United States. The following institutional demographic data provides an accurate picture of the students enrolled in Calculus I.

In the fall of 2020, 2,331 students attended DSU. Of these students, 59% are female and 41% are male. The average class size at the institution is 11:1, and the Calculus I and II classes typically have a 5-15 student enrollment. As seen in Table 1, from Fall 2012 to 2018, of the incoming students who provide ACT scores (transfer students are exempt from this requirement), 58% earned less than a 21on the ACT (Institutional Research, 2019). The U.S. Department of Education (2018) has determined earning a 21 or higher on the

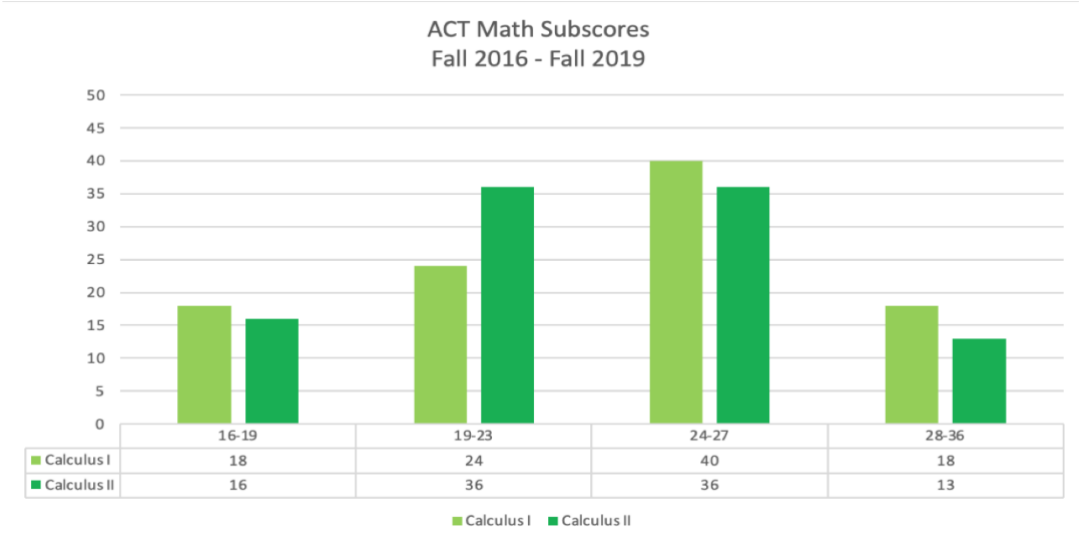
ACT as an indicator of readiness for college-level mathematics. Therefore, historically, 42%, or significantly less than half, of the entering freshmen are considered ready to learn the subject matter at hand.

Table 1
Percent of incoming students earning a 21 or higher on the ACT

	Fall 2012	**Fall 2013**	**Fall 2014**	**Fall 2015**	**Fall 2016**	**Fall 2017**	**Fall 2018**
Percent of first-time *freshmen* who have an ACT composite score of 21 or above	41.4%	41.2%	47.6%	46.4%	55.5%	54.6%	53.8%

At Delta State, students may use their ACT math sub-scores to place into various general education math pathways. In particular, a student with an ACT math subscore of 24 or higher may begin their college math coursework with Calculus I. A lower ACT math score will require the student to take either College Algebra or Trigonometry before entering into the calculus sequence. Table 2 shows that historically roughly half of the students taking Calculus I and II at Delta State have ACT scores that necessitate at least one prerequisite math course before entering into the calculus sequence.

Table 2
ACT math sub-scores of DSU Calculus I and Calculus II students



Beginning in the 2019-2020 academic year, Delta State University initiated the co-requisite model in Calculus I and II. This model requires all Calculus I and II students to enroll in a corequisite lab section paired with their class. The instructor of record presides over the corequisite lab. The purpose of implementing the corequisite model is to reinforce remedial content and to foster content retention in subsequent mathematics and science courses.

Educational Framework

Gamification in education refers to the process of increasing students' engagement, enthusiasm, and retention by integrating game design components in an academic setting. The basic premise is that students learn best when they are enjoying what they are doing. Additionally, students need achievements to strive for. ("Gamification," 2022)

The idea of gamification has become very popular within the last ten years and has been applied to numerous fields, ranging from personal health to human resources to government. We can all recall at least several training sessions for work in which we have had some type of computer game at the end of the training that tests the material being taught.

Gamification traverses a variety of both theoretical and empirical knowledge and technological platforms. It has been described in various manners, such as "the use of game design elements in non-game contexts," "the phenomenon of creating gameful experiences," or "the process of making activities more game-like." ("Gamification," 2022)

In education specifically, gamification refers to the introduction of game design elements and gameful experiences in the development of learning methodologies. It fosters learning through such channels as participatory approaches, collaboration, self-guided study, and strengthening student creativity and retention. ("Gamification," 2022)

Elements of games to consider for student motivation and participation include the following ("Gamification," 2022):

- Immediate feedback
- Student engagement
- Scaffolded learning
- Mastery-based pathways
- Progress indicators
- Social connectivity
- Student self-efficacy

There are many benefits of gamification in the academic environment. In particular, it embraces a growth mindset, affording the students a sense of teamwork and belonging in the classroom. If done effectively, all students are given the opportunity to participate in playing the games as well as achieve early success. (Martin-Gay, 2022). Furthermore, gamification provides for timely and frequent feedback, such as bell-ringers at the beginning of class or digital scavenger hunts.

An instructor can implement gamification within the classroom by utilizing a wide variety of activities. For example, an instructor may choose to give points for achieving non-academic goals such as perfect attendance or consistently turning in work on time. Gamification may include the process of incorporating a competitive structure to an activity or required behavior either between groups within the classroom, between classes,

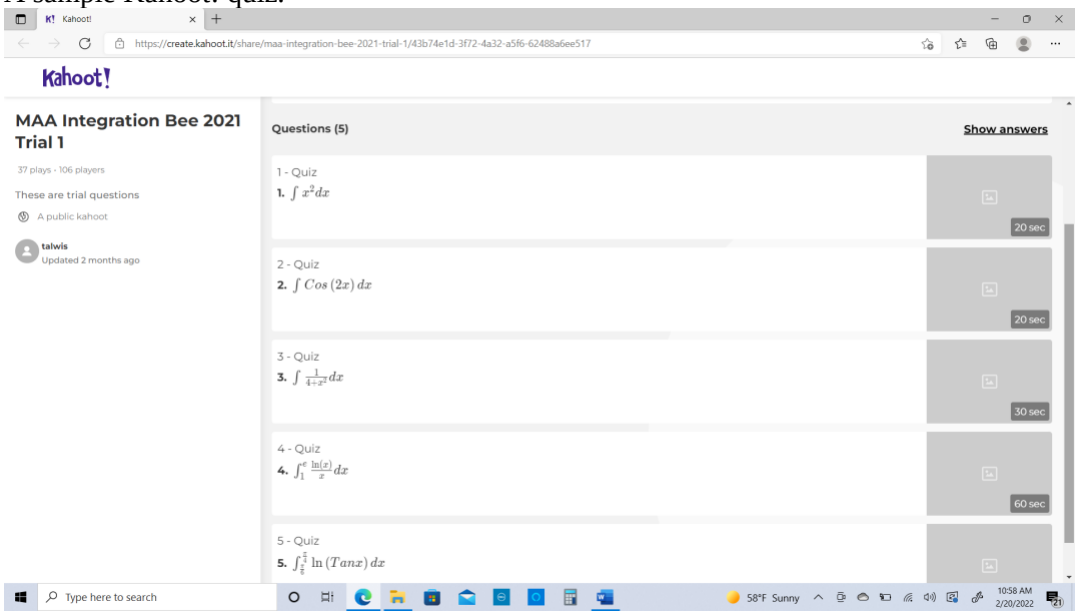
or even between the instructor and the students. Instead of points, the instructor may instead choose to award badges or homework passes for meeting personal or academic goals. As is evident here, gamification encompasses a broad spectrum of instructional techniques, each with the intent to encourage and to facilitate reflection on personal performance.

Model

We now introduce the implementation of gamification in the corequisite Calculus I and II courses. Over the past several decades, collegiate mathematics courses have steadily expanded their use of learning management systems (LMS) for both formative and summative assessments. (Bondurant, Putnam, & Townsend, 2019) While the use of such LMS tools offer significant advantages, such as a shortened feedback loop and a wider availability of practice problems, we have noticed a significant tendency towards student fatigue when encouraged to engage in supplementary practice problems, whether independently or in a group setting.

Thus, the inspiration for this instructional design originated with a Kahoot! game written by Dr. Tilak de Alwis from Southeastern Louisiana University for an undergraduate integration bee at the Spring Meeting for the Louisiana/Mississippi Section of the Mathematical Association of America (MAA) held virtually during the spring of 2021.

Table 3
A sample Kahoot! quiz.



For the integration bee, students from area colleges and universities competed via Zoom using Kahoot!. A sample of questions designed by Alwis is given in Table 3. From our observations, we were pleased to see that the students who participated in the competition actively embraced the gaming approach to integration. With this in mind, we decided to implement a similar idea within the Calculus I and Calculus II sequence at Delta State University. These two courses at Delta State, which now have a required one-hour weekly

lab component, would utilize Kahoot! games during lab time to practice and strengthen differentiation and integration techniques.

The original intent of the implementation of the Kahoot! quizzes was to provide opportunities for the students to engage with recently acquired course content in meaningful and interesting ways. Another objective at the onset of this academic year was to foster enthusiasm through periodic competitions between the Calculus I and Calculus II sections. Competitions between the Calculus I and Calculus II students were to be based on overall mastery points from the accumulated Kahoot! quizzes within each section.

Results

After implementing the gamified Kahoot! quizzes in the fall of 2021, the instructors quickly recognized a need to modify much of the original design. It was apparent that longer and more involved questions were not successful. Also, due to the small class size, students were uncomfortable with the publicly assigned point values within the quizzes. The quizzes were modified to shorter problems, often with embedded graphs and figures. The shorter quizzes focused on single-step procedures and conceptual mastery. In addition, questions were given a zero-point value to alleviate pressure and anxiety on lower performing students. With the modifications to the original design, the instructors chose to postpone the class competition until the structure of the quizzes and associated mastery point accumulation was more clearly defined.

Conclusion

Overall, student response to the modified format was positive. After analyzing data at the end of the semester, the approach to the calculus Kahoot! games was once again reconsidered after realizing the need for more frequent games each week as well as more targeted supplementary remediation, such as with factoring or identifying the domain of a function. For the spring of 2022, the games were played at the beginning of class and consisted mainly of shorter questions that address prior topics and remedial concerns that were identified through historical practice in teaching the Calculus I and Calculus II sections.

In addition to the mid-year modifications, the instructors have chosen to redefine the competition component of the gamification for the corequisite calculus courses. The quizzes will be used as bell-ringers at the start of each class, rather than utilized exclusively within the lab. Quizzes will emphasize remedial content as either preparatory sets or formative assessment. Rather than use an inter-class competition, students will have the opportunity to convert every 10 mastery points into one bonus point on their next unit assessment, with points resetting at the start of each new unit. In this way, the competition will be more individualized and will remain private with the zero-point structure incorporated in the fall of 2021. Moving forward, we hope to see an increase in student engagement as well as improved content retention throughout the calculus sequence.

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