Augmenting Experiential Learning with a Game-based Student Response System

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***Abstract*—This Innovative Practice Category Full Paper, analyses the effect of a game-based student response system to enhance experiential learning. The introductory engineering course offered for the freshman computer engineering cohort is designed with engineering practice at its core. Each week, the students spend two three-hour studio sessions experiencing engineering through hands-on practical applications followed by a two-hour reflective session. Among the two studios each week, only one is graded. The graded studios are designed with questions that supplement the practical application and spark reflective thinking. Consecutively, it is a good indicator of the effectiveness of the session. The ungraded studio sessions are designed the same as the graded ones but lack indicators of their efficacy for active implementation. To address this, an online game-based response system, Kahoot! is integrated with the ungraded studio sessions. Kahoot! combines game-based learning with the ease of a student response system that is useful in creating a stimulating environment and targets the competitive nature of students to supplement the ungraded studios. Kahoot! stands out from ordinary student response systems as it integrates a response time to the student's answers. Both qualitative and quantitative assessment results on the effectiveness of Kahoot! to augment experiential learning will be presented.**

***Index Terms*—Game-Based learning, student response systems, experiential learning, Kahoot!**

I. Introduction

Experiential learning is a teaching and learning methodology of creating hands-on experiences that involves the students reflecting on these experiences [1]. Embedding experiential learning in engineering education at higher level courses is easily achieved by using capstone projects and industrial internships but incorporating it into fundamental freshman courses where core theoretical knowledge needs to be taught is more challenging. On the other hand, if experiential learning is implemented at the freshman level, the students can visualize the theoretical concepts come to life and a stronger integration between theory and practice can be achieved [2]. Kolb's four stage learning cycle is the widely used theory in experiential learning. The first stage starts with creating a concrete experience for the student, which is followed by the student reflecting on their experience in the second stage. This leads to conceptualizing the reflective observations to understand the relationships between them. The student then actively implements what he/she has learnt into practice in the final stage [3].

The implementation of experiential learning results in varied unique experiences for the students that cannot be assessed using traditional classroom methods [4]. Moreover, the process to get to the outcome is as important as the product resulting in the importance of using the learning space, that includes the student and the environment, in developing assessment strategies [5].

The introductory engineering course offered for the freshman computer engineering cohort is designed with engineering practice at its core. Each week, the students spend two three-hour studio sessions experiencing engineering through hands-on practical applications followed by a two-hour reflective session. Among the two studios each week, one is graded while the other is ungraded. The graded studios are designed with assessments that supplement the varied outcomes of the studios and spark reflective thinking. Consecutively, it is a good indicator of the effectiveness of the session. The ungraded studios are designed like the graded studios but provide for a more leisurely implementation of the learning space. The students maintain a learning journal for all graded and ungraded studios for reflective observation and conceptualizing the theory, but the content is subjective to the course of action they choose to implement in these sessions. A disadvantage of the studios being ungraded is the lack of indicators that assess the active implementation of the theory learned in these sessions. To address this challenge, we propose the use of an online game-based response system within the ungraded studio sessions.

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II. Literature Review

A. Student Response Systems

Student response systems (SRS) form the basis of converting a passive classroom to an active classroom. They appear in literature under different names such as audience response systems (ARS), classroom response systems (CRS) and personal response systems (PRS) [6]. The use of SRS in classroom promotes participation and engagement of students, enables interaction and discussions in the classroom and provides an avenue for formative assessment and feedback [7].

Wood et.al. studied the effect of SRS on student learning and attitude and realized that students are more engaged in the classroom with SRS [8]. Hunsu et.al analysed the effects of audience response systems (ARS) in the broader scheme of cognitive and non-cognitive learning outcomes. They found a small yet significant effect of ARS on these outcomes and concluded that careful design of the questions is required to gain potential benefits of ARS [9]. Caldwell analyzed 25 peer reviewed articles focusing on the rationale for using ARS and exploring questioning strategies with ARS [10]. Jones et.al concluded that the use of classroom response systems influenced the grade of the student if they knew it was for course credit vis--vis no credit and proposed their use to increase student accountability [11]. Though there are multiple reviews of literature on classroom response systems, none focus on the effect of student response systems in experiential learning.

B. Gamification and Kahoot!

Gamification is an educational methodology that motivates students to learn using game elements in learning environments. The objective is to create a learning environment that piques the interest of the students to continue learning. Hamari et.al analyzed peer reviewed empirical studies on gamification and their findings indicate that gamification provides positive effects in outcomes but is a function of the context of implementation [12].Lavoue et.al provided a framework to adapt gamification elements according to student reactions. They concluded that students with adapted gamification features spent significantly more time in the learning environment [13]

Different game elements can be used to augment a learning environment. Souza et.al introduced badges and leaderboards in an introductory software course. Their study concluded that use of leaderboards had mixed results but use of badges that provide social recognition was a big motivating factor for the students [14]. The use of role-play and rewards in a software project course resulted in improvement in soft skills of students [15]. Gamification can be used in experiential learning to enhance the reflective thinking and implementation of concepts. Katsontonis et.al relate cognitive and experiential learning to gamification and game-based learning in the cyber security education domain. They also provide directions for feasibility and assessment towards developing live competitions for experiential learning [16].

Kahoot! is an online student response system platform that integrates game-based learning elements into a student response system. Kahoot! has been used in teacher education analyzing the perspective of students and teachers in integrating it in the classroom [17]. The authors also analyse the potential issues with implementing Kahoot! but conclude that adoption of Kahoot! promotes greater student engagement in learning. The effectiveness of Kahoot! with respect to Google Forms and Quizizz on the students perception was studied by Chaiyo and Nokham [18]. They concluded that Kahoot and Quizizz had significant advantage over Google Forms in enjoyment, motivation satisfaction and concentration of students. This is evident as Kahoot and Quizizz integrate game elements in their design of the learning environment. Another study used Kahoot! in a computer programming course and received feedback that the students enjoyed the Kahoot! activity and it piqued their interest in computer programming [19].

The current work focuses on the use of game elements of rewards and leaderboards integrated into a student response system using the Kahoot! platform to augment experiential learning. Since, there is a gap in literature with regards to use of game-based student response systems in experimental learning, the current work can provide insights into their effectiveness.

III. Methodology

A. Design of Studio Sessions

Each week, the students spend two three-hour studio sessions experiencing engineering through hands-on practical applications followed by a two-hour reflective session. Among the two studios each week, one is graded while the other is ungraded. Both the graded and ungraded studios implement Kolbs four stage learning cycle methodology in their design [3]. The following stages are implemented in the design of the studio sessions. These stages are visualized through a sample studio topic on DC Circuit Principles as an example:

1) Defining the Learning Outcomes for each Studio Session: Each studio is conceptualized by defining the learning outcomes desired from the session. These learning outcomes outline the theory the student should know by the end of the studio session. The weekly learning outcomes build on those from the preceding weeks. For the sample studio topic on DC Circuit Principles, the following learning outcomes were formalized:

- Explain the working principle of a bridge network the Wheatstone Bridge
- Apply Potential Divider principle in a DC circuit
- Estimate the potential difference between two nodes in a circuit, and appreciate the concept of voltage polarity

2) Creating a Concrete Experience: Each studio is planned with one to three learning activities that aim to create a concrete experience for the students. These activities are derived from the intended learning outcomes and focus on the students experiencing different aspects of engineering through hands-on practical applications encountered by the student in their daily lives. For the sample studio topic on DC Circuit Principles, the following activity was planned for the students:

- Activity - Estimate the change in resistance using a Wheatstone Bridge

3) Reflective Observation by the Student: After completing each activity the students are given time to record their observations in their learning journal. They try to link the observations with prior knowledge from previous studios or other modules. These reflections are also recorded in their graded reports if the studio is graded.

4) Abstract Conceptualization of the Reflections: The students assimilate what they observed and try to find the relationship between different parameters. They are encouraged to use technological tools to do so. These concepts are recorded in their learning journals and their graded report sheets if the studio is graded. For the sample studio on DC Circuit Principles, the students derive the relationship between the change in current and voltage for different resistances and the expression to calculate the change in unknown resistance. They plot the observations using technological tools and reflect on the variations in the unknown resistance.

5) Active Experimentation: Once the reflections are conceptualized, another activity , numerical problem or application problem is designed to actively implement these concepts to deepen the students understanding of the concept. For the sample studio session on DC Circuit Principles, the following active experimentation activity was planned:

- Activity - Derive the Thevenin equivalent across the different points of the circuit. This activity links the current studio session to a previous studio session.

These activities were designed for both graded and ungraded sessions, but it was expected that some fatigue may set in towards the end of the sessions. The graded sessions had the motivations of marks or credits, but the ungraded sessions had no such motivation to assess the active implementation of theory learnt in these sessions.

To address this challenge, it is proposed to use the Kahoot! platform as a game based student response system at the end of ungraded studio sessions.

B. *Kahoot! Integration with the Ungraded Studio Sessions*

Kahoot! is a game-based student response system that provides tools for creating quizzes. When playing Kahoot! in the classroom, the instructor launches Kahoot! in a web browser connected to screens visible to all students. The students launch the URL *kahoot.it* on their own devices, enter a game pin and a nickname to join the game as shown in Fig. 1

Once the students sign up, the instructor starts the game. The questions along with the answers are shown on the screen while the students device show them different colors and symbols representing the different options for that question as shown in Fig. 2. The students can choose the color/symbol they feel is the correct answer. There is an on-screen timer that counts down to zero as well along with the number of students that have answered the question. During the quiz, Kahoot plays music and sounds similar to a game show to give a competitive atmosphere in the class.

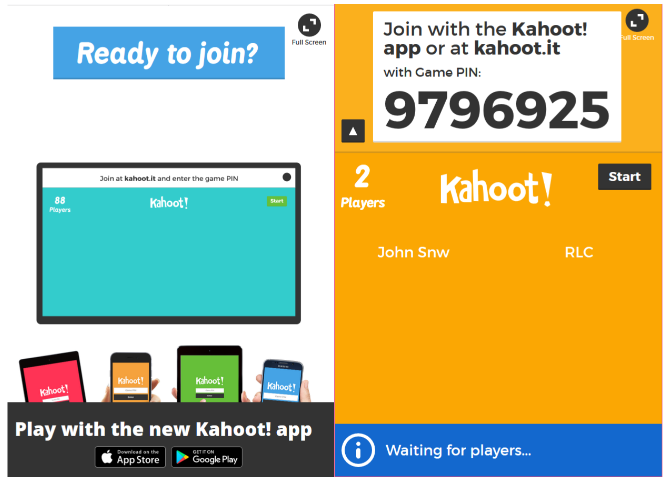

Fig. 1. The Kahoot interface (Left) and the joining screen (Right) for students

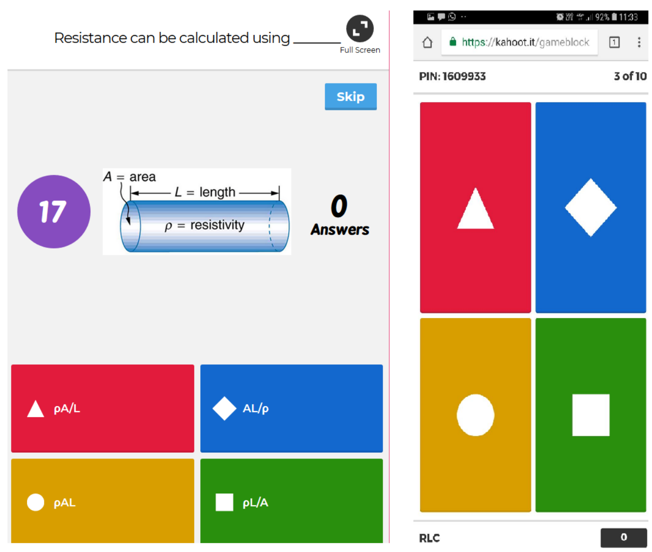

Fig. 2. Kahoot displaying a sample question on the screens (Left) and the options screen for the students (Right)

At the end of each question, a distribution shows the student responses and a leaderboard with the top 5 students is shown on the screen. The students are given feedback on the correctness of their responses and their individual scores. Kahoot! differs from other SRS in using a time component to grade and mark the students. The faster a student responds with the correct answer the higher they scores relative to their peers. At the end of each quiz, the top three students are identified and given *rewards* for their performance in the quiz.

The Kahoot! quizzes were administered at the end of the ungraded studio sessions. They tested the concepts covered in the ungraded studios as well as their application and numerical problems.

C. Design of Questions

Designing effective questions is a critical component in ensuring an effective student response system-based learning. The questions should be concise but not leave out necessary information. A question should be designed to assess student preparation and their understanding of the material, reveal student misunderstandings, assess students ability to reflect and implement lecture material to a new situation. [10], [20]. The Kahoot questions were designed keeping in mind the above characteristics in the following three categories:

- Conceptual Questions:These questions tested the students understanding of the concepts covered in the studio. The questions were also phrased to reveal misunderstandings students may have about these concepts.
- Application-based Questions: These questions challenged the students in applying the concepts to different applications and case scenarios. The student must reflect and implement the concepts learnt in the studio in a different situation.
- Numerical Questions: These questions focused on testing the student on their ability to apply concepts to numerical problems. The options were designed such that if the students understood the concepts wrongly and applied a wrong mathematical expression they would still arrive at one of the incorrect options. These misunderstandings were later cleared at the end of each question during the Kahoot! quiz.

IV. Results and Discussion

In this section, the quantitative results from Kahoot! SRS and a survey on student perception of usage of Kahoot! SRS are presented. The survey was optional, voluntary, and anonymous. Out of a cohort size of 123 students, 115 responded to the survey.

A. Data from Kahoot! SRS

Kahoot! quizzes were conducted in 11 studio sessions over the course of the semester. Each quiz session had 8 questions on an average. A record of each student's answer response for a question along with the student's time taken and score is provided. Time allocated by instructor for a question is also captured. In total, there are 96 questions for the 11 studio sessions and about 8500 student responses.

B. Distribution of question categories

The three categories of questions - Conceptual, Application and Numerical, were well-represented in numbers over all the studio sessions. The distribution of question count for the three categories are presented in the form of a histogram in Figure 3.

C. Time taken to answer questions

Each question is labeled belonging to only one of the three question categories. The average time taken by students to answer questions of a certain category decomposed on whether the responses were correct or incorrect is shown in Figure 4 in the form of a bar plot. It can be seen from Figure 4 that overall, the average time taken for correct responses for all the categories is lesser than that of incorrect responses. As would be expected, responses to conceptual questions are faster than that to application-based and numerical questions.

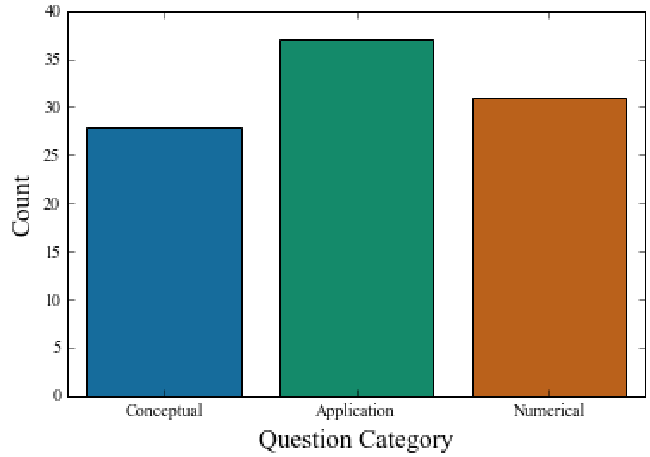

Fig. 3. Histogram of questions counts across the different question categories

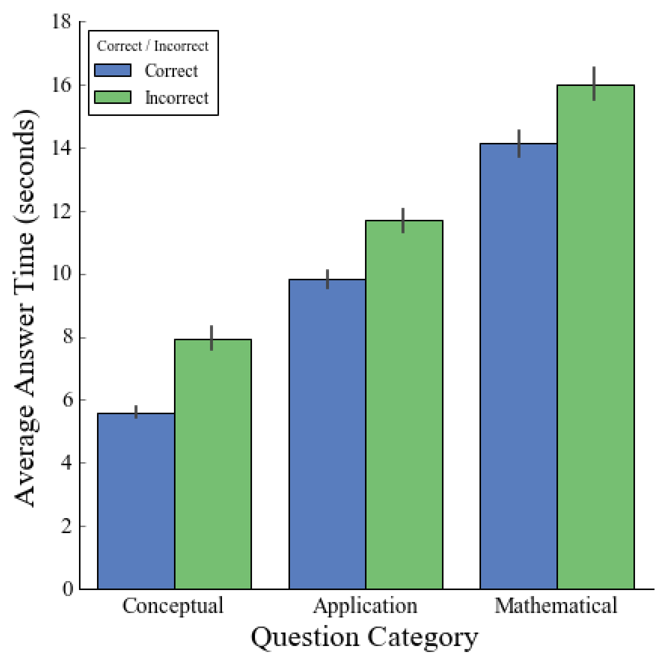

Fig. 4. Average Answer Time for the different Question Categories across Response result

D. Correctness Proportion vs Answer Time

Fast average time responses may not shed information on the proportion of students who got the answer correct for a particular question. In Figure 5, the proportion of correct responses is plotted against the average time taken for each of the questions. The questions are also labeled according to the question category they belong to.

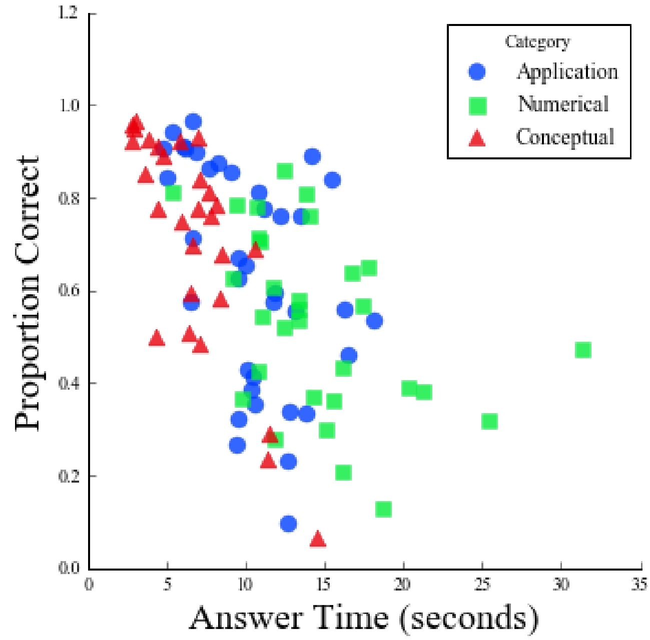

Fig. 5. Scatter plot of proportion correct for a question versus the average time taken by correct responders over different question categories

From Figure 5, we can observe that for most of the conceptual questions, the responses are fast and the correctness proportion is also relatively high. This can be inferred from the fact that the data points associated with conceptual category is clustered around the top left region of the plot.

The spread of application category questions' data points along the answer time axis is quite low, however, the proportion correct is largely variant. Numerical questions on the other hand, are scattered around the plot. This may be a result of the difference in the mathematical difficulty of different numerical questions.

To observe the correctness proportion in particular across the different categories, we have plotted the distribution of correctness proportion in a bar plot in Figure 6.

E. Student Perception of Kahoot!

At the end of the semester, a survey on the usage of Kahoot! SRS was conducted to learn about students' perceptions. Students were asked to provide their feedback on whether Kahoot! helped them to understand, apply and reflect on the material taught in the studio sessions. Also, feedback was sought on whether Kahoot! helped in peer learning and whether the prizes provided for Kahoot! quiz winners acted as a source of motivation.

The students were posed the following questions and their responses were obtained on a likert scale. A 5-point ordinal scale was provided to the respondents to rate the degree to which they agree, disagree or neutral to each of the questions. The choices for the responses were - Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree.

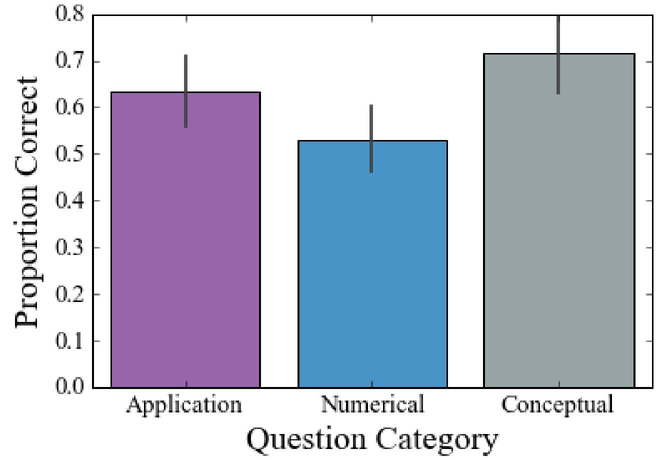

Fig. 6. Correctness proportion over the different question categories

- **Q1** - Do you think Kahoot! quizzes helped you to **understand** concepts during studio sessions?
- **Q2** - Do you think Kahoot! quizzes helped you to **apply** concepts during studio sessions to solve problems?
- **Q3** - Did the **prizes** awarded for the Kahoot! quizzes performance **motivate** your learning?
- **Q4** - Did Kahoot! quizzes help you **reflect** on the quality of your learning?
- **Q5** - Did Kahoot! quizzes help you learn with your **peers** ?

Analysis of the survey results shows that more than 90% of the students agree that the usage of Kahoot! helped them understand, apply and reflect on the material taught in the studio sessions.

Analysis of the student perception survey results are presented in Figure 7. For all the questions, the bars representing "Agree" and "Strongly Agree" response counts (green and blue color) are prominently high. The number of votes for "Disagree" are relatively low across all questions, and those for "Strongly Disagree" was 0 for three questions. The survey results show that Kahoot! quizzes were favored by the students and that they did have a perceived impact on the students' learning.

V. Conclusion and Future Works

This study analyses the benefits of using a game-based student response system (Kahoot!) to augment experiential learning in an introductory engineering course offered for the freshman computer engineering cohort. Kahoot! was used to supplement the ungraded studio sessions of the course to address the lack of indicators that assess the active implementation of theory in these sessions. It was found that using Kahoot! aided the instructors to obtain real-time feedback of students' comprehension of the studio learning outcomes. This was used as a formative assessment to identify and rectify gaps in student understanding.

The design of the Kahoot! questions ensured that the students actively implement their reflected observations and

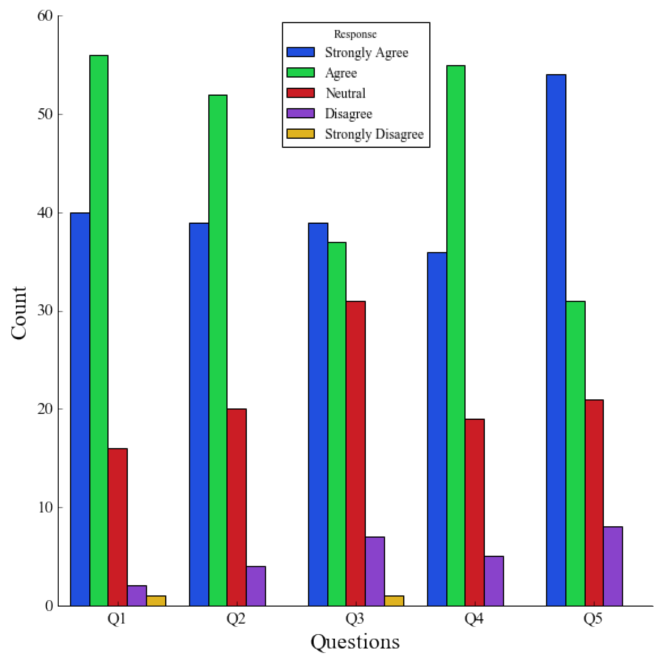

Fig. 7. Analysis of student perception survey results

corresponding formulated theories from the studio sessions to deepen the understanding of the fundamentals involved. This is evident from the qualitative analyses of the Kahoot! data across all question categories.

The feedback from the survey validates our assumption that introducing a game-based student response system promotes student learning in an experiential learning environment.

This study can be enhanced to give deeper insights on student understanding by labeling each category question as '*easy*', '*medium*' or '*hard*'. An extension to this framework could be to challenge students with deeper Kahoot! questions for attempt outside the studio session.

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