Game-based learning in software engineering education: A systematic literature review

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Abstract

The issues with traditional methods of education and the growing skills gap in several key knowledge areas like software engineering are well known. After the realisation that massive open online courses (MOOC) did not contain the ability to transform education, all the research efforts have moved to game-based learning. From a theoretical standpoint, game-based learning has all the components to be a potential solution.

The last literature review done on gamification of software engineering education happened in 2018. This is an ideal timeframe to revisit and redo the systematic literature review because (1) Changes in the technology and technology related industries occur rapidly. (2) The previous study had focussed purely on gamification rather than game-based learning. (3) Other areas of education had begun to show improved results by using game-based learning.

This systematic literature review found that new studies show a consistent trend of learning performance improvement amongst learners. User motivation and engagement have also shown improvement due to the use of game-based learning platforms. The main reason observed for this is, the focus on building serious games with engaging narratives rather than just using game elements around traditional courses. Other aspects that have contributed to improved performance of game-based learning platforms are better user experience, in-depth knowledge coverage, focus on aesthetics and improved ability to collaborate. The main areas of improvements are, depth of coverage of software engineering knowledge area, overall technology maturity of platforms, increased risks of possible health issues and social pressure to perform as part of the gaming community.

Keywords: Game-based learning, serious games, software engineering, education

Declaration

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Philosophy in Evidence Based Management at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

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1 Introduction

The MICT (media information communication technology) sector's demand for software engineering skills in South Africa has been on the rise over the last decade and the demand-supply gap has risen to around 20 percent based on survey data of the year 2021 (Schofield et al., 2021). This gap is set to increase with research showing that the technology awareness and adoption rate of university students is low compared to other developing countries (Olatoye et al., 2021). South Africa's ranking in the International Telecommunication Union's ICT (information communication technology) Development Index and World Economic Forum's Networked Readiness Index has always been very low (Kirlidog et al., 2018). South Africa needs to find a mechanism to reverse the trends, if it wishes to reap the benefits of rapid advancements that are happening in the technology domain. The South African national government has shown commitment to approaches which could assist in reducing the skills gap and is exploring several of them (Schofield et al., 2021). They have reached out to both academia and industry, but progress has been very slow. This research wishes to explore the possibility of using "game-based learning" as a method to reduce the software engineering skills gap in South Africa.

1.1 Background

Societies have always used games as the most common source of entertainment (Alexiou et al., 2020). As families became nuclear and individuals in societies became more and more isolated, children found refuge in computer games. To engage the target audience further, game developers have taken the immersive experience in virtual reality gaming to increasingly realistic levels (Schleifer, 2018). Instead of fighting this change, researchers have started to think of other roles games could play, other than just entertainment. There seems to be a lot of effort being put into serious games (Mullins et al., 2020) or gamification that leads to value creation (Hollig et al.,2020). Several researchers like Perini et al. (2018) believe that game-based learning tools can be used not just for entertainment but also to grow student engagement and improve methods of education.

Even though research over the last three decades has shown mixed results in learning performance improvement by using game-based learning, the activity in the game-based learning domain has been consistent (Fu et al., 2020; Garcia et al., 2020; Tay et al., 2022; Trinidad et al.,2021). There seems to be a study in each subject, from elementary maths to nursing training. There are studies done on students from grade 5 all the way to bachelor's degree academic programs. Additionally, there are game-based learning studies that have been performed on professionals not only to upskill them on their core jobs but also to improve

their leadership skills (Sousa et al., 2019), teamwork skills (Austin et al., 2019) and soft skills (Garcia et al., 2020).

1.2 The research problem

Alhammad and Moreno (2018) did the last Literature review on gamification of software engineering. This study can be considered out of date now due to two main reasons. First, the focus of the study was on Literature that was produced within the time range 2007 to 2017. Technology changes happen at a rapid pace and the game-based learning domain has been subject to a flurry of activity in recent years. There have been other Literature reviews that were done by scholars in the field of game-based learning (Fu et al., 2020; Garcia et al., 2020; Tay et al., 2022), but none focussed on software engineering.

Second, Alhammad and Moreno (2018) had focussed mainly on gamification, which is the use of game elements (for example, badges, levels, avatars) in a serious context which here is the domain of software engineering education. Software engineering courses were not turned into learning games, as game-based learning promises. Central to game-based learning is a serious game which requires a game narrative, game mechanics and game aesthetics. In the absence of these, the study was incomplete and requires revision.

Several studies have been conducted to test the impact of game-based learning courses on learner performance before the year 2018. There have been positive results on the student engagement and motivational aspects, but the jury is still out on individual cognitive performance improvement. The years 2018 to 2022 have been action packed on the game-based learning subject area front. Has the inconclusive stance on the cognitive performance improvement changed or is it still the same?

COVID-19 had forced all education to happen online and parents have accepted it as a worthy alternative (O'Farrell et al., 2021). During lockdown, students had minimal interaction with their friends, barring some online discussions. Within their confinement, students did get used to online education and online games. Gordillo et al. (2022) have gone to the extent of predicting that online education will become mainstream within the current decade and traditional education will be left behind. Game-based learning is often practiced as a combination of a flipped classroom, and gaming and problem resolution in a physical or virtual classroom. The acceptance of online education and education using video content will push the case for game-based learning.

In primary and secondary education, the drop-out rate is low due to parental engagement and motivation, but tertiary education witnesses high dropout rates if interest and motivation level are not high enough. In software engineering education, the drop-out rate is significantly higher due to the difficulty level of the course content (Kazimoglu, 2020). Often students think that content being taught to them is neither interesting nor relevant (Zhao et al., 2022). The game-based learning platforms are able to attain the highest motivation rates and will have a much higher rate to completion compared to traditional and online education (Buchinger et al., 2018; Cooper et al., 2020).

The information technology space in general and the game-based learning platforms space, are high activity domains. A lot of work is being done and there are a lot of competing game developers working in tandem (O'Farrell et al., 2021). This should lead to the rapid improvement in gaming technology and improvement in the overall maturity of game-based learning platform. Therefore, a duration of 5 years could have changed the landscape completely.

The information technology skills gap is continuously on the rise (Schofield et al., 2021). A study focussed on game-based learning at the internship level provides several approaches to address the skills gap issue. Firstly, it will be able to guide the conversion process from ready skill to contributing skill (Kirlidog et al., 2018). Second, it uses the familiar language of computer games where current software engineering students invest a significant amount of free time (Schleifer, 2018). Lastly, the community of practice fully internalises the new member and ensures mutual support going forward (Makinen, 2022), which is critical for the fast-changing nature of the information technology industry.

1.3 Objective of the literature review.

The current education processes, systems and methods have some deficiencies. Initial results of the assessments of using game-based learning in education had provided positive results in motivation and not statistically significant learning performance improvement. More specifically, within software engineering, there was little evidence to convincingly state the benefits of game-based learning over traditional methods of education in 2018 (Alhammad et al., 2018). In the information technology world, five years is a very long time. Over the 2018 – 2022 timeframe, have the results of these assessments changed? COVID-19 has brought in acceptance for online education. Can flipped classrooms and game-based learning practiced together have the potential to play a bigger role in software engineering education?

1.3.1 Game-based learning in software engineering education

Software engineering courses in universities have been found to be repetitive (O'Farrell et al., 2021). The same traditional methods of education have been used to deliver software engineering education for decades. The traditional methods are boring and de-motivating for both the educators and the learners. It will be difficult to solve the current skills shortage issue in software engineering using traditional methods.

In the field of education, some research has been done using game-based learning platforms to deliver university courses in software engineering knowledge areas. This study will try to understand all the software engineering knowledge areas where studies have been done using game-based learning platforms.

RQ1. In which software engineering knowledge areas have studies been conducted to deliver educational courses using game-based learning platforms?

1.3.2 Serious games for software engineering knowledge areas

Several studies have been done across various areas of education globally. Keeping the scope restricted to software engineering, this research will try to understand the nature of game-based learning platforms that were used in each study? There might be a need to build a custom platform for each study or the same game-based platform could be customised for multiple courses. This study will try to ascertain all the serious games that were used for conducting game-based learning studies in each software engineering knowledge area. Some game-based platforms could have succeeded, and others could have failed. This study will try to compare the key attributes of game-based platforms that succeeded against those that did not.

RQ2. What are the serious games used to build game-based learning courses in various studies for each software engineering knowledge area?

1.3.3 Observed benefits of game-based learning

In the last systematic literature review that was done to ascertain the benefits of game-based learning platforms in software engineering, motivation showed improvement and learning performance showed no change (Alhammad et al., 2018). This study will try to ascertain how these two parameters are faring currently. It will also try to understand all the benefits that game-based platforms are delivering to the whole eco-system, encompassing learners, educators, universities, game-makers and more. Apart from these two parameters, user-

friendliness, engagement, educator control and more will be analysed. This information will be restricted to the analysis done by the literature being reviewed.

RQ3. What improvements have been observed due to the use of game-based learning platforms in software engineering?

1.3.4 Observed shortcomings of game-based learning

Game-based learning platforms have not gained enough traction to replace traditional methods of education yet. There could be some observed issues that are slowing down its uptake within the user community. The reasons might range from broad issues like, low investment in the domain and low maturity of technology to more specific issues like, 3D immersive tools causing medical issues, such as spatial disorientation in young learners. This study will try to analyse all such issues that the game-based learning platforms are facing when it comes to building serious games for software-engineering knowledge areas.

RQ4. What issues have been observed due to the use of game-based learning in software engineering education?

1.4 Research contribution

1.4.1 Theoretical contribution

After the systematic literature review done in 2018 to test the influence of gamification on software engineering, there has been limited work done on the literature review front. Although, there has been extensive work done using game-based learning to build educational platforms in general and software engineering educational platforms in particular. A systematic literature review of the work done between 2018 – 2022 could consolidate all findings and guide the game-based learning theory in several ways. (1) Consolidate the knowledge on the influence of game-based learning in various areas in software engineering. (2) Indicate an increase in the level of influence that game-based learning theory has on learner performance across various parameters. (3) Showcase the areas within game-based learning theory that still require further work. (4) Learning and motivation are current considered the core drivers of game-based learning research. There is possibility of finding new pillars on which the theoretical foundations of game-based learning theory.

1.4.2 Practical contribution

The South African government is struggling with the technology skills gap problem (Schofield et al., 2021). This research could provide guidance on a new way of addressing this problem. Game-based learning courses have the potential to rapidly alleviate the skills gap issue by converting graduates into practitioners at a fast pace. Students in various provinces that have been found to be technology phobic (Olatoye et al., 2021), might be more open to using the game medium, which is a familiar platform for them due to their use of it for entertainment.

The MICT (media information communication technology) sector could make the game-based learning courses the standard practice for their internships. Most of them hire a huge number of graduates from several universities. Instead of taking them through traditional internship programs, they could build customised courses using game-based learning principles. This will assist in making the interns more effective faster and reduce skills gap.

If the results of the game-based learning courses are positive in terms of learning performance, academia could play multiple roles in the future. (1) There might be opportunity for universities to collaborate with industry to design and build custom courses. (2) The universities could run these courses for the industry. (3) There could be opportunity to gamify a few final year courses in preparation for the upcoming internship. This research could be used as guidance for all such initiatives.

This study will be able to identify the main platforms that have been built using game-based learning guidance for various knowledge areas in software engineering. It will also be able to identify the benefits vis-à-vis other platforms being used in the same knowledge area. Lastly, all the issues with game-based learning at the industry level will be identified. This information will assist both educators and game designers to work in collaboration to identify opportunities that will enable the rapid enhancement and maturity of these platforms.

1.4.3 Methodological contribution

Systematic literature reviews have been performed successfully in various areas. Within the game-based learning space, no similar study has been performed that focussed on software engineering education. The last similar study used gamification where the application was restricted to game elements alone. If successful, this study will be the first systematic literature review has been applied to game-based learning.

2 Methods and Analysis

Systematic literature review is a scientific and methodical analysis of a chosen topic in detail to answer specific pre-defined questions (Garcia et al., 2020). One of the key features of a systematic literature review is its replicability and transparency (Krath et al., 2021). This evidence-based approach draws scientific conclusions to research questions through a mapping of available literature. This study has closely followed the systematic literature review methodology. A mistake in any aspect of the methodology has the potential of undermining the entire research's golden thread (Edmondson et al., 2007). Therefore, every aspect of the methodology is critical for the success of the research.

2.1 Research methodology

The researcher has selected Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) as the guiding framework for this systematic literature review. The PRISMA 2020 statement provides an exhaustive checklist of aspects to report when performing a systematic literature review (Page et al., 2021). It combines the years of intelligence generated by researchers across the globe to ensure 360-degree quality assurance of a systematic literature review. This research has been guided by the PRISMA framework and aligns with it as far as possible.

2.2 Research questions

The main construct analysed by the research is game-based learning. The boundary of this systematic literature review on game-based learning is software engineering education. As a first step of the study, the four main research questions were identified. They are:

RQ1. In which software engineering knowledge areas have studies been conducted to deliver educational courses using game-based learning platforms?

RQ2. What are the serious games used to build game-based learning courses in various studies for each software engineering knowledge areas?

RQ3. What improvements have been observed due to the use of game-based learning platforms in software engineering?

RQ4. What issues have been observed due to the use of game-based learning in software engineering education?

2.3 Identification of electronic databases

The researcher initially performed random searches on nine databases to find ones with the best results. The high-level search terms used initially were the following: ("game-based learning" AND "Software engineering" AND "education"). Alhammad et al. (2018) had used a similar term with gamification in place of game-based learning. The search was restricted to the years 2018 to 2022, since we are specifically looking for latest information on the game-based learning construct. Only articles written in the English language were accessed. The search was restricted to journal articles only.

Based on the results observed, the following databases were finalised for literature search:

- Scopus
- IEEE Explore
- Science Direct
- Web of Science

This selection was consistent with the proposal of Swacha (2021) who had stated on the bibliometric analysis of gamification research that the above four databases have the best results.

Once the search was concluded on these four databases, other databases were assessed to verify if any additional good articles have been overlooked. The results gave very few relevant articles and upon detailed review, most of them could be excluded from further study.

2.4 Removing the Academic Journal Guide 3+ filter

The researcher applied the academic journal guide 3+ filter on the results set manually. There were no articles that passed the filter. The reason for this might have been (1) game-based learning in software engineering education is a relatively new field of study. (2) Game-based learning is more a scientific construct than a management based one.

Trinidad et al. (2021) surveyed the most influential journals in gamification. The two most influential journals identified by them which cover almost 90% of the publications on game-based learning to date are, Computers in Human Behaviour (academic journal guide ranked 2 for the year 2021) and Computers and Education (academic journal guide ranked 2 for the year 2021). Even the other influential articles and authors had mainly published in academic journal guide rank 1 and 2. Therefore, for this study, it was important to exclude the academic journal guide 3+ filter.

Once the search was concluded on these four databases, other databases were assessed to verify if any additional good articles have been overlooked. The results gave very few relevant articles and upon detailed review, most of them could be excluded from further study.

2.5 Final Literature search

Figure 1 shows the flow diagram of the literature selection process. Based on the initial search criteria, all the articles on the results obtained were downloaded. Figure 1 shows the number of articles extracted per database. Mendeley was used to remove duplicates and manage reference traceability.

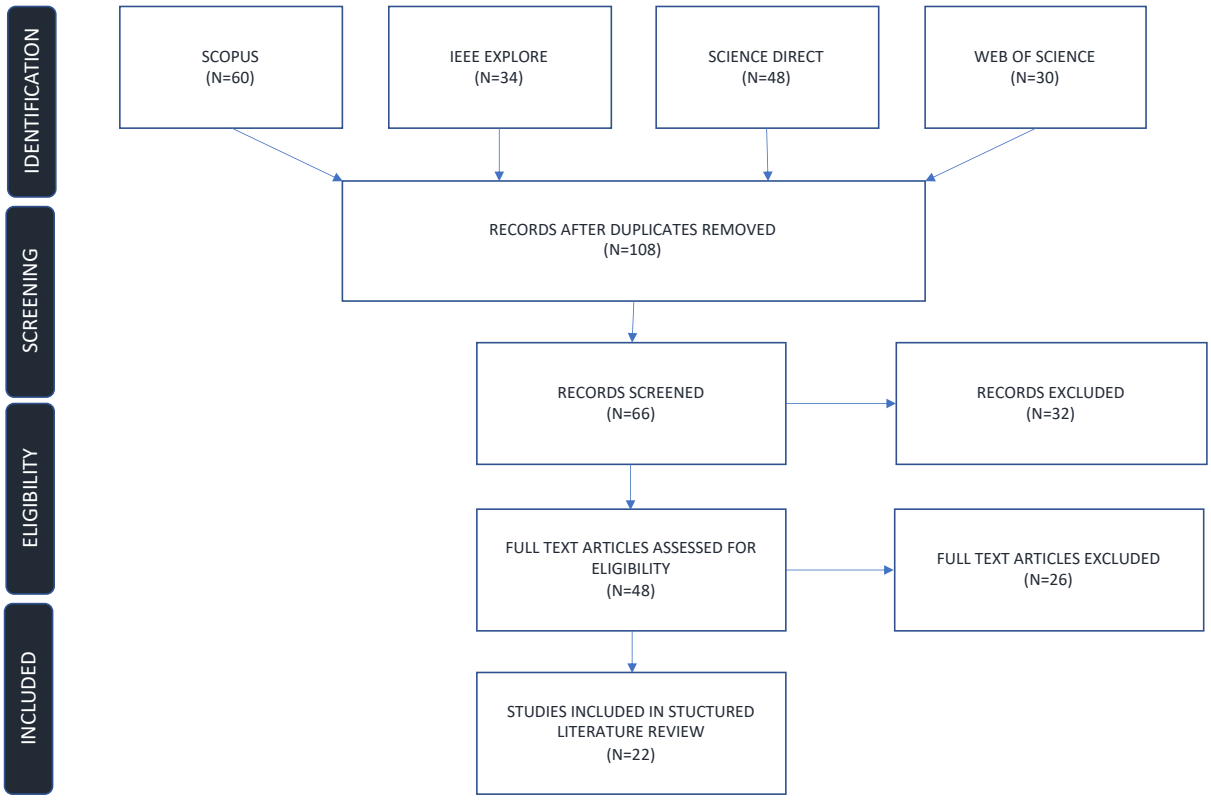

Figure 1: Flow diagram depicting the selection process

2.6 Study screening

For the process of screening to be effective, a three-step process needs to be followed (Krath et al., 2021), title screening, abstract screening and full-text screening. As shown in *Figure 1*, the next step followed was article screening. Within the screening process, titles were

screened as a first parse. If there was doubt about relevance, the abstract was immediately reviewed to ensure validity of results. During the screening process, 32 articles were excluded.

2.7 Eligibility testing

As shown in *Figure 1*, the next step followed was eligibility testing. For this purpose, the content of the whole article was read in detail and a decision was made on the basis of pre-defined inclusion and exclusion criteria. At this point, all conference papers were not excluded since there was no study found which dealt with software quality assurance education using game-based learning platforms, barring two conference papers.

Inclusion criteria:

1. Studies dealing with “Game-based learning” AND
2. Studies dealing with “Software engineering education”

Exclusion criteria:

1. Studies dealing with “gamification” or use of just game elements in a traditional or online educational course
2. Studies dealing with non-digital board games
3. Studies dealing with “game-based learning” AND “software engineering” but not education
4. Studies whose full text was not accessible

By applying the exclusion criteria during full-text reading, 26 articles were excluded. This exercise left us with a final useable sample for 22 articles and 2 conference papers which were used for a high-level mention.

2.8 Data extraction

All the final 22 articles were read in detail with a view towards answering the research questions. The answer to RQ1 was easily accessible at this level. To some extent, even RQ2 could be answered, barring areas where multiple software engineering knowledge areas were dealt with in a single article. In order to enrich the information about serious games per knowledge area (RQ2), some pieces of text were extracted from documents and summarised with reference tracebility in excel. When it came to understanding improvements over the last 5 years, a consolidated view had to be created. Initially, the researcher directly copied pieces of text that supported RQ3 or RQ4 and built a catalogue in excel. At times, some paragraphs had to be summarised to get a clear view on a particular topic.

2.9 Data analysis

Thematic analysis was used to make sense of the huge amount of data extracted from the 22 studies. The steps used to perform thematic analysis has been provided in figure 2 (Cruze et al., 2011).

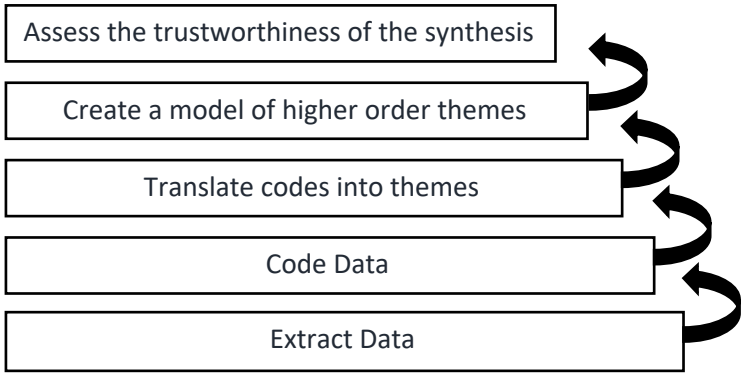

Figure 2: Thematic Analysis Process

Within the excel file where all the data had been extracted, coding was performed using simple labels. From the codes, themes were observed and grouped. Based on the theme being generated, answers to sub-questions could be identified and grouped as category. All the data corresponding to a category across articles was pulled together and cross analysed. The answers to RQ3 and RQ4 were prepared based on this method.

2.10 Quality

Exhaustive Search: Using only four databases felt like there might be information that could have been missed. Therefore, the researcher conducted further searches on two additional databases. None of the results found cleared the exclusion criteria.

Data Extraction: There is a possibility of inaccurate interpretation of qualitative data. The researcher re-read the full-text and cross checked if the observed code corresponded with the actual code put in initially.

2.11 Limitations of the research design and methods

All the journal articles used for systematic literature review are from low ranked journals. Although these are the only articles available currently, but the level of confidence we can vest in them from information perspective is questionable. As more trustworthy information gets generated, revisiting this research would be a good idea.

In order to remove certain individual related biases from the data analysis process, it advisable that a second researcher to review the findings. Since the design of this research doesn't allow a second opinion from a fellow researcher, there are certain individual related biases that cannot be removed.

3 Structured Literature Review

3.1 Introduction

Gamification is quickly gaining significance both in research and practice and has sparked considerable interest amongst researchers across the globe. They believe that the pleasure association of the concept game can be used to make difficult tasks easy (Spanellis et al., 2021; Mullins et al., 2020). This is especially relevant in the field of education. Here, researchers believe gamification to be the most appropriate process for creating engaging learning environments (Swacha, 2021). Gamification creates an environment geared towards the efficient uptake and comprehension of complex concepts (Jagust et al., 2018). It facilitates greater student collaboration which enables more effective problem solving (Park et al., 2019). Due to these reasons and several more, gamification of education has gained enough importance to have a sub-discipline focussed on this topic alone called game-based learning (Krath et al., 2021). Recently, it has been forecasted that game-based learning will be one of the top trends in the field of education (Elizabeth et al., 2019).

3.2 Gamification and game elements

In a seminal paper on gamification, Deterding et al. (2011, p9) defined gamification as “the use of design elements characteristic of games in non-game contexts”. This definition has been widely cited in extant gamification literature as a versatile term covering several broad game-influenced areas. The game elements (Krath et al., 2021) mentioned in the definition had various types, like social (for example, badges, statuses or avatars), competitive (for example, points, leader boards or levels), teaming (for example, categories, themes or avatar groups) and many more. These elements were used as means to make serious tasks with a defined outcome less overbearing and more enjoyable. Seaborn and Fels (2015, p. 17) later improved the definition of gamification to “the intentional use of game elements for a gameful experience of non-game tasks and contexts”. Gamification achieved tremendous success in business areas like, marketing and product development (Wang et al., 2020) where customers needed to be incentivised to engage. On the education front, Bai et al. (2020) conducted a meta-analysis and concluded that gamification improves learning performance due to factors like, motivation improvement, quick performance feedback and achievement recognition. Gamification does not change the core process of educating; it rather works as a tool to support the overall experience.

Use of game elements formed the core of any gamification project. The boundary of usefulness of gamification has already been ascertained. The aspect to maturity that was

lacking was building a taxonomy of game elements which could guide the user community. Schobel et al. (2020) devised a detailed taxonomy splitting up game elements into various categories and explained their use in game design. This taxonomy can be used by gamification practitioners to quickly gamify serious tasks.

3.3 Serious games

While gamification is the application of game elements to real world tasks, serious games contain a fully-fledged game (Krath et al., 2021). The only common aspect among them is gameful experience (Deterding et al., 2011). Serious games are digital games whose narrative and mechanics have been constructed with a form of education as its primary objective and entertainment or fun as secondary objective (Alexiou et al., 2020). They have been successfully applied as training tool in various industries. Serious games have shown enhanced cognitive results, higher motivation and greater learner satisfaction (Buchinger et al., 2018).

Some of the principles designed for serious games are the following (Marcelino et al., 2022):

- The main objective of a serious game should be educational and ultimately all aspects should drive towards it
- Content knowledge should lead to better performance at the serious game
- There game design should encourage students to acquire greater knowledge in the chosen subject area
- The game should be able to measure knowledge acquired

All the serious game developed follow the above principles at the least.

3.4 Defining game-based learning

Development of serious game gave rise to several use-cases, until all the education specific aspects of gamification were aggregated under the umbrella term game-based learning (Jagust et al., 2018). Therefore, game-based learning always has a serious game in its core but has educating as a main outcome. There is always a well-defined set of learning objectives of game-based learning (Plass et al., 2015).

Sousa et al. (2019) proposed that game-based learning provides a virtual world solution to several educational problems. Technology advancements have taken game-based learning courses into rich immersive 3D experiences (Siala et al., 2019). Aspects like learning by play-acting or following virtual narratives are seen as highly effective learning tools. A learner's virtual avatar progresses through a self-paced learning journey whilst improving their social recognition, status changes and achievements. (Bhattacharyya et al., 2020). These aspects

make the learning journey more pleasurable and highly motivating.

Mullins et al. (2020) believe that advances in cognitive neuroscience have allowed modern game-based learning researchers understand that effective learning requires both favourable emotional and cognitive states. Thus, game-based learning strives to provide educators with control over both these aspects.

Combining the key ideas proposed by various researchers, game-based learning can be defined as:

> *Game-based learning is the cognitive process that is enabled using a serious game at its core to provide an immersive learning experience to "learners" and greater emotional and cognitive control to "educators".*

3.5 Conceptual model of game-based learning

All efforts in game-based learning starts with a non-gamified course with a finite set of clearly defined learning goals. To enable the transformation of the course, game-based learning researchers have extensively worked on the foundations of game design. Figure 3 shows a proposed conceptual model for the game-based learning construct.

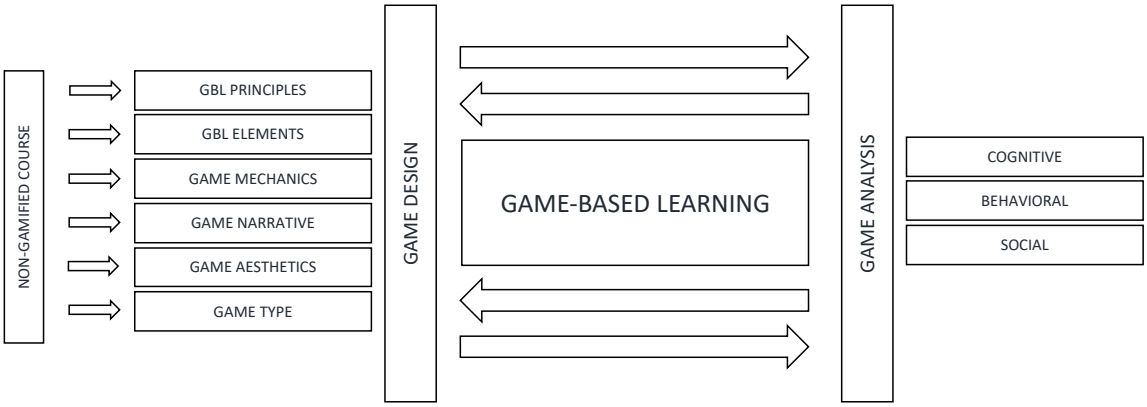

Figure 3: Proposed conceptual model for game-based learning

3.5.1 Game design

Game design plays the same role as the architecture does to a building. The seminal work of Liu et al. (2017) created a framework for game design that is widely accepted by all researchers as best practice. They created processes for combining game design antecedents that could lead to rapid prototyping on modern gamified platforms. Silic and Lowry

(2020) created a use-case where all the game design framework was successfully put to test.

3.5.1.1 Game principles

Almost duplicating initial robotics principles, researchers have proposed gamification principles (Liu et al., 2017) and they are subscribed to the whole digital game development community.

3.5.1.2 Game elements

Game elements are the only aspect of gamification that have been carried over to the game-based learning domain. They cover all the aspects that provide a gameful experience outside the game. These include but are not limited to elements like leader-boards, badges, avatars and game levels. Schobel et al. (2020) clearly defined a taxonomy for game elements that can soon become an accepted standard.

3.5.1.3 Game narrative

The main story that provides an engaging background to initiate the learning process is called the game narrative (Plass et al., 2015). All the actions built within the game have the game narrative as the fabric that joins them in the background. The game narrative captures the imagination of the learner and builds the golden thread of the learning process.

3.5.1.4 Game mechanics

All the allowed actions of the learner while playing the game is called game mechanics. Games mechanics are designed with the learning objectives in mind. Mullins and Sabherwal (2020) are building standard set of game mechanics which could be used as user-machine interaction stereotypes in game design. All correct actions are incentivised, and all wrong actions are penalized. Therefore, changes in a game elements are triggered through the execution of a game mechanic (Plass et al., 2015). Educators can also use these to guide learner behaviour.

3.5.1.5 Game aesthetics

The narrative is relayed to the game player using a visual elaboration. All aspects that cover the look and feel are grouped under game aesthetics. It also determines the visual feedback of the actioned mechanics. A generic theme is followed across major modules or the whole game. Game designers prepare a set of building blocks for a theme and use them across the game application.

3.5.1.6 Game type

Researchers are modifying game parameters to ensure that the right cognitive, motivational and behavioural goals are achieved. Jagust et al. (2018) are trying to define the right game type using the parameters of competition, collaboration and adaptability to achieve the desired outcomes. The optimal balance of game type and outcome type is a subject of immense debate (Mullins et al., 2020). Höllig et al. (2020) are working on adaptability based on user types and preferences. Several authors are analysing how to ensure that there is no dip in motivation right through the educational program which have been a shallow u-shape in most courses.

3.5.2 Game analysis

The methods of game analysis from a biometric perspective are a rather new field. Several researchers are collecting learners' multi-modal data (MMD) to analyse success and failure of game features (Giannakos et al., 2019). Sharma and Giannakos (2020) have analysed all the research on gaming analysis using MMD, and outlined behavioural trajectories, learning outcome, learning-task performance, teacher support, engagement, and student feedback. This work can be synthesised into a standard feature-sets for game design.

Qian and Clark (2016, p. 52) have defined game outcomes as "21st century skills (critical thinking, creativity, communication, and collaboration), cognitive (retention, transfer, cognitive load, and knowledge acquisition), skills (motor, spatial, and visual skills) or behavioural (behaviours and attitudes)." Although, through the use of game analysis tools, most researchers are primarily trying to assess the game performance along three dimensions, cognitive (for example, learning and retention), behavioural (for example, motivation and engagement), and social (for example, teamwork and leadership).

3.5.2.1 Cognitive

The primary goal of any game-based learning is some form of education. Most of the design is performed with this goal in mind. There are several theories that support the use of game-based learning for education. Primary among them is situated learning theory.

Situated Learning Theory proposes that learning best happens in the actual context within which the task needs to be performed (Spanellis et al., 2021). It emphasizes that new skills can be best learned by joining an actual group of practitioners of the skill, referred to as community of practice (Fox, 2000). The learners need to start performing the simplest tasks of the discipline and climb the complexity ladder while watching the experts, referred to as

legitimate peripheral participation (Lave et al., 1991). Game-based learning provides a virtual environment to learn by doing situatedly.

3.5.2.2 Behavioural

Motivation

The main theme behind game-based learning's popularity is the gameful experience it provides. The pleasure association attracts players and assists them learn without making the task of learning onerous. The main features of game designs, like adventure, inquisitively, challenge, are intrinsically motivating (Plass et al., 2015).

3.5.2.3 Social

Teamwork

Researchers have found high correlation between team cohesion and overall performance (Austin et al., 2019). The reasoning provided for this phenomenon is, easy sharing of critical task information, desire to help each other, have a shared responsibility to achieve a task. Game-based learning can be easily designed to foster teamwork both amongst peer and educators.

Other skills like leadership, communication, innovation, stress management and several others can be taught using game-based learning (Garcia et al., 2020). All that is needed is a well-designed narrative and an engaging platform.

3.5.3 Testing game-based learning courses

Researchers across the globe are busy comparing learning performance data across gamified and non-gamified courses. These efforts are yielding mixed results. Bhattacharyya et al. (2020) have proposed that the modern youth can put in exceptional effort when social recognition is the outcome. Small things like digital badges are affecting self-efficacy theories immensely (Casilli et al., 2016). Austin et al. (2019) observed that with team-based-gaming, motivation improved significantly but learning did get slightly compromised. Using a similar approach, Pe-Than et al. (2017) did an experiment to analyse how collaboration and competition affect learning and motivation.

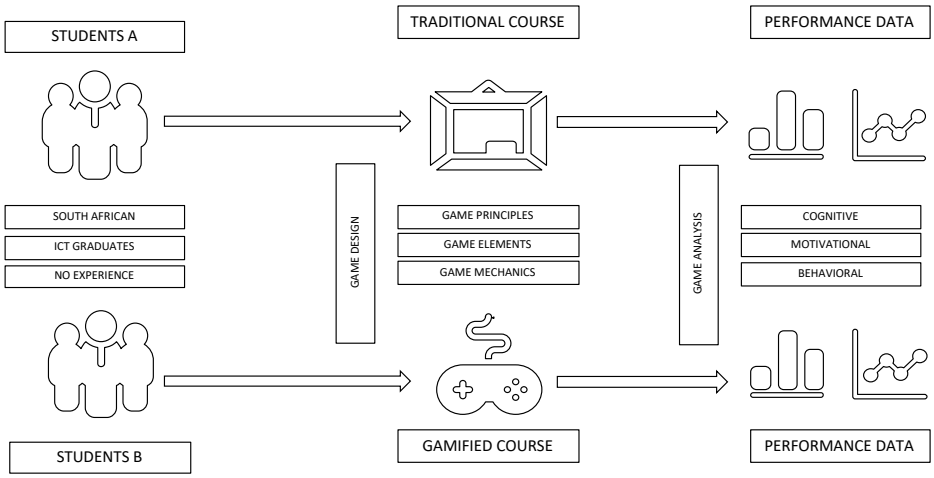

Figure 4: Game-based learning experimental setup

Figure 4 shows a high-level experimental setup for testing a game-based learning course's learning performance impact against a control group (Perini et al., 2018; Kwak et al., 2018; Kwon et al., 2021). The single point of simulation is the gamified course, where several input parameters can be varied to test different results. Park et al. (2019) gamified an IT training course called GAMESIT. This gamified system showed far better learning outcomes as compared to just the e-Learning Module. The researchers had to experiment and devise a specific mix of game design elements to achieve the desired result. Typically, the main course is conducted in a flipped classroom mode, where the core subject matter is distributed as video lectures and the control class is run by a human instructor for problem solving and paper-based exercises. The experimental class performs exercises using game-based learning platforms alongside a narrative.

The core ingredients for testing needs to be logically selected for each study based on the desired outcomes. This study aims to improve learning performance using a game-based learning platform by augmenting it with the attributes of situated learning theory.

3.6 Game-based learning in education

Game-based learning has become one of the most researcher constructs in the field of education (Fu et al., 2020; Garcia et al., 2020; Tay et al., 2022). There seems to be a study in each subject, from elementary maths to nursing training. There are studies done on students from grade five all the way to bachelor's degree academic programs. Additionally, there are game-based learning studies that have been performed on professionals not only to skill them up on their core jobs but also to improve their leadership skills (Sousa et al., 2019), teamwork skills (Austin, 2019) and soft skills (Garcia et al., 2020). The main reason for the focus is

3.6.1 Emotional state of educators and learners

Educators have been delivering the same course content year after year. Every educator in each discipline must do the same. As they all possess human deficiencies, their performance during the lectures depends on several aspects of their emotional state. This dependence changes the quality of course content delivery that the students receive and becomes a huge risk for them. The emotional state of the learner becomes a second factor within the learning process. Mullins et al. (2020) tested the effect of emotions on three cognitive processes. It was discovered that the learner's emotional state dictates the performance of memory, retention and decision making. Therefore, positive pro-education emotional state is mandatory for both the learner and educator for effective education to take place. Current methods of education have little focus on the emotional states of educators of learners. Game-based learning changes this through the dual influence on emotion and cognition.

Memory: Game-based learning provide an immersive experience to the learners. The emotions created during these activities influence the amygdala, thus creating episodic memory through strong association with the gamified tasks (Mullins et al., 2020).

Attention: Game-based learning tasks have far greater visual appeal by design. The emotions evoked, whether positive of negative, remove the occurrence of "inattentional blindness" (Mullins et al., 2020).

Decision Making: Game-based learning tasks are designed for the player to expect rewards for correct decision and punishment of inaccurate ones (Mullins et al., 2020). This phenomenon always creates an unconscious awareness. This emotional alertness re-focusses the decision making and improves its quality tremendously.

3.7 Game-based learning in software engineering

A lot of tasks in software engineering are repetitive and mundane (Lopez-Fernandez et al., 2021). Common examples of such tasks are finding bugs in code. The repetitive aspects of any form of education could be converted to one of the available options, like, flipped classrooms. Similarly, game-based learning has the potential of opening a lot of options to both the educators and the learner. The upcoming sections analyse these aspects in detail and an option to transform educational methods.

3.7.1 Software Engineering knowledge areas

Software engineering courses vary from institution to institution and from country to country. Although, there are a basic set of courses that stay consistent everywhere. These are courses which align well with the software development lifecycle areas. Rather than treating them as individual courses, which would give rise to university flavours, the courses here have been divided based on knowledge areas. The main knowledge areas that are consistent across most universities are, software project management (including agile), software requirements engineering, software system design, software construction, software quality assurance, soft skills (Souza et al., 2018). These knowledge areas seem aligned to both waterfall and agile software development methodologies (Lopez-Fernandez et al., 2022; Marcelino et al., 2022).

3.7.2 Data collected per knowledge area

As a first step, the researcher classified all the selected articles into their knowledge areas. This was done to ensure that all knowledge areas were being represented in the data analysis. The *Table 1* below shows the number of articles that were found for each knowledge area. They have also been spread over our selected time horizon of 2018 – 2022.

	2018	**2019**	**2020**	**2021**	**2022**
Software Project Management (including agile)	0	0	0	2	1
Software Requirements Engineering	1	0	1	0	0
Software System Design	0	1	0	0	0
Software Construction (programming)	1	1	3	1	1
Software Quality Assurance (testing)	1	0	0	1	0
Soft Skills (for Software Engineers)	0	0	1	0	0
All knowledge areas	3	2	1	1	1
TOTAL	6	4	6	5	3

Table 1: Selected articles summary

As expected, most of the work is being done in the software construction knowledge area. Programming forms the core of the software engineering curriculum and is the most in demand skill in the MICT industry. One article focussed on improving the soft-skills of software engineers has also been analysed. This is a part of the overall curriculum and often a critical, yet under-valued skill in the industry. Some game-based learning platforms have been built to support all aspects of software engineering. They have been classified under “All knowledge areas”.

Based on these, it can be conclusively said that game-based learning platforms have been

built for all the software engineering knowledge areas.

3.7.3 Serious games per knowledge area

The domain of game-based learning platforms encompasses several types of games like, board games, role-play games, partially gamified systems, and fully digital serious games. For the purposes of this study, only fully digital games have been analysed. The researcher believes that the prevalence of all other forms of game-based platform is purely for inexpensive proof of concepts. In the end state, only fully digital serious games will exist.

Gordillo et al. (2022) believe that the reason for the low-prevalence of game-based learning courses is due to the scarcity and low maturity options available to the educators. The amount of effort being put by researchers, entrepreneurs and IT companies should soon yield results. This section tries to analyse the game-based learning platforms that have been tested by researchers in each knowledge area.

Software Project Management (including agile)

There are two main software project management methodologies being followed by software engineering practitioners, waterfall and agile. Within waterfall there are several guides that have been built, like PMBOK and PRINCE2 (Marcelino et al., 2022). Even in the case of agile, several guides are available now like SCRUM (Lopez-Fernandez et al., 2021) and SAFe (O'Farrell et al, 2021).

Table 2 lists project management serious games for each methodology. This study has not analysed the quality of these serious games. The researcher though has reviewed articles (Lopez-Fernandez et al., 2021; Marcelino et al., 2022; O'Farrell et al, 2021) where the serious games mentioned were tested to check the learning performance enabled by them.

Serious Game	Focus
PM-Game	PMBOK principles
SimProject	PMBOK principles
The Crowd Training Game	PMBOK principles
ScrumVR	Scrum principles
PlaySAFe (Unity)	SAFe principles

Table 2: Project Management Serious Games

These games form part of a game-based learning platform and have shown comprehensive

coverage of the methodology they gamify. These are not the only games within the knowledge area. There might be other commercial games available, but no studies have been conducted on them.

Within software engineering, project management is the knowledge area that requires maximum interaction (Lopez-Fernandez et al., 2021). It requires all stakeholders' participation to deliver a software product. There is planning involved in a lot of sub-areas and the decisions could be mission critical for the success or failure of the project (Marcelino et al., 2022). All the proposed serious games can simulate the planning process and show positive/negative consequences of the decisions made. They can mimic social interactions through well designed game mechanics and several abstract concepts can be taught through them (Lopez-Fernandez et al., 2021).

Software Requirements Engineering

Software requirements engineering covers major sub-processes like requirement elicitation, specification, management, verification, and validation (Soo et al., 2018). If not done correctly, it poses huge risks to the overall delivery. It has always been one of the most important but most ignored knowledge areas of software engineering. This is evidenced by the fact that there still isn't a clear guide for requirements engineering in the agile space (Cooper et al., 2020). Consistent with this trend is the lack of good studies in the domain. The researcher could only find one good study and one conference paper (excluded from systematic literature review) on requirements engineering.

Table 3 lists serious games for requirements engineering and their core focus areas. Like in the case of Project Management knowledge area, these games have been found by the researcher in reviewed articles (Cooper et al., 2020).

Serious Game	Focus
SW-Quantum	Risks of unclear requirements
RCAG	Full requirements engineering
REfine	Requirements elicitation
UserStory	Requirements elicitation

Table 3: Requirements Engineering Serious Games

The quality of the games is not directly tested. Although, the studies analysed have great reviews for them.

Requirement engineering requires high interaction with business stakeholders who have limited understanding of software engineering processes. It is therefore difficult to engage the business stakeholders if they cannot be educated first. The serious games like RCAG and UserStory help in educating the stakeholders and engages them with rewards (Cooper et al., 2020). Since some of the business stakeholders are future users of the built platform, their reaction to the game can help refine requirements and prepare them for testing later (Soo et al., 2018). This leads to a 360-degree motivation and is good for the overall success of projects.

Since the games required role playing in the virtual world, all the students had a better understanding of the consequences of their actions. This coupled with reinforcement through a point system helps create sustaining memory and therefore leads to better learning performance.

Software system design

Software system design plays a similar role as architecture in construction. A poor design has the potential to destroy a best written software project. The value realisation of a project completely depends on it (Fuster-Guillo et al., 2019).

Table 6 below lists some of the games using which studies were conducted to test the learning performance improvement in software design. This study has not tested the performance of the games.

Serious Game	Focus
Kahoot	Computer Architecture
CUDATHON	Design hackathon

Table 4: Software Design Serious Game

The table also provides the core focus area of the game, within the area of software engineering. These are not the only games within the knowledge area. There might be other commercial games available, but no studies have been conducted on them.

Software design is an area which could benefit immensely through game-based learnings visual representations. By using game-based learning's animation aspects, it is easy to clearly point out the dependencies that one system has on other systems in the overall technology

architecture (Fuster-Guillo et al., 2019). Difficult conceptual problem solving methods could be taught by using well-built animation.

Software Construction (programming)

Amongst all the knowledge areas within software engineering, software construction or programming is most critical. A lot of research has already been done to understand the issues learners face in mastering programming. (1) The core concepts of programming are very difficult to grasp for a beginner (Kazimoglu, 2020). (2) Mastering the syntax and approaching new work with it is difficult (Topalli et al., 2018). (3) Students are not able to pick up critical thinking skills (Kazimoglu, 2020). (4) Ability to see both the bigger picture and the detail simultaneously is difficult (Topalli et al., 2018).

Table 4 below lists some of the games used in studies which were conducted to test the learning performance improvement in software construction. This study has not tested the performance of the games.

Serious Game	Focus
GSD-Aware	Global software development
Newton (Unity)	Generic programming concepts
Program your Robot	Constructing Algorithms
QC	SQL programming competition
Scratch	Programming concepts

Table 5 Software Construction Serious Game

The table also provides the core focus area of the game, within the area of software construction. There are other great commercial games for learning and practicing coding like Wu's Castle, CodeCombat, CodeSpell, Minicolon and more (Zhao et al., 2019). They might be better games for learning programming and maybe a study needs to be conducted using them.

The ability to write good code needs both analytical ability and years of practice. For initiation into this journey, the first step should capture the learner's imagination and generate a passion for the domain. Most of the games proposed provide analytically challenging programming tasks within competitive environments (Morales-Trujillo et al., 2020). Additionally, intuitive, and engaging user interfaces are created to ensure ease of use (Zhao et al., 2022). All aspects of game-based learning like, game mechanics, game dynamic and game elements have been used to motivate and engage the players (Vizcaino et al., 2020).

One of the main shortcomings of programming has been the need to remember how to write code that is syntactically correct (Topalli et al., 2018). There is a need for a programming language where more effort is invested in problem solving rather than syntactical accuracy. All the games discussed above have greater emphasis on problem solving.

Software Quality Assurance (testing)

Most of the work in software engineering education is focussed on programming. Even though software quality assurance is a key component of software engineering, studies often ignore the knowledge area. Verification and validation of code forms an integral part of the knowledge of a developer at a minimum (Lorincz, 2021). An expert at quality assurance works twice as fast as a good programmer (Miljanovic et al., 2017). There is severe frustration and demotivation related to debugging.

Therefore, a medium like game-based learning can make the tasks related to quality assurance less arduous. Unfortunately, there are very few studies that are done in this space. All the literature available on the use of game-based learning in quality assurance are conference papers and have been thus ignored. The researcher has used the information regarding quality assurance from studies that talked about use of game-based learning across all software engineering knowledge areas.

Within the conference papers that were reviewed, the main games highlighted were RoboBug and Gidget.

All knowledge areas

Software engineering courses that cover all knowledge areas help in looking at the bigger picture. The end goal of software engineering is to deliver high quality code, on time and cost effectively. Yet most of the software engineering courses are highly theoretical and are not able to deliver the desired value using traditional methods (Elizabeth et al., 2019). Simulation of real-life problems can help students understand software engineering better. Gordillo et al. (2022) successfully created a game-based platform that can simulate software engineering problems and teach students through it.

Table 5 below lists some of the games used in the studies that were conducted to test the

learning performance improvement in all knowledge areas of software engineering. This study has not tested the performance of the games.

Serious Game	Focus
SGAME	Full Software Engineering
SGAME - SCORM	Full Software Engineering
Create@School	Design, Programming and Project Management
Simul-ESW	Full Software Engineering

Table 6: Software Engineering Serious Game

The table also provides the core focus area of the game, within the area of software engineering. Since they have been tested in an educational context, these games could act as good candidates for further studies in the overall software engineering knowledge area.

Overall software engineering courses that have been built on game-based learning platforms are showing good results. They can gamify all the moving pieces of the software engineering puzzle and provide learners with a unified environment for learning (Hosseini et al., 2019). There is evidence to suggest that the software engineering education community is obsessed by games (Elizabeth et al., 2019). One of the approaches proposed to teach software engineering holistically is to engage students in the process of building a digital game (Gaeta et al., 2019). Some educators are recommending a mix of traditional and game-based courses for software engineering.

3.7.4 Learning performance comparison

The main objective of all game-based learning system is to improve the learning performance of its users compared to the traditional, online or video-based courses. In the last systematic literature review done, Alhammad et al. (2018) had found that most studies did not find a significant improvement in learning performance. The key test for this study was to check if the trends on this parameter had changed.

Table 7 below lists the results that each study reviewed has provided. If the study has found the learning performance improvement to be statistically significant, it has been marked user statistically significant positive. The opposite is marked under statistically significant negative. Whereas if there is no significant observed change, it is marked as not statistically significant.

Software Engineering Knowledge Area	Statistically Significant Positive	Not Statistically Significant	Statistically Significant Negative
Software Project Management (including agile)	3	0	0
Software Requirements Engineering	2	0	0
Software System Design	1	0	0
Software Construction (programming)	7	0	0
Software Quality Assurance (testing)	0	0	0
Soft Skills (for Software Engineers)	1	0	0
All knowledge areas	6	2	0

Table 7: Learning Performance Improvement

Around 90% of the studies showed a statistically significant improvement in learning performance. There were several factors that contributed to the change like, the use of game-based learning in place of just gamification elements, better thought-out game narratives, superior animation quality and overall better user experience. These aspects have been discussed in detail in chapter 4, under the discussion section of the literature review.

3.7.5 Learning motivation comparison

Traditionally, learning motivation improvement has been one of the core benefits of game-based learning courses. The pleasure association of game-based learning platforms has always attracted users to it. Alhammad et al. (2018) had found consistently high results on this parameter.

Table 8 below lists the results that each study reviewed has provided. If the study has found the learning motivation improvement to be statistically significant, it has been marked user statistically significant positive. The opposite is marked under statistically significant negative. Whereas if there is no significant observed change, it is marked as not statistically significant.

Software Engineering Knowledge Area	Statistically Significant Positive	Not Statistically Significant	Statistically Significant Negative
Software Project Management (including agile)	3	0	0
Software Requirements Engineering	2	0	0
Software System Design	1	0	0
Software Construction (programming)	7	0	0
Software Quality Assurance (testing)	0	0	0
Soft Skills (for Software Engineers)	1	0	0
All knowledge areas	8	0	0

Table 8: Learning Motivation Improvement

As expected, all the articles reviewed found better learning motivation in game-based platforms compared to traditional, online or video-based education. A consistent result in this area confirms that a focus on learning performance improvement, does not undo the positives of other areas.

3.7.6 User engagement comparison

The previously conducted systematic literature reviews have less focus on user engagement and higher focus on learning performance. Mullins et al. (2020) concluded that a user's emotional engagement leads to better learning performance. Therefore, this aspect has been analysed in detail in this study.

Table 9 below lists the results that each study reviewed has provided. If the study has found the learning performance improvement to be statistically significant, it has been marked user statistically significant positive. The opposite is marked under statistically significant negative. Whereas if there is no significant observed change, it is marked as not statistically significant.

Software Engineering Knowledge Area	Statistically Significant Positive	Not Statistically Significant	Statistically Significant Negative
Software Project Management (including agile)	3	0	0
Software Requirements Engineering	2	0	0
Software System Design	1	0	0
Software Construction (programming)	7	0	0
Software Quality Assurance (testing)	0	0	0
Soft Skills (for Software Engineers)	1	0	0
All knowledge areas	8	0	0

Table 9: User engagement improvement

All the articles reviewed found better user engagement in game-based platforms compared to traditional, online or video-based education. One of the main changes that have happened over the last five years in the technology industry is the focus on customer experience. This aspect had influenced the game-based learning tools too. There is high focus on improving methods to engage the learners and educators. This might be in the form of better user interface design, game elements or background music. There is emphasis on keeping all the senses positively engaged with the game-based learning system.

3.7.7 Issues with game-based learning platforms

A lot of valuable changes have happened in the game-based learning domain for software engineering education, which could work as a business case for more universities to test them. While this process would start happening soon, there are still some issues within the platforms that need further work.

Table 10 below lists the issues highlighted in game-based learning platforms in the articles reviewed. It also shows the number of articles that have talked about the same issue within the 22 articles reviewed.

Issue category	Issues	References
Information	Doesn't cover the knowledge areas exhaustively	2
	Doesn't summarize information for revision	1
Technology	Animation quality is low	2
	Mostly made for a single device type	3
	Game narrative doesn't align with knowledge area	3
Health issues	Grows screen time immensely	1
	Immersive technology head-gear causes dizziness	2
Player identity	If anonymous, learners misbehave	2
	If not anonymous, learners are sometimes victims of social pressure	2
Educator	Control focus on course content rather than game	1

Table 10: Game-based learning platform issues

These are the top issues that have been extracted. When some systems are analysed, it did feel like they were built for proof-of-concept purposes. While other platforms were fully functional platforms and some of the above issues were not there. This list could guide game developers about the feedback the user community is providing on the work done thus far.

3.7.8 Summary of literature review

All the game-based learning platform developers were ignoring the research outcomes and believing in the technology. Their persistence and the technical changes have helped turn around the learning improvement goal trend. Most studies reviewed have shown an improvement in learning performance of the user.

Theoretically, it was always believed that a game-based learning platform should work effectively on achieving educational goals. It perfectly mimics the situated learning theory perfectly (Lave et al., 1991). It correctly appeals to all the emotions to align fully with the emotional-cognitive theory (Mullins et al., 2020). These trends just had to reflect in practice and the analysed studies have confirmed it.

The other aspects like motivation and engagement were already accepted benefits of game-based learning platforms. Current studies have been able reinforce this understanding.

There are still areas of improvement. Apart from possible health issues and social pressure, everything else seems to be rectifiable through an investment of money and time. As game-based learning platforms mature, all the open issues should get fixed.

4 Discussion of Literature Review

This study has highlighted that game-based learning's role in software engineering has changed considerably over the last 5 years. Doubts about the potential of game-based learning have been clearly dispelled. The question now is, in what form and to what extent will game-based learning be used in software engineering education? The following sections will discuss this transformational journey.

Firstly, it was found that the learning needs to be pushed to the background and fun should be brought to the fore (Elizabeth et al., 2019). If this can be done effectively, learning will happen automatically, and the students will not be unduly stressed.

4.1 Game-based learning in software engineering knowledge areas

Based on the initial literature search results before applying the filter criteria (108), it can be concluded that there is a lot of game-based learning work happening in the software engineering education domain. Even more encouraging is the fact that these studies are not concentrated in a single region, they are happening globally.

As expected, the most critical aspect of software engineering, software construction, takes a mammoth share of the work done. There is similar emphasis on project management and software engineering as a holistic subject.

The areas which still need effort are software requirements engineering, software design, software quality assurance and soft skills.

The publication in high quality journals is still an issue. None of the work retrieved, featured in a journal with an academic journal guide ranking of 3+. This can be interpreted as work that is progressing towards maturity but not fully matured yet. This is consistent with the state of the game-based learning domain. It is in flux but quickly evolving for the better. Studies that have greater academic rigor can be expected soon.

4.2 Serious games built for software engineering education

Serious games form the core of all game-based learning platforms. Based on the number of games available, it is easy to infer that the game development community is huge.

This study was able to find multiple games for each knowledge area. Again, as expected the number of games in the areas like software construction is way more than all the other knowledge areas combined (Krath et al., 2021). One of the other aspects observed was that the commercial software construction games like Wu's Castle, CodeCombat, CodeSpell, Minicolon and more (Zhao et al., 2019) have not been used for any of the studies.

There were several serious games options for software project management and overall software engineering as well. Some studies in project management were using commercial games as well (Lopez-Fernandez et al., 2021; O'Farrell et al, 2021).

The other aspect of software engineering like, software requirements engineering, software design, software quality assurance and soft skills have fewer options available. Once the uptake of these solutions grow, there will certainly be multiple options of games available in these areas too.

4.3 Observed benefits of game-based learning in software engineering education

4.3.1 Learning performance improvement

Lave and Wenger (1991) proposed that true learning can happen in the exact social context within which the learning is meant to be practiced. Virtual reality systems, used to build serious games, simulate the near real environment (Lopez-Fernandez et al., 2021). Game-based learning platforms built using virtual reality technology provides a risk free environment in which a student can practice learned content without the risk of consequences. This social context within which the seekers of true knowledge need to be situated is called community of practice (Brown & Duguid, 1991), where one starts as a novice and gradually transforms into an expert. Game-based learning platforms enable joint participation of learners and educators at different level of expertise. This forms the ideal learning environment. There are several other theories using which success of a game-based platform can be explained. Worth mentioning amongst them are, cognition-emotion theory, flow theory and goal-setting theory.

Therefore, it is not surprising that most of the studies found a growth in learning performance through the use of game-based learning platforms as compared to traditional methods of education. Similar results were found when a comparison was done against video based or online education. Additionally, game-based learning provides an environment of practicing a skill through repetition (Lopez-Fernandez et al., 2021). This environment is available at all times and is inexpensive.

4.3.2 User experience improvement

Most of the game developers invest a lot of time on user experience, thus making learning easy for the participants (Lopez-Fernandez et al., 2021). This user-friendliness encourages learners to start the skill acquisition journey on game-based learning platforms. They ensure that rules can be understood easily and complicated concepts a visually explained.

Game-based learning developers have started investing a lot of time in preparing game narratives. They also seamlessly integrate the narrative with the knowledge of the subject area. The principle followed is that fun should be in the fore and learning should happen automatically in the background.

Game-based learning developer focus a lot on aesthetics. They build some of the most authentic setups for complete alignment with the narrative. Even the background music is carefully selected for each aspect. The learners are fully focussed since all their senses are engaged and there is little opportunity to lose focus. All these aspects contribute to the high user experience score of the game-based learning environment.

4.3.3 User motivation improvement

The games are built for instant feedback. Whether it is success or failure, the learner finds out immediately. By doing this, the game-based learning platform achieves high engagement and interactivity. Mistake can be fixed quickly and the learner can go back on the learning through playing journey.

Game-based learning tools are being designed as platforms that assist in better collaboration alongside software engineering education, both with other learners and the educator being fully enagaged (Elizabeth et al., 2019).

The games are designed to celebrate success and the games elements are designed for being ostentatious on behalf of the learner (Zhao et al., 2019). Since the identity of the learner is his/her avatar, the mistakes hide behind it but the real person can feel the celebration. All these aspects keep the learner highly motivated and keep bringing him/her back to the game-based learning platform.

4.4 Observed issues of game-based learning in software engineering education

Overall there are several great reasons to adopt game-based learning platforms as the new trend in education but there are still some aspects that might hold back adoption. There are come themes pointing towards recurring issues that need to be addressed. (1) Some of the serious games still seem to be in proof-of-concept mode. (2) The subject are knowledge provided in some systems is not complete. (3) The animation in some systems are under-developed and require more effort.

These aspects do not show a lack of skill but a cautious investment of time and effort. The developers of the platform would put in more effort as the acceptance grows. Based on the current trends, the investments and the effort put in game-based learning platforms should grow soon.

Some articles did talk about physical and mental issues like, (1) increase in screen time of learners. (2) Cyber-bullying and fake identities associated with online platforms. (3) Fear of failure causing mental trauma. These aspects are part of our increasingly online lives and work styles. Creating practice environment for learners would assist in overcoming mental issues. The learner type could choose the environment to use.

Some of these issues can also be prevented by the educator. Additionally, during game-play, the educator needs to do close monitoring to test if learning objectives are being met (Gaeta et al., 2019). If learners are left alone, they focus more on the gaming aspects.

There are other issues like discomfort caused by the 3D immersive head-gear. Such issues will always be there and would be overcome by technical improvements over time. These should definitely form part of the snag-list of the game-based learning technical community.

5 Conclusion

There has hardly been any change in the method of undergraduate education for several decades. The researcher believes that this study is as much for the learner as it is for the educator. Game-based learning offers several new options for the educator and learner. They could select a flipped classroom with video lectures and game-based learning in class. A combination of digital and non-digital games could be used if found effective. In each of the choices made, the most repetitive tasks will always be replaced by fully automated ones, thus making the whole process more efficient.

Game-based learning platforms have exhibited better learning performance for software engineering students in a majority of the articles analysed. There has been little doubt about the game-based learning platform's ability to motivate students better even in the literature reviews performed in 2018. These articles have further reinforced the belief.

As the pressure on the software engineering industry of South Africa mounts to deliver more, faster and better, there will be further demand to involve more software engineering skills. The need to speed-up upskilling of software engineers is bound to grow. Traditional methods have shown slower results as compared to game-based learning platforms.

Students of game-based learning courses are learning by doing. They are exposed to real world problems in the virtual world, specially designed to educate them. Since the education is less theory based and more practically oriented, it stays with the students much longer.

The quality of serious games used were not at the same level across all the studies. Some games are basic, whereas others have high-end immersive technology being used. Yet the studies have provided mostly positive learning and motivational results. Which suggests that students and educators are ready for game-based learning platforms.

The game-based learning platforms should proliferate faster based on the efforts being put in by the researchers, entrepreneurs, and corporations. They are motivated by their desire is to create near real world learning environments.

Game-based learning platforms are not free from issues. The students using the platform suffer from exposure to excess screen time compared to traditional classroom education. If the game uses immersive 3D technology where additional head-gear needs to be worn, there are potential health risks such as spatial disorientation and nausea.

There have been attempts to cover all areas of software engineering, but when analysed in detail, there are still gaps in knowledge covered. The coverage should slowly become complete as the uptake grows, and companies spend more time in building the game-based learning platforms.

5.1 Limitations

Game-based learning platforms are a quickly evolving and maturing. There has been a lot of work done in the field of education in general but not in software engineering. Therefore, there wasn't a lot of literature available in the AJG3+ journals. Once more literature is published in the leading journals, redoing this exercise would provide more refined results.

This study has treated game-based learning platform as a black-box and all the platforms as similar. Whereas, each game-based learning platform is unique, with specific components being designed for a specific outcome. This will continue to be the case till the function of each component is standardised or studies are done to determine their influence.

5.2 Future Work

There are other great commercial games for learning and practicing coding like Wu's Castle, CodeCombat, CodeSpell, Minicolon and more (Zhao et al., 2019). Studies have not been conducted using them to test learning performance improvement. There might be a possibility that the manufacturers do not permit their use in an academic context due to the fear that poor results would have an impact on the sales. Although, it would be great to know how they fare when put to the test.

There is a need to ascertain which game-based learning platform works the best. For example, a comparison between ScrumVR and Playsafe in the software processes knowledge area to understand which one assists understanding of agile project management better. Additionally, we can try to understand what attributes make a particular solution superior.

There are some key knowledge areas in software engineering that have not been explored yet or have been explored only partially. Analysis of these unexplored areas will assist us in establishing an overall view of the impact.

Over the duration of a software engineering course, game-based learning platforms have been able to sustain student interest. Further studies will be needed to understand if this would hold true for long durations, like for a four-year degree, where a student would need to move from game-to-game for learning all aspects.

We have used the unit of study as the game-based learning platform. An in-depth study analysing the details of the game-based learning platform and its effects on learning, motivation and other parameters could assist in designing a optimum solution. Similarly, game types (for example, competitive, collaborative, adaptive) could be changed and variation in performance could be tested.

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