Gamification in a graduate fluid dynamics course

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Abstract

Active learning has become a dominant paradigm in STEM education. Numerous studies have demonstrated the efficacy of active learning techniques in the context of undergraduate STEM courses[1, 2]. However, there is less research on the use of these techniques in the context of graduate courses. The current work studies the use of gamification, a game-based active learning technique, in the context of a graduate-level fluid mechanics course. The study uses the gamification software *Kahoot!*[3] as a tool in a graduate fluid mechanics course. In *Kahoot!*, students use their own device (cell phone, tablet, or computer) to answer multiple choice questions in a game-like format with vivid colors and music. A scoring system and leaderboard motivate students to answer questions swiftly and accurately. The goal of this study is to understand best practices in the implementation of gamification in the graduate engineering context, and to understand student responses to the gamification approach.

Keywords

Kahoot!, gamification, graduate, fluid dynamics

Introduction

This study focuses on the use of gamification as an educational technique in the context of a graduate engineering course on fluid dynamics. Gamification is a type of active learning technique which asks students to play educational games during the course in order to increase engagement with the course material[4]. Educational techniques like gamification are heavily studied in the context of undergraduate engineering courses, and there has been great success in increasing student outcomes associated with games[4-7]. One such platform that is commonly used[4-7] is *Kahoot!*[3], and hence *Kahoot!* will be used for this study. Although gamification is well studied in the undergraduate context, there has been less research on the use of such techniques in the graduate context. As noted in[4], *Kahoot!* quizzes "cannot ask open-ended questions or receive open-ended responses", and therefore the format is less amenable to use in upper-division courses. Another important factor to consider for graduate division course is student resistance, that is whether student take the *Kahoot!* quiz to be a truly educational format or whether they take it to be a gimmick. Little research in this area exists, however, Ref. 8 details some strategies to overcome this particular difficulty. (Resistance will not be a focus of this study.)

Methodology

The platform chosen for the study was *Kahoot!*[3], a free educational software platform designed for making educational games. *Kahoot!* is multiplatform and is available online or using

specialized apps for the cellphone or ipad. *Kahoot!* has been used in numerous studies on gamification[4-7]. *Kahoot!* consists of a multiple choice question and answer response system. The *Kahoot!* interface displays the questions using a vibrant color scheme and motivating music. The interested reader is referred to the extant literature for more information[4-7].

In the course, *Kahoot!* exercises were generally administered mid-class, and they covered material that was demonstrated in either the current class or the previous class. Over the course of the semester two varieties of *Kahoot!* exercises were tested herein called Short Form (or Standard) *Kahoot!* and Long Form.

Limitations of *Kahoot!*

From experience, I note that the *Kahoot!* platform is most easily geared towards short, plain language questions and responses. This is also noted in[4]. However, more detailed graphics and explanation can be supplied as an included image. This is important for the ability to use *Kahoot!* for quizzes in advanced engineering and science courses. Many such question will require either the use of graphics, the inclusion of mathematical fonts that are non-standard to the *Kahoot!* online editor, or both. For this reason, I took the strategy of generating questions and solution as a separate written document, and including an image of this document within *Kahoot!*. Students were then tasked with choosing **A**, **B**, **C**, or **D** in the Kahoot! interface. (See Figures 1 and 2 below.)

Short Form (Standard) *Kahoot!* exercises were simple quiz questions. Students were typically given 60 seconds to read the question, ask for clarifying information, and answer. I have informally observed that most students answer the question quickly, however, at least one student always takes then entire time period. This suggests that including a known time limit causes students to want to max-out, in order to minimize the chance of error. However, this is to a certain degree, antithetical to the purpose of the *Kahoot!* quizzes, which is to provide fast feedback to the instructor. This will need to be investigated further in the future. Short Form exercises were most conducive to testing simple definitions or concepts. It is therefore recommended that the theory of ConcepTests[9] may be useful for the development of short form exercises.

An example short form *Kahoot!* is given below and discusses Einstein summation convention for tensors. The convention represents the contraction of two first order tensors using doubled subscripted indices. Since the resulting expression is a scalar, it cannot be contracted further, and, accordingly, any index can appear at most twice. This point was made in the lecture and explained using an example in class. Students who understand the principle will easily notice the response to the *Kahoot!* question as, **A**, which contains more than two occurrences of the index, j.

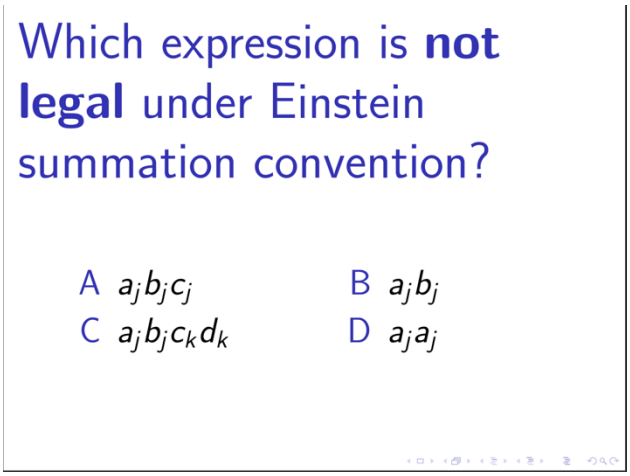

Figure 1: A standard *Kahoot!* exercise.

Long Form *Kahoot!* exercises were more complex quizzes that hybridized traditional quizzes with Short Form *Kahoot!* exercises. For a graduate course, it may be appropriate to delve into problems that are more difficult than can be understood through 60 second questions. In this form students were given a quiz question to work on for 5 to 15 minutes depending on the difficulty. Then a standard *Kahoot!* was given which delved into the concepts necessary to solve the quiz problems. These questions may include the actual solution or ancillary information such as the boundary conditions used to find the result or an intermediate solution.

An example question given in the course covered the topic of the Lamb-Oseen vortex, circulation, and boundary layers. The students were given 10 minutes to

1. Compute the quantity Q_c, defined as the line integral of velocity around a closed curve. They were tasked to compute Q_c for the Lamb-Oseen vortex and a solid-like body rotation.
2. Take the inviscid limit of this line integral for the Lamb-Oseen vortex.
3. Compare that result to the infinite radius solution of the Lamb-Oseen vortex.

They were then given a standard *Kahoot!* quiz (Figure 2). The first question merely requested the answer to (3). Since students already had, in this case, 10 minutes to solve the problem. They were given only 20 seconds to respond to the result, **D**. This exercise also implicitly introduced the idea that Q_c is in fact the circulation, which had been previously discussed without a formal definition. After emphasizing this fact, and discussing some properties of the circulation, students were asked a standard *Kahoot!* question about the circulation. In this case, they were supposed to know that the circulation does not depend upon time for an inviscid two-dimensional flow, **A**.

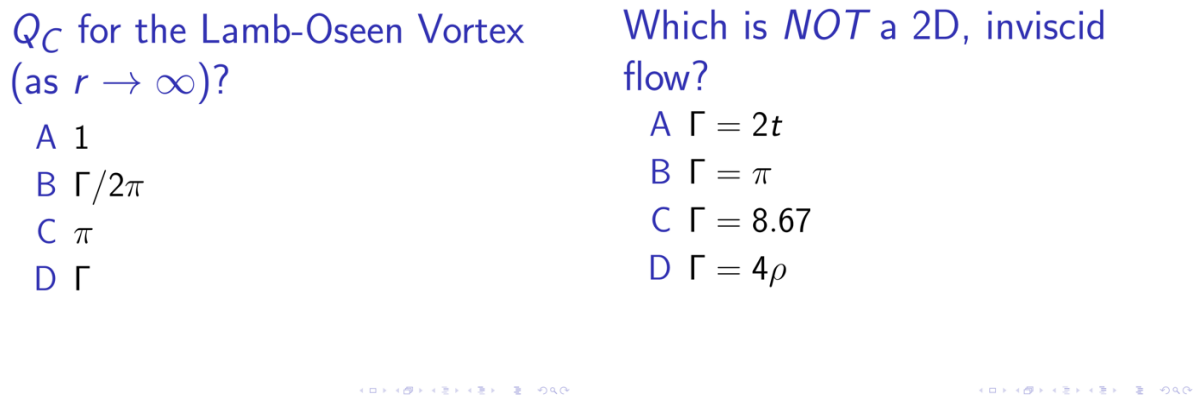

Figure 2: A Long Form *Kahoot!* exercise that requires knowledge from a previously administered quiz.

Evaluation of Learning

The effectiveness of *Kahoot!* was self-assessed by the students through the administration of a survey. Notwithstanding the inherent limitations of self-assessment in education[10], it was important for this initial study to get some initial data which can be used to motivate more rigorous studies in the future. The survey asked students about the effectiveness of *Kahoot!* in terms of increasing engagement with the course materials, and with respect to actually causing the students to learn more. Additionally, the students were asked to compare the efficacy of the *Kahoot!* to traditional quizzes, and further were asked to compare Short Form quizzes to Long Form quizzes. To encourage participation, I offered one bonus point on everyone's exam grade, if 80% of the students completed the survey. (Since the survey was completed anonymously, there was no way to offer targeted rewards to only those who participate.)

The data from the surveys suggests that *Kahoot!* can be a useful tool in graduate education. The self-assessed data suggests most students benefited from using *Kahoot!* in the classroom while the remainder saw neither benefit nor detriment. In particular, *Kahoot!* appear to increase student engagement with the material, and help students to learn new material, and are both more engaging and effective at stimulating learning than traditional quizzes. Students generally preferred Long Form *Kahoot!* quizzes to Short Form (Standard) quizzes because they do a better job of testing for depth of knowledge. The incorporation of more deep exercises such as these will be important for the use of educational games in advanced courses.

Future work will seek to understand how to best tune *Kahoot!* questions to enhance student learning for graduate and upper-division undergraduate courses.

Raw Data

Have you used Kahoot quizzes (or similar technologies) in any previous course?

- Yes ***4/11***
- No ***7/11***

Would you say that Kahoot quizzes make the classroom environment more engaging?

- True ***6/11***
- Neither true nor false ***5/11***
- False ***0/11***

Would you say that Kahoot quizzes help you to learn more effectively?

- True ***9/11***
- Neither true nor false ***2/11***
- False ***0/11***

Would you say that Kahoot quizzes are at least as engaging as traditional quizzes?

- True ***8/11***
- Neither true nor false ***2/11***
- False ***1/11***

Would you say that Kahoot quizzes were at least as effective as traditional quizzes for helping you to learn?

- True ***8/11***
- Neither true nor false ***1/11***
- False ***2/11***

Which type of Kahoot! exercise did you find most engaging?

- Short Form ***1/11***
- Long Form ***5/11***
- Both are equal ***5/11***

Which type of Kahoot! exercise was the best at helping you to learn new material?

- Short Form ***2/11***
- Long Form ***7/11***
- Both are equal ***2/11***

Would you recommend the use of Kahoot! quizzes in future iterations of this course?

- Yes ***9/11***
- No ***2/11***

References

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Biography

John Palmore Jr is an Assistant Professor in the Mechanical Engineering Department at Virginia Tech. He specializes in multiphase thermo-fluid flows. Dr. Palmore's technical research focuses on developing numerical algorithms for simulating these flows using high performance computing. His educational research focuses upon incorporating technology into the classroom. Dr. Palmore is an active member of several professional societies including the American Institute of Aeronautics and Astronautics, the American Society of Mechanical Engineers, the Society for Industrial and Applied Mathematics, and the National Society of Black Engineers.