

Incorporating Games into Circuits Instruction with Kahoot!

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Abstract

Gaming as used for eLearning is becoming more popular and is widely used in blended and flipped classroom teaching modalities. Many platforms exist to assist instructors in developing game play to teach STEM related subjects. In this paper we explore using Kahoot! as a platform to teach concepts in a basic electrical circuit analysis course. We investigate the structure of Kahoot! and the types of topics we want to explore from circuit analysis. This project is part of a larger plan to explore other gaming platforms and develop novel game platforms to aid in the instruction of STEM based courses. The goal is to create a baseline by which to judge the more complex formats against a known, yet fairly basic, quiz-show type platform as is Kahoot! Since many of the students have experienced Kahoot!, the learning curve will be very small, and we will be able to establish assessment norms by which we can evaluate further development. While this paper explores the use of Kahoot!, ultimately, the aim is to develop a game based on student outcomes and through the use of feedback develop early intervention indicators, via the game, which may lead to higher retention rates.

Keywords

Computer-based Instruction, Games, eLearning, Assessment, Electrical Circuits.

Introduction

Instructors are constantly on a quest to engage students to make learning more interesting and fun. Interesting and fun are the hallmark of what games are all about. The challenge is to incorporate the material into the game and maintain the aspects of interesting and fun. The challenge is even more so when dealing with STEM topics that typically require long periods of intense study to master. A game that can hold interest and still convey the required knowledge is the goal of game-based learning.

The shift from a traditional lecture-based class to blended (some of the time in class lecture and some problem solving) or fully flipped (lectures given via videos outside class with class time used for Q/A and problem solving) has made game-based learning more enticing. The instructor may setup games, competitions, or group activities to challenge the students to solve problems in class. The instructor is there to help guide the students for immediate feedback to help develop the skills needed to answer questions.

The majority of the authors on this paper are experienced in teaching electric circuits. Circuits is a challenging subject matter at its core, so any technique to help educate the students is welcome. A long-term goal of the research is to develop an end-to-end circuits instruction platform that concentrates on student outcomes and retention rates, but to reach that goal we have focused our initial effort on the fundamental components of circuits, namely Ohm's law and Kirchhoff's equations. Nearly all other concepts in circuits flow from these fundamental components, hence our decision to start with these.

As mentioned previously, we plan to build a full gaming platform, complete with assessment and learning outcome tools, but that too is a long-range goal that will even surpass the circuits area and move to a more general STEM focus. However, before we can get there, we need to establish a baseline for a gaming environment so we can measure if our future plans increase learning. Due to its relatively inexpensive nature and prior usage by one of the authors, we are using Kahoot! as the baseline gaming tool. Kahoot! is a quiz-based platform that allows the instructor to create quiz-show type game scenarios. It is easily setup with very little learning curve for both the instructor and students. Using Kahoot! we plan to create our initial question sets and establish how a typical student performs using this platform. We are currently in the process of establishing the measurement criteria and game questions we will be using in this initial investigation. The measurement criteria will be then used in the more complex gaming platform.

The main purpose of this paper is to establish the concept and to elicit feedback from colleagues to help us improve our process. The gaming platform will be developed in conjunction with a Senior Design course in Computer Science. The lessons learned from the initial study will then be used to guide the form and function of the full platform.

Games in Education

Opportunities for eLearning abound in formal and informal education with engineering education being no exception. The current generation of students in engineering classrooms have years of exposure to electronic multimedia for education, entertainment, and information. Electronic tools and resources are widely available to both students and educators. Engineering educators have sought to adapt various technologies for eLearning especially in conjunction with instructional approaches that include online, asynchronous, and/or blended learning features.

Games in education offer the potential to improve application of and engagement with the content material. Games can provide elements of active learning, of feedback, of interactivity, and of fun. However, the game design [1] must incorporate the desired content to promote the learning process in meaningful ways, e.g., address one or more cognitive levels as given in Bloom's taxonomy. Engineering educators have active interest in gaming approaches, and related pedagogy is an ongoing research area [1]–[4]. Many of these efforts attest to the improvement in student outcomes.

Educational games can have many forms. Examples include virtual escape rooms in which students solve topical puzzles and role-playing situations with topical tasks [4]–[9]. The format can be elaborate with a video presentation [4, 6, 8] or simple with an interactive quiz format. Students may complete levels, compete against time or other students, or work toward team performance goals [7].

One game option uses available software platforms in which the educator provides the topical content for a selected type of game. Kahoot! [10] is a popular choice and has been used for college courses in several disciplines [9], [11]–[14]. It runs on a variety of student devices, can be live or asynchronous, provides participation and performance results, etc.

Kahoot! as a Platform

For the purpose of our study, we have chosen to use Kahoot! as our gamified learning platform for the initial assessment since some of the investigating group members have prior positive experience of using this platform.

A. Kahoot!

Kahoot! is an online learning tool that is designed to engage students in learning through gamification. We will primarily use Kahoot! for its quizzing features. Instructors can create their own questions or use Kahoot! repository. It can be used in remote or in-person live settings. Student access to Kahoot! quizzes is free though the number of students that can participate in each quiz varies depending on the version that the instructor paid for. Different options are available to be used at school level or to be used by an individual teacher. Two individual teacher

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options that are suitable to our needs are available for less than \$10 per month (excluding any current promotional pricing) as of July 2023.

B. Kahoot! Question Types

For the reasonably priced versions (under \$10 per month), the question types include (a) Multiple choice with a single correct answer, (b) Multiple choice with multiple correct answers, (c) True or False, (d) Puzzle (arrange tiles), and (e) Poll. Higher payment options include additional question types, some of these are (a) Type your answer, (b) Slider, (c) Word Cloud, and (d) Brainstorm etc.

For each question, a different time limit can be added. Each question can be designated to have standard points (same calculation for each correct response with submission time taken into account), double points for correct answers, or no points at all, etc. The quiz can be set up to be played live during a class or can be assigned to be completed outside of the class time. For the live setting, the instructor starts the quiz on their end and a screen with instructions for students to join is brought up. Students enter the Game PIN shown in instructions and then choose a name that shows up on launch screen projected by the instructor during class. This name is used to track each participant's performance throughout the quiz.

Students can participate in the quiz using a phone, tablet, or a laptop etc. using the Kahoot! app or website. On their screens, students see all of the answer options as color and shape coded. Students then click or tap on their chosen answer option and submit their response. Figure 1 shows a sample question projected on the instructor screen and the corresponding answer options that show up on student devices. The projected question shows the question text, answer options, the time remaining (purple bubble indicates 28 seconds remaining), and number of responses received (purple bubble indicates 0 responses received after first 2 seconds).

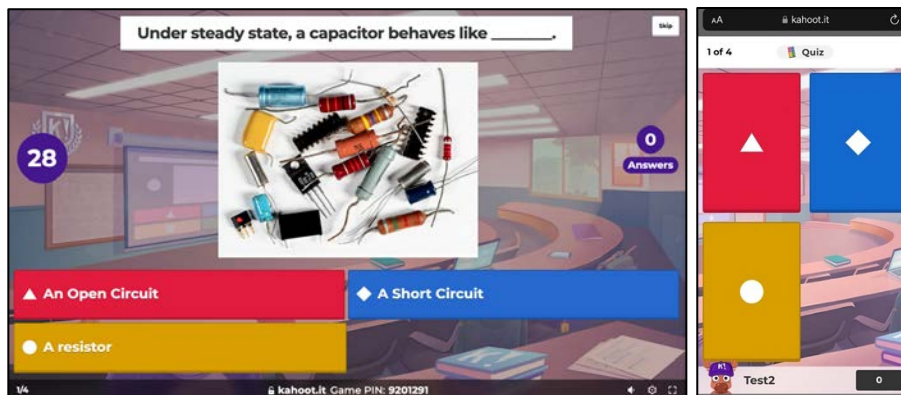


Figure 1: (Left) Projected sample question view on instructor screen visible to all students and (Right) color and shape coded answer options on student devices.

C. Assessment of a Kahoot! Game

Different types of assessment feedbacks are available through Kahoot! These include direct feedback that each student receives after each question and at the end of the quiz, and anonymized group feedback projected on instructor screen after each question, and individual student assessment post quiz. This instant feedback after each question can help an instructor identify common and/or repeated misconceptions and provides an opportunity to revise the misconceptions before building on those concepts. At the same time, students have the opportunity to bring up any gaps in their understanding and ask questions to clarify the concept. Based on the nature of the quiz (first time introduction versus revision etc.), the instructor can repeat the same quiz or bring up another quiz built on the same concepts to give students an opportunity to improve and test their understanding after post-quiz discussion.

The instructor can generate, view, and download different types of report after the quiz has concluded. The instructor can choose to view a summary that includes total number of questions, total number of participants, the percentage of correct responses, and total time taken to conclude the quiz. Other views include an assessment of each player or participant that shows the percentage of correct responses each participant submitted and can be expanded to see their performance for each question. A report is also generated for each question showing the number of correct and incorrect responses received thus, identifying the concepts that students might need more help with. Figure 2 shows a report generated for each question. This can be further expanded to view feedback on each answer option.

The screenshot shows a Kahoot! report interface with tabs for Summary, Players (14), Questions (4), and Feedback. The 'Questions (4)' tab is active. At the top right, there are buttons for 'Expanded view' and 'Compact view'. Below the tabs, there is a search bar and a dropdown menu for 'All (4)'. The main content is a table with columns for 'Question', 'Type', and 'Correct/incorrect'. The table lists four questions with their respective types and correct response percentages.

Question	Type	Correct/incorrect
1 A resistor does not absorb any average power.	True or false	93%
2 An AC load is said to consume power at -45° of power angle. The power factor is _____ type.	Quiz	86%
3 An AC load is said to consume 100 VA of power. This is _____.	Quiz	64%
4 An inductor does not absorb any average power.	True or false	71%

Figure 2: Kahoot! generated report showing statistics on correct (green) and incorrect (red) responses for each question after the conclusion of a quiz.

The assessment can be anonymized by asking students to use dummy names or the instructor can require that the students use their own name to participate in which case the instructor can follow each students' progress over time and intercede when needed. The intervention could connect a student with additional resources or help to identify individual challenges prohibiting them from

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achieving learning outcomes. The summary report identifies the students that may need help based on their scores and those students who did not finish responding to either some or all of the questions in time. Feedback driven individual intervention is only possible if the students can be identified. End of the quiz reports are generated for both live and assigned versions of the quiz.

Game Content for Electrical Circuits

The foundation of electrical circuit analysis is Ohm's Law, power, parallel and series components, and Kirchhoff's Current and Voltage Laws. Students often struggle with mastering these basic concepts making later material which builds upon these principles more difficult for them.

A. Selected Concepts

The initial concepts chosen for this project were mesh current and node voltage analysis. These are fundamental tools in electrical circuit analysis and depend upon many of the basic concepts with which students struggle. This allows for a hierarchy structure of tasks beginning at the most basic level of identifying nodes, for example, to the more complex tasks of solving for mesh currents or node voltages in given circuits.

At the beginning level, tasks consist of:

- identifying nodes, loops and meshes,
- assigning polarity of voltages and directions of currents,
- determining currents and voltage for short circuits and open circuits, and
- determining currents and voltages based upon parallel and series combinations of components.

At the intermediate level, tasks move to applications of the basic concepts from the beginning-level tasks such as:

- using Ohm's law to express the current through a resistor in terms of the voltage across it,
- using Ohm's law to express the voltage across a resistor in terms of the current through it,
- using Kirchhoff's Current Law (KCL) at nodes and over larger portions of the circuit,
- using Kirchhoff's Voltage Law (KVL) around paths in the circuit including across open circuits, and
- dealing with voltage and current sources in KVL and KCL equations.

Finally, advanced level tasks using concepts covered in the beginning and intermediate task include:

- setting up and solving mesh current and node voltage problems and
- identifying and incorporating supermeshes and supernodes in mesh current and node voltage problems.

B. Mapping Question to Content Type

The basic question types in Kahoot! are multiple choice with either single or multiple answers, true/false, poll, and a puzzle or arranging tiles in order. These provide excellent avenues for addressing beginning level concepts as shown in Figure 3.

1. A $10\ \Omega$ resistor is in parallel with a short circuit. What is the total resistance across the resistor terminals?
 - a. $0\ \Omega$
 - b. $10\ \Omega$
 - c. Infinite
2. A $10\ \Omega$ resistor is in series with a short circuit. What is the total resistance across the resistor terminals?
 - a. $0\ \Omega$
 - b. $10\ \Omega$
 - c. Infinite
3. A short circuit appears in parallel with an open circuit. What is the effective resistance?
 - a. $0\ \Omega$
 - b. Infinite
 - c. Need more information

Figure 3: Sample Kahoot! Multiple Choice Questions for Open and Short Circuits

The more advanced package for Kahoot! contains a word cloud, type your own answer, slider responses, brainstorming, and open-ended questions as well allowing the students to use “audio” for the question to be read aloud. Some of these features would be very useful in the more advanced concepts. For now, the project will limit itself to the basic package and focus on development from the ground up.

C. Mapping Content to Learning (Six Bloom’s Taxonomy Categories)

Bloom’s Taxonomy offers educators a guide to structure their courses’ learning objectives for optimal learning [15]. The proposed gaming tool activities and assessments, to enhance learning, will use the Taxonomy list created for the cognitive domain [15]. Table 1 shows the learning concepts/objectives chosen for each learning level.

Table 1: Mapping planned gaming activity components to Bloom’s taxonomy levels.

Taxonomy Level	Mesh & Node Analysis Component
Knowledge	<ul style="list-style-type: none"> • Identify the circuit components in each circuit. • Identify the number of nodes, loops, and meshes in each circuit. • Identify the polarity of the different voltages, and direction of the different currents in each circuit. • Identify the controlling voltages and currents for dependent sources in each circuit. • Identify the supernodes and super meshes, if any, in each circuit.
Comprehension	<ul style="list-style-type: none"> • Using Ohm’s law, calculate either the voltage across a resistor or the current through the resistor given other quantities. • Determine current and voltage for short circuits and open circuits. • Determine currents and voltage based upon parallel and series combinations of components. • Apply and verify Kirchhoff’s Current Law (KCL) at nodes in a circuit. • Apply and verify Kirchhoff’s Voltage Law (KVL) in loops/meshes in a circuit.
Application	<ul style="list-style-type: none"> • Using Ohm’s law to express the current through a resistor in terms of voltage across it. • Using Ohm’s law to express the voltage across a resistor in terms of current through it. • Using KCL at nodes and over larger portions of the circuit • Using KVL in meshes and around paths in the circuit including across open circuits. • Dealing with voltage and current sources in KVL and KCL equations.

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Analysis	<ul style="list-style-type: none">• Setting up and solving mesh-current and node-voltage problems.• Identifying and incorporating supermeshes and supernodes in mesh current and node voltage problems.
Synthesis	<ul style="list-style-type: none">• Create your own open-ended mesh-current and node-voltage problem/solution based on set criteria.
Evaluation	<ul style="list-style-type: none">• Evaluate the completion and correctness of the solution considering a time-based assessment.

Each mentioned component, in Table 1, will form an assessment activity in the Kahoot gaming environment. The overall goal, of the planned activities, is to train students to successfully solve the final exam time-based problems.

Summary and Implementation Plans

In this paper we have constructed an initial plan to use gameplay to assist in STEM-based education. Our initial target area is that of fundamental concepts in electrical circuit analysis. Our baseline game platform is Kahoot! Using these, we are in the process of establishing the game questions and assessments for game-based learning.

Kahoot! provides a wonderful baseline due to its well-established user interface, simplicity in use, and basic level quiz format. We will be able to experiment with multiple question types to establish what will provide the most help to a typical student in a circuits course and what, if any, does gameplay assist in learning.

The choice of starting with circuit analysis has more to do with the expertise areas of the authors than anything else, yet it is an extremely challenging and rich subject area to develop the questions and test our hypotheses of game-based learning. While the ultimate goal is to develop the platform for a full course in circuits, and even courses beyond circuits, to help focus the scope of the initial stage of the project we selected to focus on the fundamentals of circuit analysis. Ohms' Law and Kirchhoff's Laws form the basis of all circuit analysis and are the most logical starting points for this research.

The final gaming platform is the most unknown part of the project. For this reason, we will be eliciting the help of the Senior Design class in Computer Science to help develop a game platform. The design teams will be given the base concept in the first semester of their Senior Design course and allowed to select a platform to develop a game around. Within the Senior Design ecosystem, students will be encouraged to explore how their game facets may map to

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learning concepts within Bloom's Taxonomy to potentially generalize their game platforms beyond the circuits examples. The most promising game platform would then be selected for full development in the second semester. While this is occurring, the knowledge gained from the Kahoot! experiments will help guide the students into the types of problems students in circuit analysis run into and where they need the most instruction.

Further development may see the addition of external devices to add hands-on, physical experiments that the student will need to perform to advance in the game. One concept is to have a small circuit board connected via a microprocessor to a host computer where the student will have to construct a circuit or predict a parameter value based on the analysis from the game. Finally, and potentially the most critical component of the research, will be to establish learning outcomes and measures. In order for this project to be useful to future instructors, knowledge about what to expect and how to measure the success of their students will be important. Our goal is to provide the student with a learning environment that stimulates and enhances learning, knowing what to expect will be invaluable to the instructor of the course.

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