Using Games as a Tool for Electrical Engineering Education: A Literature Review

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Abstract

Game-based learning (GBL) and gamification are becoming increasingly popular among educators and researchers. This paper is the first to explore the history of GBL studies in electrical engineering specifically, and is intended to provide context for future experiments in the field. The review shows that while the number of empirical studies on GBL is growing, there is still very little usable data pertaining to electrical engineering education. The results are generally positive and indicate that GBL can potentially improve student engagement, enjoyment, motivation, competence, teamwork, and grades.

1 Introduction

Faced with a decline in the number of engineering students over the past decade [1, 2] and increased pressure from the industry to produce excellent engineers, [3, 4, 5, 6] some engineering faculty members are seeking out new tactics to improve student engagement and comprehension. Although the traditional lecture-style format is still the predominant mode of instruction in higher education, [7, 8] a recent proliferation of research into active learning has yielded promising results. [9, 10]

The chief tenet of the active learning model is that students learn the most when they spend a significant amount of time on activities which directly engage them with the learning process. [11] In many ways this idea is not new. Homework assignments, laboratory exercises, and in-class dialogues are examples of active learning techniques that have long been regarded as staples of modern education. However, research into active learning as an educational paradigm almost exclusively refers to the use of engagement activities in the classroom, with the instructor typically taking on the role of facilitator. This is in contrast to the traditional transmission model, where instructors act as purveyors and the primary authority of knowledge, and other activities like homework are merely a supplement to lectures. [12] So far, studies done on active learning methodology have pointed to its remarkable success as a teaching tool, and its acceptance as a valid method of instruction is becoming prevalent within the academic community. [9, 10, 11, 12]

With a surge of investigations showing exciting results, many educators are eager to utilize active learning techniques in their curricula. But although there is remarkable interest in their use among education experts, the question of which techniques in particular are the most conducive to student success is still largely unanswered, as evidenced by the wild variations of methodologies that have been explored in research. Some of the methods that have been proposed include project-based learning, problem-based learning, cooperative learning, "think-pair-share" discussions, peer review, role-playing activities, and game-based learning (GBL).

The scope of this paper will focus on the latter approach, and its goal is to investigate the existing literature on GBL and form conclusions about what needs to be done to improve the body of knowledge. The purpose of this review is to support an experiment which will implement GBL in several upper-level undergraduate communication systems courses. The paper will first begin by defining terminology. Second, it will describe the methodology used to obtain current research. Third, it will summarize relevant works in the field and indicate any central themes discovered. Finally, it will attempt to provide recommendations about how future research should be conducted.

2 Definitions

2.1 Game-Based Learning

Game-based learning has been described by most authors as the use of games in the learning process, most often where learning targets are embedded in a game itself. [8, 13, 14] It is sometimes distinguished from *gamification*, which is a framework that generally employs the "veneer" of a game by using specific game elements without necessarily involving complete games *per se*. In this paper, game-based learning will be used as an umbrella term to encompass GBL itself as well as gamification, serious games, and learning activities involving game elements in general.

2.2 Gamification

Gamification is nearly universally regarded as the use of game mechanics and design traits in contexts that otherwise have nothing to do with games. [15, 16, 17, 18, 19] This is the definition that will be used throughout this paper, but some authors have developed other interpretations. One subtle but notable deviation proposed by Hamari, Koivisto, and Sarsa is gamification as the "process of enhancing services with (motivational) affordances in order to invoke gameful experiences and further behavioral outcomes."[20] The perspective offered by this definition places the emphasis on the intention of gamification to mimic the emotional and psychological experiences provided by actual games, rather than simply borrowing their design elements.

The concept of *game elements* refers to specific game mechanics that are used in the gamification process. Examples include **quests/missions** (tasks that players can complete for rewards), **experience points** (a quantitative indication of how much progress a player has made), **badges** (visualizations of achievements), and **leaderboards** (a public table of data showing how much progress each player has made). [21] The latter three are sometimes confusingly referred to together as "PBL", which can also mean *problem-based learning* in different contexts. [12, 22, 23, 24, 25, 26]

2.3 Games and Serious Games

Serious games are closely related to game-based learning and refer to games whose main purpose is for learning or problem-solving rather than leisure. [9, 17, 27].

However, there is some disagreement within the literature about what is meant by a "game" at all. Game play is defined by [14] as "the interaction with the game through its rules, the connections between player and game, challenges and solution and the plot & player's emotional connection with the plot." [28] refers to games as "the range of 'interactive strategies' focusing on the actions and interactions of students." [17] reiterates Lloyd P. Rieber's claim that serious game play is "an intensive and voluntary learning interaction consisting of both cognitive and physical elements" which is "purposeful, or goal oriented". [28] puts forth a different opinion, claiming that games "offer a simple form of a reward – the pleasure of playing, without serious consequences for failure." Some definitions are even more ambiguous, claiming that serious games are simply "the essence of innovation" and characterized by their ability to challenge established rules. [17]

In this paper, "games" will loosely refer to any structured types of play which have certain characteristics in common with each other; for example the use of points, levels, competition, and storytelling. However, the reader is encouraged to research this concept further and form their own conclusion about what defines a game.

3 Methodology

The literature was obtained by querying the following databases: ACM Digital Library, ACS Publications, EBSCOHost, ERIC, Google Scholar, IEEE

Xplore, JSTOR, and ProQuest. The keywords *game-based learning, gameful, games + education, gamification, GBL, serious games*, and *serious play* were used as search terms. Consultants at Western Washington University's Research-Writing Studio also helped with this process.

From the results generated, only papers and books written in English which describe the use of games or game elements to achieve learning targets (either directly or indirectly) were considered as part of the literature review. Additionally, the citations made by major works were examined in case other authors had referenced additional useful literature not found from the database searches.

An overview of the literature investigated for this paper can be found in table I below.

Research Category	**Citations**
Non-Empirical Studies	[6, 7, 13, 22, 23, 25, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54]
Empirical Studies	[8, 10, 16, 21, 24, 26, 27, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82]
Concerning Electrical Engineering	[27, 32, 35, 52, 56, 59, 63, 81, 82, 83]
Concerning Other STEM Topics	[6, 8, 16, 18, 21, 23, 24, 26, 28, 29, 30, 33, 34, 38, 39, 40, 41, 42, 44, 46, 47, 49, 50, 53, 54, 55, 57, 60, 61, 62, 65, 68, 69, 72, 73, 74, 75, 76, 77, 78, 79, 80, 84, 85, 86, 87]
Concerning Non-Digital Games	[6, 7, 23, 24, 26, 28, 30, 33, 36, 38, 48, 58, 81, 86]
Literature Reviews	[19, 20, 88, 89, 90, 91, 92, 93, 94, 95, 96]
Other	[9, 14, 15, 17, 66, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107]
Papers Published in January 2015-April 2016	[10, 13, 14, 21, 22, 23, 24, 25, 26, 29, 36, 37, 38, 39, 44, 45, 46, 47, 48, 52, 55, 57, 59, 60, 63, 70, 71, 72, 73, 83, 84, 88, 97, 98, 99, 100, 102, 103, 104, 105, 106, 108, 109]

TABLE I – Literature Reviewed

4 Summary of Relevant Works

While there have been a handful of literature reviews that have assessed research on gamification (see table 1), only two have focused on STEM applications [89, 96] and just one on engineering applications [89]. So far, no literature reviews have been conducted on the role of GBL in electrical engineering education in particular. However, the review published in 2016 by Bodnar, Anastasio, Enszer, and Burkey [89] does an excellent job of summarizing work that's been done on games in engineering education, and the reader is encouraged to read their analysis as a primer. The purpose of this section is twofold: First, to supplement the work carried out by Bodnar et al. by examining research published since their review was conducted, and second to look more closely at studies done within electrical engineering specifically.

4.1 Summary of Previous Literature Reviews

In 1992, Randel, Morris, Wetzel, and Whitehill conducted one of the earliest available literature reviews on games in education. They found that 56% of 68 studies concluded that games had no significant impact on student performance, while just 32% concluded that games had a significantly positive impact. However, Randel et al. did find that games had a positive impact in 89% of studies involving math or physics. [93]

A later review from 2005 by O'Neil, Wainess, and Baker evaluated 15 years of research and found that although the potential of GBL was "promising", very few empirical studies had been done to validate this claim. [92] The same sentiment was echoed by Connolly et al. in 2012 [94] and to a lesser extent by Hamari et al. in 2014, who lamented the lack of more rigorous methodologies but conceded that there was probably enough evidence to support the use of gamification. [20] In July 2015, a literature review by Calderón and Ruiz summarized research on serious games in the context of software project management and similarly found that the majority of research touted many benefits of GBL but did not illustrate them empirically. [96]

In November 2015, Boyle, Hainey, and Connolly et al. presented an alternate point of view when they published an addendum to their previous work (as in [94]) and reported that "many more" papers demonstrating positive outcomes empirically had since been published. They also noted that progress has been made in identifying the most engaging features of learning games, including the use of goals, rewards, and interactive multimedia. Nonetheless, they maintained that research into specific game elements and frameworks, while having improved in quality, was still "piecemeal" and rarely comprehensive. [95]

The research review of serious games in engineering education conducted in January 2016 by Bodnar et al. agrees, and references the authors of [91], [92], and [94] in a discussion of the need for more empirical research. Nonetheless, Bodnar et al. reported that 87% of studies (out of 62) demonstrated positive results from gamification, while only 13% demonstrated neutral results and none demonstrated negative results. [89]

4.2 Summary of Recent Studies

Although the previous literature reviews have already examined the majority of existing GBL research in detail, the steady increase of publications as described by [20], [89], and [95] suggests that an update is warranted.

The review published by Bodnar et al. can easily be considered the most comprehensive and relevant available document to this paper, so only studies not considered there will be described in detail here. Because their research was completed in late 2014, it is reasonable to assume that only papers published from 2015-2016 need be summarized. The discussion in section 5 will take into account studies that have already been investigated by other literature reviews even if they are not explicitly described below.

4.2.1 Education Studies

[10] (2016) used the Brazilian platform MeuTutor to study the effect of gamification elements on students in an online environment (N=833) and found that the inclusion of missions and trophies may contribute to more questions being answered correctly.

[21] (2015) also used MeuTutor to conduct an observational study on the use of gamification elements to teach mathematics, with each topic assigned to its own "level". The results indicate that learning outcomes were improved by badges and experience points for some levels but not others, and overall the data was inconclusive.

[22] (2015) developed a gamification framework based on self-determination theory which used elements like leaderboards and badges in an online environment. The study found that while student motivation increased, competence with the material was unchanged.

[23] (2015) used a group role-playing game to study the efficacy of project-based learning for engineering students. The game was used in a master's level information systems project course and was evaluated from student responses on an exit questionnaire. 77% of students reported an increase in the quality of their work and 79% reported that they could see themselves reusing the course's framework in their professional lives. The authors of the study did not make use of a control group because they believed that group would be at a learning disadvantage compared to students who played the role-playing game.

[24] (2015) used gamification elements in two software engineering courses and demonstrated that student involvement in the learning process improved.

However, the study also found that in one of the gamified courses, average grades were significantly lower than those in the control group.

[25] (2015) studied the effect of similar gamification elements on children with dyslexia and found that they may increase motivation.

[26] (2015) used a learning management system and experience points to motivate engineering students learning about process management and found significant improvements in teamwork, punctuality, and participation.

[36] (2012) used a digital/mobile gamified environment to teach computer science to 131 students. The study showed that student attention, motivation, and learning improved with the gamified environment, but in some cases the findings were not statistically significant.

[29] (2015) used the programming puzzle game LightBot to teach introductory comper science to 45 students and investigated whether GBL improves competence according to ABET criteria. The study reported mostly positive results but found an increased percentage of students displaying "unsatisfactory" teamwork performance due to a higher course dropout rate.

[38] (2016) made recommendations for implementing gamification and presented a case study of a systems and design course that had been taught using a role play/simulation game. The study found that gamification increased students' motivation and engagement, but no data was included to support this claim.

[48] (2015) studied the gamification of an online course for 22 Master of Education students, using quests and experience points to improve engagement and learning outcomes. A modified leaderboard was also used which displayed rankings by score but hid students' names. The study found that student motivation was greatly increased, and that students who earned the most experience points also earned the highest scores in other areas of the course.

[60] (2015) describes an experiment with 56 first-year students studying data structures at Goa University. The students were randomly assigned to either a traditional control group, a gamification group using Moodle, an adaptive system group using Smart Sparrow's Adaptive eLearning Platform, or a combined group using both Moodle and Smart Sparrow. The Moodle gamification platform allowed for mechanics like experience points, badges, levels, and leaderboards, while the Smart Sparrow adaptive system platform learned from students' progress and actions to customize their learning experience. Data from the study shows that students who received traditional instruction performed marginally better than those who participated in either a gamified or adaptive system, but students who participated in the combined gamification-adaptation system performed significantly better than the other groups.

[109] (2015) tested gamification in an online course for PhD students in Saudi Arabia and Sudan. The instructor used storylines, missions, points, leaderboards, badges, tutorials, social engagement loops, and levels as the main gam-

ification elements. In the gamified class, homework was turned in on-time 90% of the time compared to 80% turned in late for the non-gamified version. Additionally, participants responded that they enjoyed the gamification elements and were motivated by badges and competition elements.

[55] (2015) implemented a digital game to teach algorithm concepts and found that users of the game were able to demonstrate learning outcomes better than non-users.

[70] (2015) studied whether a mobile puzzle and quiz game could teach 36 university students how to use library resources. The study did not find a significant difference in performance between the control and experimental groups.

[44] (2015) attempted to find out whether serious games could improve learning outcomes for students studying mathematical modeling at the National Research Tomsk Polytechnic University. The players worked in teams of 3-4 and completed three activity stations (playing a puzzle board game about mathematical models, solving a problem through programming, and playing a board game about random number generators and conditional statements). The study found through observation that the games improved teamwork, creativity, independence, and ability to synthesize technical information.

[73] (2015) describes the digital role-playing game *Classcraft* and investigated what motivated students to play the game. The study found that students who desired a performance advantage in class were more inclined to play the game, but perceived social influence, condition of facilities, and content quality did not affect their decision to play.

[45] (2015) investigated the effects of collaboration and competition on learning using *MatchingHero* (a modified version of the matching game *Concentration*). The results from the study were inconclusive.

[46] (2015) describes a serious game developed for engineering management students. The authors received positive feedback from students but did not conduct any formal experiments.

[13] (2015) surveyed 103 university students and faculty from Malaysia and found that the majority had positive opinions of GBL.

[106] (2015) studied instructors' attitudes toward serious games using data collected from 1668 Finnish primary and secondary schoolteachers. The study showed that the teachers' pre-conceived notions about GBL are strong indicators of whether GBL is used, and that female teachers perceive more value in GBL and use it more often than male teachers. Additionally, female students were reported to benefit more from GBL than male students.

The authors of [14], [47], [97], and [100] proposed gamification frameworks and best-practices but did not validate their claims as part of their proposals.

[52], [59], [63], and [83] are additional recently-published papers that pertain specifically to electrical engineering and will be described in detail in section

4.3.

4.2.2 Non-Education Studies

[39] (2016) describes an architecture for gamifying a code review process but did not conduct a validation experiment.

[103] (2016) conducted an empirical study with 31 participants to find out whether gamification increased users' motivation to submit ratings in an online recommender system and concluded that it did.

[104] (2016) studied the effect of competition in detail and connected the results to gamification applications. 391 professional participants were organized into teams of 5-12 members including a team leader, and data was collected through surveys. The study found that competition within teams significantly improved task complexity (which in turn had a strong positive relationship with performance) and psychological safety (which had a weak relationship with performance) while increasing conflict (no direct relationship with performance).

4.3 Summary of Studies Relevant to Electrical Engineering

[35] (2011) focuses on a set of laboratory exercises used in a signal processing course at the University of Sarajevo. The exercises make use of familiar acoustic signals and challenge students to replicate what they hear by manipulating sine waves in MATLAB. Although the paper refers to this activity as a form of gameplay, the authors use few actual game mechanics except perhaps the element of competition from students working in teams to achieve the best signal. While it could be argued that problem-based learning or tinkering might be better keywords for the study, post-surveys indicate that students did enjoy and find more value in these lab exercises than a traditional lab format.

[56] (2011) describes a mobile quiz application used in two digital electronics classes at the University of Tennessee at Martin. Although the paper presents the software as a game-style tool, there seem to be few game mechanics present and the authors may be relying on the delivery method (smartphones) to make the quizzes enjoyable. Nonetheless, the authors note that its use improved student grades on a midterm by 5%-15%.

[82] (2011) describes a digital 3D puzzle game used to teach digital electronics fundamentals to 13 undergraduate study participants. Learning outcomes were not measured directly, but the participants reported believing that the video game was a more effective way to learn digital electronics concepts than traditional methods, and also that video games are good tools to teach electrical engineering in general. They also reported enjoying the game and being much more motivated to learn.

[27] (2012) used custom online "mini-games" to teach digital electronics fundamentals to 25 volunteer students over the course of a week. The study used pre and post-test surveys to collect data. The results showed that students received the games positively and thought that they were a desirable way to learn digital electronics. The study also found that participants needed an average of 3 play sessions in order to understand the mini-games well enough to achieve a passing score. Additionally, the authors noted that the way data was presented within the games impacted student performance (for example, students took longer when data was presented in tables).

[81] (2012) is a study conducted at the Air Force Institute of Technology with 36 graduate students who played *DETABOO* (an adapted version of the *Taboo* card game) to learn about signal processing. The game was played with two teams in 50-minute class periods. A post-survey from the course shows that while most students felt that the game was a positive addition to their course, the majority also felt that their performance had not improved from playing the game. In general, the students felt that the game should be used as a supplement to lectures (possibly as a final exam review). Analysis of student grades showed that game participants scored better on the final exam than non-participants, but there was no significant difference on grades for projects and other exams.

[32] (2014) explains the creation a video game called *Circuit Warz* for PCs and mobile devices used to teach basic electronics theory at the University of Ulster. The game appears to be fairly sophisticated compared to other games of its kind, especially because of its included analytical tools. However, it has yet to be tested experimentally.

[52] (2015) describes *Game of Ohms*, a board game implemented in a physics class at Wentworth Institute of Technology used to teach introductory electronics theory to 150 students. The game was played by two teams which each attempted to build a circuit with a (secret) specified resistance. Each team took turns adding components to the circuit to meet their goal, and then worked together to solve the total resistance of the final circuit. The exercise was graded on points scored. The authors collected data to measure learning outcomes between a control and experimental group and found that students who played *Game of Ohms* made significant improvements in their understanding of advanced circuits as well as achieving an average grade 11% higher than the control group. Additionally, students who played the game spent about 80 minutes longer in the laboratory even when not required to, and were observably more engaged with the material. The authors suggest that the competitive atmosphere encouraged group interaction.

In [59] (2015), a form of GBL was implemented in a microcontrollers class by challenging students to create games as their projects. The study found that the introduction of games greatly increased interest in the course among computer science students and improved overall project scores.

[63] (2015) presents a 2-D platform game used to teach RADAR basics to 34 university students and found that only 6% of students failed an introductory exam after playing the game compared with 38% who failed before playing. In addition, the students reported that they enjoyed the game and learned a lot. No control group was used.

[83] (2015) describes a digital game designed to teach electronic design automation to second year engineering students. No empirical data was collected, but the authors intend to make the game available to the public to "crowd-source" data.

5 Results & Discussion

5.1 Disagreements on Terminology

Although experts have attempted to neatly define the terms *gamification*, *serious games*, and *GBL* as distinct methodologies, there appears to be significant overlap among definitions and it is not always clear at what point a gameified environment becomes a serious game in its own right. Furthermore (as discussed in section 2) there seems to be confusion about what a game actually *is*. For example, both [35] and [56] emphasize the use of "game-play" in their studies even when no obvious game mechanics are present. This indicates that researchers have different assumptions about what is meant by a *game*, and perhaps by extension, what kinds of activities are fun and engaging.

5.2 Conclusions About GBL

5.2.1 Effect on Behavioral and Learning Outcomes

There is no shortage of papers that proclaim many benefits of games in education. They often praise GBL's potential to skyrocket student engagement, boost learning, and encourage qualities like teamwork and motivation. [8, 28, 30, 89, 90] This view is perhaps vocied the most vocally by James Paul Gee, one of the leading experts on GBL. His ideals have been cited often by other scholars, who echo his optimism. [17, 90, 110, 111] It is tempting to think of games as a kind of miracle cure for student apathy, especially because contemporary students already spend so much time gaming. [8, 16] But does introducing games into education actually work to improve learning and engagement targets?

Based on the literature reviewed, the answer is probably "yes," although it depends on what the educator is trying to achieve. If nothing else, it is clear that student opinions on GBL are very positive, and most students report enjoying educational activities involving games. [7, 13, 16, 19, 23, 27, 34, 35, 46, 52, 56, 59, 61, 62, 81, 82, 109]

In recent years, more quantitative evidence has emerged suggesting that GBL can improve grades. [48, 52, 54, 56, 59, 60, 63, 65] However, some studies which have attempted to measure grade changes have been inconclusive, [7, 28, 61, 109] and one found that grades may be negatively impacted.[28] Because so few studies have empirically examined the effect of GBL on grades, more research is required to form a firm conclusion.

Currently, there appears to be a stronger argument for GBL's potential as a motivational tool than a way to improve grades. The majority of studies have found that games and gamification significantly improve student engagement and desire to learn. [6, 8, 16, 19, 24, 25, 26, 30, 36, 37, 38, 48, 61, 82] Additionally, studies measuring improvements in competence have yielded positive results [7, 23, 29, 36, 37, 44, 48, 52, 55, 56, 59, 63, 109] and research on GBL's ability to encourage teamwork are similarly optimistic. [16, 19, 23, 26, 44, 52] The data also suggests that GBL provides educational benefits for individuals who have cognitive disabilities because of its suitability for self-paced work. [25, 58, 64]

Nonetheless, there are still many studies which have mixed or inconclusive results for one or more of these outcomes, which again points to the necessity of more research. [7, 10, 22, 28, 45, 60, 61, 70, 81, 109]

5.2.2 Preparation for the Future

One concern about gamification is whether students who grow accustomed to learning through games will be at a disadvantage when they get to the "real world" and are tasked with doing work that has not been packaged in a fun, easy-to-swallow form. However, educators can take a little comfort in knowing that industry trends seem to be in their favor. Many major companies have begun to introduce game elements within their products or internal processes, including Adobe, Autodesk, IBM, Khan Academy, Microsoft, Nike, and others. [15, 61] A report from 2011 estimated that by 2015, "more than 50% of organizations that magnage innovation processes [would] gamify those processes." [15] A separate report claimed that "70% of the to 2,000 global organizations will use 'gamified' applications ... by 2014." Although it is not within the scope of this paper to verify whether these claims became true, they indicate that GBL and gamification are becoming more embraced in the workplace. According to a Pew Research Center report, 53% of surveyed technology experts agreed that major advances in the use of gamification would develop by 2020. [18] Furthermore, games may provide a useful context for simulations of phenomena that students will encounter as engineers in the real world and provide them with a a safe environment in which to prepare for them. [6, 8, 14, 18, 23, 35, 58, 64]

5.3 Recommendations for Implementing GBL

5.3.1 Conducting Experiments

Most literature on game-based learning concludes with advice from the authors about how to design experiments and class activities, and so predictably the recommendations are varied and sometimes contradictory. The suggestions in this section are a consolidation of findings from the studies that appeared to be most successful.

The most often repeated observation within the literature is that GBL desperately needs more empirical studies and qualitative data. Although empirical research is becoming increasingly prevalent, there is still a significant need for more experimental validation using large sample sizes. Furthermore, much of the previous research has implemented many different game elements simultaneously under the umbrella of "GBL" and then attempted to analyze the framework's effectiveness as a whole. There are likely nuances in the effects between different game mechanics that are not yet understood, and may be very difficult to use the existing literature to determine which specific mechanics or affordances are the most conducive (or harmful) to learning. [13] Therefore, future researchers might consider narrowing the scope of their study to a very specific question (for example, whether a particular game or game element, like leaderboards, helps improve grades.) Another alternative is to collect data for "modular experiments" within the context of a longer period of time–for example, focusing on a specific activity or mechanic each week and collecting data on its effect as well as the larger effect of game-based learning on the class in general.

As suggested by Bodnar et al., researchers should strongly consider performing their experiment in consultation with education experts. [89]

5.3.2 Instructor vs. Facilitator

Because active learning–and especially game-based learning–is such a radical paradigm shift in academia, it will be necessary for educators to re-think their roles within the classroom. According to [12], "the real challenge in college teaching is not covering the material for the students; it's uncovering the material with the students." In other words, instructors will need to spend more time acting as curators of thoughtful, intentional, and enjoyable learning environments and less time as intellectual authorities.

In the same vein, allowing students to work together and build a sense of community may have a strong impact on success. [8, 12, 35] Providing plenty of opportunities to interact with fellow students, ask questions, and teach each other could help mitigate some of the potential negative effects of a competitive environment. [6] It may also be useful to involve students in the creation process of game elements because it encourages critical thinking and provides an incentive to be successful. [101]

5.3.3 Game Mechanics

The research that has been done on GBL has not yet scratched the surface of the many possibilities of what forms serious games and gamification could take. However, a comprehensive study by Barata et al. suggests that quests and challenges are useful tools to foster engagement, competence, and enjoyment. In their study, challenges motivated students to participate in online discussions, perform previously disliked tasks, and created a sense of autonomy. Still, the authors warn that the challenges must be designed carefully to be as meaningful as possible, and should be evenly spaced so that students do not become bored after completing many in a short timeframe. [61]

Another common theme throughout the literature is the need for integrated reflection and debrief opportunities within the game environment, and that instructors should develop a plan to help students recognize what they have learned through playing. [7, 19, 28]

6 Limitations

Although results from the literature are optimistic, there are limitations to the conclusions drawn by this review. The most obvious one is that some relevant works may have been omitted because they were not contained in the databases used or were not accessible through the resources available at Western Washington University. It is also possible that studies have been withheld from publication because they did not produce desirable results.

Additionally, the discrepancies between publications about the difference between gamification, GBL, project-based learning, problem-based learning, and other active learning techniques mean that some relevant studies were likely not found because they did not include keywords related to GBL. It is possible that some researchers have implemented serious games without recognizing them as such, for example perhaps thinking of a role-playing activity as a project instead of a game.

7 Conclusion

This literature review examined the existing body of research on game-based learning as of April 2016 with an emphasis on studies relating to electrical engineering and studies published recently (2015-2016). The review gave a brief overview on GBL and defined vocabulary, summarized previous literature reviews as well as relevant studies, discussed the results found, and made suggestions for future GBL researchers and educators.

The review confirms the need for more empirical research–especially within electrical engineering–and quantitative data with large sample sizes and targeted research questions. In addition, the field of GBL research would be better served by more consistent terminology. Although GBL has been applied to electrical engineering topics in some instances, experiments within the field are vastly different and rarely empirical so few conclusions can be drawn from them. The most common GBL experiments for electrical engineering are used to teach digital electronics and signal processing, but the methods of implementation are dissimilar.

The research shows that the potential for game-based learning is promising, and is very well-liked by students compared to traditional instruction methods. There is some data to suggest that gamification and serious games can improve grades and learning outcomes as well as intangible skills like teamwork and motivation. Although there is a significant amount of both positive and neutral data alike, only one study observed considerable negative consequences from using GBL. Therefore, so far it seems that there are few downsides to implementing GBL as long as the instructor has the time and resources to invest in creating a meaningful experience.

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