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Gamification in Computer Science Education: a Systematic Literature Review

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I am Ph.D student at North Dakota State University. My research work is to see how different Learning strategies affect the student learning.

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1. Introduction:

Programming is known for its complexity and difficulty. It is believed to be difficult to instruct and to learn. Many students in programming courses have difficulties mastering required competencies and skills. At an introductory level, this problem is considerably more pronounced. Students often view programming courses as hard, relatively unmanageable work. Regardless of student perceptions about learning programming, the outcomes are often disappointing. Many institutes report dropout rates of 20 – 40 percent in their introductory programming courses [11] [28].

The high attrition rate in programming courses has drawn the attention of researchers to investigate the causes and solutions. Several studies have found various factors that affect dropout, of which a lack of motivation, engagement and confidence are among the most significant [29]. Although the demand for computing is increasing, computer science sees high dropout rate [29].

One method of addressing these issues would be by means of behavioral change accomplished by using gamification. Gamification is widely defined as the "use of game design elements in non-game contexts in an effort to increase user-engagement" [6]. Gamification has become popular in educational contexts recently [11] as it motivates students, and the use of game elements creates an engaging experience and improves the learning experience [12]. Gartner predicts that organizations dealing with innovation processes will gamify those processes [10]. While there is an abundance of research being published on gamification in education, it is still necessary to gain a better understanding the effectiveness of gamification in CS education.

The authors of this research are involved with the development of the SEP-CyLE - Software Engineering and Programming Cyberlearning Environment (https://stem-cyle.cis.fiu.edu/) [27]. SEP-CyLE is a cyber learning environment and serves as a platform for developing and deploying self-contained learning modules (developed and vetted by experts) related to software engineering and programming concepts. During the development of the system, gamification elements (GEs) were identified as one method of getting students to be more involved in learning programming concepts contained in the digital learning objects. To gain better understanding of the impact of GEs in computer science education and their effect on student learning, a systematic literature review was conducted to identify and classify the various GEs and how they affect student learning.

More formally stated, the goal of this paper is to:

> *Analyze literature for the purpose of understanding and evaluating gamification elements with respect to their effects on student learning in the context of software engineering and computer science courses.*

The remainder of the paper is structured as follows: Section 2 presents the context of gamification. The methods of the systematic literature review are detailed in section 3. Section 4 reports the results of the literature review. Section 5 presents a discussion of results. Finally, a conclusion is presented in section 6.

2. The Context of Gamification and Game elements:

Gamification has become a buzzword in the academia, because of its increased popularity. More recently, gamification has become a standout amongst the most important trends in technology [31]. There is ample anecdotal evidence that gamification can enhance students' engagement and motivation through the use of game design elements in non-game contexts [30].

Gamification provides a means to enhance engagement by making it fun by having participants earn rewards (such as points, badges, challenges etc.). A good example of usage of gamification elements is the programming website Stack Overflow, where the users gain points and badges for answering the software related questions by enabling the users to vote in favor of the best responses to the posted questions. The user is not guaranteed to achieve appreciation for each of their submissions. Gamification is not productive when the learners play an entire game without engaging in activities or accomplishing a task. One bad example, is when GAP retailer tried to gamify the store check-in, so that consumers get free pair of jeans. Most of the consumers wanted free pair of jeans rather than checking in at the store [32]. Once consumers found out that all free jeans were gone, they stopped checking in. This is a classic example where users were interested in reward than that of the gamified activity.

The literature on gamification has various (often competing) definitions of gamification and suggested approaches for implementing gamification. This motivated a need for a comprehensive review of gamification, its different forms, and their benefits in an educational setting. The motivation behind the use of gamification design elements in an educational context is not same as their natural occurrence in traditional game deign. In the case of the former, the goal is to enhance engagement and motivation, while in the latter the goal is entertain.

3. Research Approach - Systematic Literature Review:

This section describes the process used for performing systematic literature review of identifying the GEs in software engineering and computer science courses. This includes the research approach, which describes the review protocol, research questions, the sources to be included in the literature review, inclusion and exclusion criteria used for conducting the study, and the data is analyzed and extracted. In the following, we will go through these steps with more detail.

This systematic review is based on guidelines established by Kitchenham and Charters [7] in *Guidelines for Performing Systematic Literature Reviews in Software Engineering*. A systematic literature review is a means of assessing and interpreting all the accessible research applied to a specific research question, area of interest. The following steps were implemented in accordance with the guidelines for a systematic literature review established by Kitchenham and Charters [7].

Step: 1: Research Questions:

The aim of this paper is to identify and evaluate the usefulness of gamification elements most commonly used in CS and SE courses on student learning. To do this we formulated three research questions:

RQ1: What are the most commonly used gamification elements in CS and SE courses?
RQ2: What is the evidence for the benefits of these gamification elements on student learning?
RQ3: How can answers to RQ1 and RQ2 be incorporated into the design of cyber learning environments?

The First question explores the use of GEs in software engineering and computer science courses. The Second research question is constructed to separate the GEs that been empirically validated from those which are based on anecdotal evidence. The third question helps us focus the aim towards improving the design of SEP-CyLE.

Step 2: Source selection and search:

Initially, an ad hoc review was performed in order to assist with the development of search strings and to provide the list of conference proceedings and journals to be manually searched. Although there is a large body of research related to gamification in a broader educational context, the papers presented in this literature review are those from databases or publications containing research relating to software engineering and computer science education. The following databases were searched: ACM Digital Library, IEEE Xplore, ProQuest, and Web of Science. In addition, the following conference and journal proceedings were also reviewed to ensure that all the relevant results were included: SIGCSE, CSEE&T, ICER, ITICSE, TOCE, Computers and Education.

In order to search the selected databases, a search string was created in view of research questions identified in the previous step. The following search string contains relevant keywords and synonyms used to look through the databases:

*(game **or** gamification) **OR** (elements) **AND** (effect **or** impact) **AND** (education **or** learning **or** student **or** course **or** computer science **or** software engineering **or** lecture).*

If the database was not able to deal with entirety of the search string, the string was separated in order to fit and return an appropriate number of results. No more than 500 results were considered after examination revealed that those results after the first 500 were related. We also restricted included papers to those from 2010 or more recent to ensure that we are only using the most recent results.

Step 3: Applying inclusion exclusion Criteria:

The search resulted in a large number of papers. To further filter the set of papers the following criteria were used. Inclusion and exclusion criteria are typically used in literature reviews in

order to identify appropriate papers that could be included in the literature review. Table 1 contains the set of inclusion and exclusion criteria used as a part of this review.

Table 1: Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Papers that address RQ1 and RQ2	Publications that are not in English
Papers that contain empirical evidence	Publications not focused on student learning
Papers that can be applied to CS/SE courses	Papers that don't contain empirical results
Papers that talk about gamification	Papers that talk about designing games

Step 4: Study Execution:

After searching using all the strings on all databases and selected sources, we found 5450 papers. After applying the inclusion and exclusion criteria based on the titles of those papers, the count was reduced to 876. This was further reduced to 154 papers based on review of the abstracts. Each of the remaining papers was read in its entirety. After reading each of the selected papers, only 16 remained. Although there is a large body of research related to gamification in a broader educational context, the papers presented in this literature review are those specifically related to CS and SE education. Table 2 contains a list of the papers included in this literature review.

Table 1: List of Included Publications

ID	**Title**	**Reference**
P1	The Study of Gamification Application Architecture for Programming Language Course	[5]
P2	Applying gamification in the context of knowledge management	[15]
P3	Game2Learn: Improving the motivation of CS1 students	[4]
P4	Gamification in Educational Software Development	[19]
P5	Improving Participation and Learning with Gamification	[14]
P6	A Playful Game Changer: Fostering Student Retention in Online Education with Social Gamification	[23]
P7	On the Role of Gamification and Localization in an Open Online Learning Environment: Javala Experiences	[26]
P8	Does Gamification Work? — A Literature Review of Empirical Studies on Gamification	[1]
P9	TrAcademic: Experiences With Gamified Practical Sessions for a CS1 Course	[20]
P10	How (not) to Introduce Badges to Online Exercises	[16]
P11	Motivating Skill-Based Promotion with Badges	[24]
P12	Increasing Students' Awareness of Their Behavior in Online Learning Environments with Visualizations and Achievement Badges	[3]
P13	The Effect of Virtual Achievements on Student Engagement	[22]
P14	Gamification for Engaging Computer Science Students in Learning Activities: A Case Study	[2]
P15	A Gamified Mobile Application for Engaging New Students at University Orientation	[17]
P16	Teaching Software Engineering Through Game Design	[8]

Step 4: Data Extraction:

After the final set of studies to be included had been finalized, we extracted the following data (see Table 3) from each paper to ensure that same information was extracted from each paper and to avoid any researcher bias.

Table 3: Data Extraction Form

Field	***Description***
Study ID	Unique identifier for the paper (same as the reference number)
Bibliographic data	Author, year, title, source
Study Type	Journal/conference
Study aims	The aims or goals of the primary study
Study type	The type of research performed (e.g. case study, controlled experiment)
Gamification elements	The gamification element(s) identified by the study
Focus area	CS or SE course
Evidence/Results	Evidence regarding the usefulness of gamification elements for student learning
Concepts	The key concepts or major ideas in the primary studies
Higher-order interpretations	Limitations, guidelines or any additional information

4. Results:

The following of this section discusses about the most commonly used GEs, evidence of benefit of these elements and how could we implement these in SEP-CyLE and improve the design of SEP-CyLE.

4.1. Gamification elements:

Gamification is always defined as the use of gamification elements in non-game context, which helps in increasing the student's engagement. As there are many GEs used in previous works, this focuses on the list of GEs that have been used in in the areas of CS and SE education. Based on our literature review, we identified eleven commonly used GEs in the educational contexts. We have provided brief descriptions of each GE below.

Points (Pt): These are the rewards that are assigned to the students for the completion of a particular task. The point system is used as measure of success or an achievement.
Badges (B): These are represented as a token of achievement. These are also rewards that are assigned to students when they complete a particular task or when they reach a goal.
Leaderboards (Lb): These create a competitive environment among the students. A leaderboard is the board that displays the ranking of the students based on the points that they have earned. The display can be made individually for each score or for overall scores that are earned by the students.
Avatars (A): These are the characters that serve as a virtual representation of the player. As the player progresses in the game, they can get more items, which allows the avatar to evolve over the time.
Storylines (S): Storylines refer to the use of a narrative or a theme in the game that the user will be playing. Storyline provides additional external motivation because students become invested in the narrative and want to help progress it. The theme provides additional extrinsic motivation by relating the learning modules to something that students find more enjoyable.

Visualizations (V): This is special GE, where the student's position will be represented in the form of dot and this dot gives them a visualization that if they progress in the same pace it would provide an idea of what would the end result of the student be.
Progress bars (Pb): This shows the students about their progress in reaching a goal.
Punishment (Pu): This GE is used to award if students commit a mistake.
Levels (Le): The game will be divided into different levels. At the initial stages there would be less effort required to complete it, as the level progress it becomes more difficult for the player to complete.
Challenges (C): This would provide the user a challenge that they should complete it. On completing the challenge, the user would be rewarded. Each level can have one or more number of challenges.
Feedback (F): Feedback helps in avoiding students getting lost or confused.

We counted the number of times (frequency) each of the above GEs appeared in the primary studies. Table 4 shows the number of times each of the different GEs was identified in the literature as well as mapping study types (controlled experiment, case study or literature review) to each GE. Based on the results, badges followed closely by both points and leaderboards have been the most widely recognized (and reported) game element in CS education. The remainder of 8 GEs had much fewer papers reporting the evidence on their impact of student learning and were mostly restricted to case studies in academia (i.e., with students in university settings). More details of result from each of the primary study is presented later in the paper.

Table 4: Occurrence of GEs by Study Type

Game Element	Count	Study Type	Paper ID(s)
Badges	11	Case Study	P2, P5, P7, P10, P14
		Controlled Experiment	P6, P12, P13
		Literature Review	P8
		Skill Based promotion program	P11
Points	9	Case Study	P1, P2, P3, P4, P5, P7, P9
		Controlled Experiment	P6
		Literature Review	P8
Leaderboard	9	Case Study	P1, P4, P5, P7, P9, P14, P15
		Controlled Experiment	P6
		Literature Review	P8
Challenges	3	Case Study	P5, P15
		Literature Review	P8
Progress Bar	2	Case Study	P1
		Literature Review	P8
Levels	2	Case Study	P5
		Literature Review	P8
Feedback	2	Controlled Experiment	P12
		Literature Review	P8
Storyline	2	Controlled Experiment	P16
		Literature Review	P8
Visualizations	1	Controlled Experiment	P12
Punishment	1	Case Study	P3
Avatar	1	Case Study	P6

4.2. The Effect of Gamification:

The effects on gamification in education suggest that it is a promising technique that could be introduced into learning material. Most of the studies have shown gamification has an improvement in students understanding and their engagement. In particular, it was found that leaderboards were most motivating and that points were more effective than other GEs. Badges and progress bars were reported as being low interest elements. Studies also found a significant increase in the performance of the students when utilizing these GEs [16]. Table 5 provides a summary of papers including the focus, GEs examined, and results of the study.

Table 5: Empirical Evidence of Usefulness of Game Elements in CS Education

ID	Student Learning Focus	GEs	Results of the Study
P1	User participation, student engagement, and student achievements.	Pt, L	There was a positive impact on learning effectiveness. When the gamification elements were omitted from the application, there was decline in student achievements, decrease in user participation and user engagement.
P2	Participation of software development teams in knowledge construction processes.	Pt, B	The results evidenced an improvement in three areas: participation, collaboration and contribution). It was observed that each team member took an interest in each of the activities. The results showed 100% achievement in participation.
P3	Teaching introductory programming through game design to improve engagement, motivation, and learning.	Pt, Pu	The student interviews and observations provided strong evidence that Game2Learn could be successful at enhancing student engagement and motivation. The results were positive only when students understood the game design concepts. Conversely, the performance was poor when students attempted tasks without reading the instructions.
P4	Students use of tools when gamification elements are included in the tools	Pt, Lb	The results indicate an increase in the points earned by the group where the students can compare themselves with others.
P5	Effect of gamification on students in terms of grades, engagement, and motivation	Pt, B, Lb, L, C	There was increase in the lecture downloads from 1.5 to 3 times. Compared to non-gamified years, the number of posts per student grew significantly 4 to 6 times on the first gamified year and 6 to 10 times in second gamified year. They also observed higher minimum grades during gamified years.
P6	Do social gamification elements amplify possible positive effects	Pt, B, Lb, A	Using game and social conditions resulted in higher average retention periods. Students in the game and social conditions group had higher test scores than students in control group.
P7	Usage patterns for online learning systems when using gamification elements	Pt, B, Lb	When the gamification is used, users spent more time and completed more exercises. The total time that the student spent was significantly smaller when gamification was turned off.
P8	The contexts of gamification, dependent variables, and independent variables outcomes from gamification.	Pt, B, Lb, S, V, L, C, F	The major finding of the paper is that most of the gamification elements acted as motivational affordances but reward points, leaderboards and badges were the most influential game design elements.
P9	TrAcademic was used to gamify the practical sessions in introductory CS course.	Pt, Lb	There was a 500% increase in the attendance. TA's strongly agreed that the practical sessions were helpful to students.

P10	Badges effect on students' behavior and student attitudes towards badges.	B	The results showed that one third of the students agreed that badges were motivating, while another third indicated they were demotivating, and another third said they had no effect.
P11	How badges help student staff motivation in regards to work and retaining quality employees.	B	Authors saw an improvement in student's performance in learning technologies as badges acted as their intrinsic motivator.
P12	How badges, visualizations, and feedback affect the student performance	B, F, V	The badges helped students improve their course performance due to an urge to grab more badges.
P13	Whether badges within PeerWise have an impact on student's participation in the coursework	B	A student survey indicated that more than 60% found badges to be an enjoyable feature that helped them in their course performance. The vast majority of students in this group also indicated that they preferred having badges in their interface.
P14	Impact of gamification on student's academic performance and how gamification affects student's engagement.	B, Lb,	There is a statistically significant difference in mastering topics before and after the gamification was introduced. The results also showed students worked beyond the requirement to master the unexplored topics of the course.
P15	How gamification affects engagement in student orientation.	Lb, C	The survey results suggested that game elements were positive addition to the application and the students reported that they motivated them to learn about the campus. Authors found that leaderboard was a major motivating factor.
P16	Effect of game centric SE course on students participation, performance and exposure to real issues.	S	Authors observed that the enrollment rate was up, dropouts were down, and grades were noticeably improved. Subjective comments from the students suggested a greater interest in software engineering course.

4.3. Improving the design of CS and SE cyber learning environments:

As previously mentioned, badges, points and leaderboard are the top GEs that have been empirically evaluated in the literature. As SEP-CyLE already incorporates points and leaderboards in its system, badges are the obvious choice for addition, as they have shown positive impact on students learning in most of the cases. While it is clear that certain game elements such as badges, progress bar (and in the context that they need to be used) can help to motivate students intrinsically, incorporation of any gamification element to SEP-CyLE would need to be empirically tested.

Though gamification has shown positive effect in most of the cases, the authors have also identified potential downsides. There were some studies where the students were not motivated and in some cases, it had a negative effect on them by reducing their intrinsic motivation [24]. This should be the important aspect that should be considered while designing the learning material with game elements in it. We have to make sure that there is not only extrinsic motivation, but also the intrinsic motivation on the part of the students, though motivating the students intrinsically is not an easy task. It is always important to track if a student is losing his interest on the learning material or not. If they are losing

interest, then the system should make some intervention to restore their interest on the topic.

5. Discussion:

The purpose of the literature review was to identify the most commonly used gamification elements in computer science and software engineering courses. Unfortunately, there was not a large body of empirically validated papers confined to gamification in CS/SE courses. A total of 11 gamification elements commonly used in CS and SE courses were identified. The results from this review can assist the development (or re-design) and subsequent validation of SEP-CyLE. While SEP-CyLE already has the most common gamification elements (Points and Leaderboard) incorporated, we would like to add badges and progress bars in to SEP-CyLE and measure how these gamification elements would affect the student learning.

Some additional insights from the review results are discussed below:

Impact of GEs on subgroups: Few papers revealed that gamification had constructive outcome on women [4]. When examining the impact of gamification on localization, Lehtonen [26] found that the users of Finnish version utilized the framework for a more extended time and finished more activities that that of the English version users. Localization played an imperative part and affected the excitement of the user to use the learning environment.

Negative impacts of GEs: Despite the fact that there is more weight on positive outcomes, there is some negative effect of gamification on students. Barata showed that some students did not find the gamified learning activity engaging and enthusiasm for utilizing the platform diminished after two or three days [14]. Additionally, Auvinen reported that neither badges nor heat maps influenced the behavior of majority of the students [3]. Haaranen indicated that badges had an exceptionally negative impact on a student that he “died internally” every time he saw the badges [16].

Quality Assessment: Each and every paper was perused completely and ensured that the papers met the criteria that they contain information that they had empirical evidence for the outcomes drawn. Inclusion and exclusion criteria was strictly applied to ensure that only appropriate papers were included. The papers that were included in the study had empirical evidence on the results of application of gamification in only computer science and software engineering courses.

Limitations: Gamification in academia is in its infancy stage. In this literature review we discussed studies of gamification only in the fields of computer science and software engineering. Analysis of papers during the literature search revealed that the terminology for gamification elements is not always well-defined or consistent across studies. The number of papers that are finalized is small in number and we have drawn our conclusion from the results of these papers. Additionally, some of the studies conducted have used qualitative analysis that has not been subjected to a controlled experiment in order to provide additional support for those findings.

6. Conclusion:

In this paper we conducted systematic literature review on gamification in CS and SE educational courses and the current design of SEP-CyLE and its features. The results show that integrating gamification elements into CS and SE education helps in achieving positive educational outcomes. Particularly, the addition of gamification elements into the online learning material has been shown to increase the fun elements and also acts as a motivation factor for students to become more active in learning. In future, we plan to conduct systematic literature review on the effect of gamification beyond just CS/SE by expanding it to STEM based discipline. Additionally, we plan to continually improve the design and usability of SEP-CyLE by using most influential game elements. While there are some studies underway, we plan to report the results and conduct additional studies guided to builder a larger body of evidence on usefulness of gamification in CS/SE education.

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