LogIO: An Adaptive Gamification Learning Approach on Digital Logic Gates

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Abstract. The gamified e-learning approach has been widely used as a learning and teaching strategy, particularly in higher education. This strategy has been successfully used to engage, motivate, and enhance learning performances. However, learners or students react differently to game designs and game mechanics depending on the subject area that a particular gamified application though there are several studies shows that gamification enhances motivation. In this paper, we designed and implemented a specific learning model for the gamified digital logic gates or LogIO. Thus, thirty (30) learners evaluated and we determined how do game design elements affect learners in terms of motivation, performance, and learning experience. The main results of this study showed that learners agreed that the motivation level and usability of LogIO have a weighted mean of 4.56 and 4.49 respectively while performance and learning experience level has 81% during the utilization of the gamified mobile application. These results support the significance and relevance of adapting particular design elements for gamified digital logic gates to enhance motivation, performance, and learning experience.

1. Introduction

Nowadays, the e-learning approach is a common tool in both teaching and learning experience particularly in higher education. Thus, increasing the effectiveness, motivation, performance and learning experience of students can be achieved through gamification. Gamification has become increasingly popular as an e-learning concept in higher education that needs to be properly integrated to have achieved a positive impact on both learning and teaching process which promotes satisfaction on motivation and engagement of learners [1] and [2]. There are several studies that give lots of game design elements and yet, it remains a challenge in determining which particular design element that actually affects learner’s motivation, performance and a learning experience [3]. The proper use of game design principles is significant in leading game to motivation which then leads to learning and improved performance [4].

Teaching digital logic gate is a complex area where discussions and explanations should be accompanied with actual tools and electronic components which clearly demonstrates its operation. In the Philippines, the utilization of a gamified medium of instruction has revolutionized. As a matter of fact, the Secretary of Department of Education, Leonor M. Briones emphasized that ICT instructors or professors should devise teaching methods and strategies that will enhance creativity and motivation among learners [5] and it is time to adopt gamification strategy in education.
This paper focuses on determining how do game design elements affect learners in terms of motivation, performance and learning experience. More specifically, this paper presents an evaluation on the usability of a mobile application model of a gamified approach on learning digital logic gates in terms of usefulness, satisfaction and ease of use of the learning model.

2. Related Work
One of the focus of this study is to develop gamification with design elements for game mechanics and game dynamics specifically for learning digital logic gates. Strmečki et al. [6] presented the gamified design elements which correspond to the elements used in the research with a goal of investigating the effectiveness of gamification of an informatics online course against the conventional presentation of online learning content using text and illustrations. The result in their study indicated that an online gamification course related to computer graphics resulted in greater online course achievement. Similarly, Barata et al. [7] introduced gamification as a novel technique that applies game elements to non-game contexts to engage users and solve problems. Learning experience on a non-gamified and the gamified form of the course was compared and assessed their impact on student performance and satisfaction with a goal of introducing multiple game design elements into the course design, including experience points, levels, etc. The results in their study suggest that based on the number of lecture downloads and the number of online posts, the gamified course application will lead to greater student engagement in online course activities.

Meanwhile, Dominguez et al. [8] emphasized that gamification in e-learning platforms seems to likely increase student motivation, but it’s not trivial to achieve that effect, and for it to be fully motivating for participants a big struggle is needed when it comes to the design and implementation of the experience. Their study aims to make a pragmatic indication in the field by designing, implementing and evaluating a gamified learning experience in tertiary education. The results of their study suggest that utilizing games in the field of education can be challenged on common beliefs about the benefits being obtained.

It is stated in the study of O’Donovan et al. [9] that tertiary education generally lacks an emphasis on engaging elements that help motivate active learning. The goal of their study is to improve interaction, understanding the topic, problem-solving skills, and engagement through gamification which have a great impact on the goal of our study. The results of their study show that gamification techniques used in their design significantly improved students’ understanding and particularly their engagement. Furthermore, Osipov et al. [10] presented the new strategy to evaluate gamification tools in the e-learning approach which not only allows to deport quality training but presents an opportunity for statistical analysis of different parameters which are found in the log files in order to assess the effectiveness of the technical and pedagogical tool.

There are various studies on digital logic gates that are designed in different platforms such as web-based courseware, computer-aided application, simulators, etc. Mohandes et al. [11] stated that online courses in the electrical engineering curriculum can enhance both the teaching and learning processes since the digital logic circuit design course is the core and pre-requisite for a higher-level course in the areas of digital systems in electrical engineering course. The goal of this study is to develop a gamification application that will provide a convenient and self-paced e-learning tool for teaching and learning the fundamentals of Digital Logic Gates.

3. Design and Implementation

3.1. Design of Learning Model
The proposed gamification model for the digital logic gate is illustrated in Fig. 1. The model is composed of three (3) factors to consider in the development of digital logic gates gamified application which are principles of gamification, design elements for gamification, and student engagement parameters. This model was used as a guide in the development of the LogIO gamification for digital logic gates to enhance learners’ motivation, performance and learning.
experience. Logic Gates runs with input and output and it is significant to name the gamified mobile game as logic gates with input and output or LogIO.

![Gamification Principles](image1)

**Figure 1. Proposed Gamification Model for Digital Logic Gates.**

3.2. Implementation

LogIO was developed on top of Windows platform which supports 64-bit Android Emulator technology using an android studio. A minimum disk space requirement of 4GB (500MB for IDE + 1.5 GB for Android SDK and emulator system image). Also, a minimum screen resolution of 1280 x 800 is required. The content of the application is implemented in the English language as what is also used in one of the reference books of Moris M. Mano in the subject Logic Circuit and Switching Theory. The game starts with a quick review on binary systems which was included in the game for it is a pre-requisite topic for logic gates. Boolean Algebra and its properties, Boolean functions, logic operations, digital logic gates, and integrated circuits are the topics covered on the LogIO game [12].

3.3. Game Design Elements

Several game design elements were used and identified in numerous studies which make an application complicated and may not be relevant in the development and implementation for a gamified logic gate. This study identified the game design elements that are most significant and appropriate in the development of the gamified LogIO such as story and rules, points, levels, challenges, leaderboards, and time constraints.

As illustrated in figure 2a, the begin button will give the story and rules through a map that needs to be accomplished in sequence. The player cannot proceed with the next level as long as the current level is not yet accomplished where points will be earned at every level with different challenges. For example, a player could not play games on the integrated circuits (IC’s) once the game on logic operations are not yet done, this will make the player hooked and motivated in the game. Figure 2b shows that once a challenge is completed, an item will be unlocked as a reward and can be used in the next level or challenge. In this feature, performance and learning experience will be enhanced as the player unlocked levels of different topics. Leaderboards are also integrated to enhance a player’s motivation as ranking and statistics are shown based on the gameplay. Time constraint is significant in the game design to show how a player performs and enhance his/her learning. Figure 2c shows the logs and game statistics every time a player completes a level to enhance a player’s motivation.
4. Results and Discussion
The researchers administered an evaluation on the LogIO via convenience sampling in order to determine how do game elements affect the learners in terms of motivation, performance and learning experience. Simultaneously, thirty (30) BS Electrical Engineering students were randomly selected from different sections who have not yet taken the Logic Circuit and Switching Theory subject where digital logic gates are part of the course have evaluated the application. Different survey instruments were used to measure the motivation level, performance and learning experience level as well as the usability of the game.

4.1. Motivation
The researchers utilized the Instructional Materials Motivation Survey (IMMS) designed by Keller to measure and analyze the motivation level based on the four (4) components that affect motivation in the learning process such as attention, relevance, confidence, and satisfaction (ARCS)[13]. The IMMS survey was designed to examine the motivation levels whether the e-learning material is lined with the motivation principles. This instrument has been used, applied and proved to be consistent and valid in examining learner’s motivation for an e-learning application [14] and [15].

| Criteria        | Weighted Mean | Description   |
|-----------------|---------------|---------------|
| Attention       | 4.60          | Strongly Agree|
| Relevance       | 4.70          | Strongly Agree|
| Confidence      | 4.43          | Agree         |
| Satisfaction    | 4.50          | Strongly Agree|
| **Pooled Mean** | **4.56**      | **Strongly Agree** |

Legend (5-point Likert Rating Scale): Strongly Agree (4.50-5.00); Agree (3.50-4.49); Neutral (2.50-3.49); Disagree (1.50-2.49); Strongly Disagree (1.0-1.49).

Based on the responses of the students who responded on the survey after using the LogIO, the researchers tallied and computed for the weighted mean of a different parameters of each criterion as well as the general weighted mean. Table 1 shows that the attention factor of the gamified application has 4.60 weighted mean which means strongly agree responses. Confidence has 4.43 and satisfaction have 4.50 weighted mean and relevance has the highest weighted mean of 4.70. The general weighted mean is a strongly agree value of 4.56 which shows that the motivation level of LogIO is high and may be helpful in enhancing learners’ motivation.

4.2. Performance and Learning Experience
To provide insights on the digital logic gates gamified application, mobile application reporting in google analytics (GA) will be utilized in this study to measure the learning experience of the learners.
Application reporting in google analytics is natively integrated with Firebase which is a google application developer platform, in order to provide reporting of distinct events. This will help the researcher understand clearly how the users or players behave during the utilization of the gamified mobile application. Table 2 showed the list of features that the application will log.

Table 2. Measure on Performance and Learning Experience.

| Criteria                  | Description                                      | Percentage |
|---------------------------|--------------------------------------------------|------------|
| Earned Points/Rewards     | When a player has earned points in the game application. | 81%        |
| Level Up                  | When a player levels-up in the game.              | 81%        |
| Spend Points/Rewards      | When a player has spent points in the game.       | 82%        |
| Tutorial Begin            | When a player selects and begins with tutorial.   | 82%        |
| Tutorial Completed        | When a player completes the tutorial in the game. | 79%        |
| Unlocked Achievement      | When a player unlocks an achievement.             | 77%        |
| **Average percentage**    |                                                  | **81%**    |

As players utilize the application, some criteriato measure the players’ behavior in terms of performance and learning experience such as earned points, level-ups, spend points, tutorials begin and completed, and unlock achievements were recorded. Table 2 shows that the average percentage of frequency on performance and learning experience criteria is 81% with a base of zero (0). This means that a high percentage of utilizing the game with the integrated game design elements has also increased performance and learning experience level.

Figure 3 notably shows that the greatest percentage of LogIO players were interested in the game as the criterion for starting tutorials has 82% followed by both earned points and spend points. This simply shows that once a player keeps on accessing the tutorial page, the player is performing as well as learning as earned and spend points goes hand in hand and were also with a higher percentage of 81%.

![Figure 3. Percentage result on performance and learning experience criteria.](image)

4.3. User’s Evaluation

Shown in table 3 is the respondent level of evaluation to measure the usability of the LogIO gamified application for Bachelor of Science in Electrical Engineering of Camarines Norte State College. The study adopts the USE questionnaire in measuring the usability of the application in terms of usefulness, satisfaction, and ease of use [16]. In summary, the weighted mean of usefulness is 4.52 which means that the application is effective, productive and useful, satisfaction has a weighted mean of 4.43 which is interpreted as respondents agreed to be satisfied in using the application while ease of
use has a weighted mean of 4.53 which means that the application is user-friendly and flexible. The overall weighted mean has 4.49 in which respondents agreed for the usability of the game application.

| Criteria                  | Weighted Mean | Description |
|---------------------------|---------------|-------------|
| LogIO as to Usefulness    | 4.52          | Strongly Agree |
| LogIO as to Satisfaction  | 4.43          | Agree        |
| LogIO as to Ease of Use   | 4.53          | Strongly Agree |
| **Pooled Mean**           | **4.49**      | **Agree**    |

Legend(5-point Likert Rating Scale): Strongly Agree(4.50-5.00); Agree(3.50-4.49); Neutral(2.50-3.49); Disagree(1.50-2.49); Strongly Disagree(1.0-1.49).

5. Conclusion
Gamification has been widely used in education for decades. This teaching and learning strategy has been successfully used in higher education in order to engage, motivate and enhance learning performances of learners. Thus, adapting game designs and game mechanics that are particularly appropriate and significant in gamified digital logic gates shall enhance motivation and engagement. This paper sought to design and implement a specific learning model for the gamified digital logic gates or LogIO and thirty (30) learners evaluated the gamified application and the researchers determined how do game design elements affect learners in terms of motivation, performance and learning experience using different survey tools. The results of this study emphasized that learners agreed that the motivation level and usability of LogIO have a weighted mean of 4.56 and 4.49 respectively while performance and learning experience level has 81% during the utilization of the gamified mobile application. These results shall be a basis to support the significance and relevance of adapting particular design elements in order to enhance motivation, performance and learning experience not only for a gamified digital logic gates topic but for other subject areas.

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Acknowledgments

The researchers would like to express our gratitude to the faculty, students and administrators of Camarines Norte State College as a higher education institution, for providing necessary inputs that helped the researchers fully understand the course content, and requirements of the subject Logic Circuit and Switching Theory in creating a framework for a gamified learning approach particularly in digital logic gates.