

Bloom Taxonomy, Serious Games and Lean Learning: What Do These Topics Have in Common?

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Abstract. Lean Thinking principles and methods, in the context of highly valued production systems, are seen as the best practices and essential for competitiveness. Therefore, it requires educators, students, and employees well trained and prepared in Lean concepts to meet these demands. In this context, gamification is becoming a popular resource among educators who aim to train the principles of Lean Thinking. Among educators, Bloom's taxonomy is an objective-based assessment as it approaches a high level of detail when defining learning objectives. In the context of this paper, Bloom's Taxonomy encompasses the acquisition of knowledge, skills, and attitudes, to identify learning outcomes in serious games. This paper presents a literature review based on Bloom's Taxonomy, Serious Games and Lean learning. With this review, the authors intend to find evidence that Serious Games are suitable for Lean learning to reach the highest order level of Bloom's Taxonomy. Fourteen papers were identified in this review discussing the three topics. In just three of these papers, it was identified such evidence.

Keywords: Bloom taxonomy · Serious games · Lean learning

1 Introduction

In complex environment change, the companies need to adapt and transform themselves. Lean Thinking [1] has been a philosophy that help companies to seek more lean, flexible, sustainable and agile processes to face such complex scenarios [2, 3]. Nevertheless, there is "no Lean without learning", as referred by Powell and Reke [4]. Moreover, learning and knowledge dissemination are important processes in companies.

Lean Education, i.e., learning Lean, promote competencies that allowed to the apprentices to become able to improve Lean transformation in organizations [5, 6]. At a time when the industrial economy is being stronger allied to the knowledge economy, it is opportune to review the nature of practical education and the inherent skills developed [7]. Indeed, learning Lean implies effective and practical instructional methods such as gamification, hands-on, learning factories, role-play, simulations,

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among others [8]. In particular, some examples have demonstrated that simulation games are important instructional methods for learning Lean concepts [9–13]. Using these, learning is more practical, and objective and it is expected that using them will reduce the learning cycle time while add value to Lean teaching.

Gamification is the use of game elements in a non-game related context, with the aim of promoting learning behavior that enhances students' resources [14]. Applying game-based learning with its pedagogical benefits is a well-known instructional method recognized in Higher Education [9]. One of the main cognitive approaches to evaluate Serious Games (a second name for gamification) is Bloom's Revised Taxonomy [15]. Gamification can be a useful learning methodology for achieving all levels of Bloom's Taxonomy [16].

The increasing demand for knowledge within companies highlights the importance of measurable methods that respond to the gap between formal education and the workplace where is perceived [14]. The development and growing of a company can be determined by the ability and capacity of it and its individuals to be successfully involved in learning processes [7]. In this way, there is a clear need to evaluate empirically or study the effectiveness of gamification in relation to the results to which it is committed [16].

This article presents a literature review about Serious Games, Bloom Taxonomy and Lean learning to identify evidence that Serious Games allows effective learn Lean by allowing to highest order level of Bloom's Taxonomy.

This paper is structured in five sections. After the introduction of the objectives in this section, a brief background related to Bloom taxonomy, and game-based Lean is presented. The third section presents the research methodology. Results are presented in the fourth section. The last section, the fifth section presents the conclusions.

2 Background

2.1 Bloom's Taxonomy and Serious Games

Bloom's original taxonomy is a popular method among educators for objective-based assessment, as it allows for a high level of detail when defining learning objectives [15]. The three domains classified by Bloom [17] are: cognitive, affective, and psychomotor. The author also defines six different levels of cognitive skills: a) Knowledge; b) Comprehension; c) Application; d) Analysis; e) Synthesis; and f) Evaluation. Later it was revised by Krathwohl [18] as: 1) Remember; b) Understand; c) Apply; d) Analyze; e) Evaluate and f) Create. These are important levels for the achievement of better student learning and critical thinking results [7, 15].

The Serious Games, as a personalized learning approach to a real context, has a capacity to improve the quality of the educational system, offering opportunities to maximize the students' potential [19]. Given the current commitment of educators, Serious Games has been a positive choice for the development of Bloom's Revised Taxonomy as it can promote reaching the highest levels of learning [11]. Haring et al.

[15] considered that Bloom's Revised Taxonomy is one of the most appropriate cognitive tools for the evaluation of Serious Games. Furthermore, Nisula and Pekkola [20] concluded that the use of Serious Games based on Bloom's Taxonomy prepares professionals for complex and multidisciplinary work environments in a constantly changing world.

2.2 Game-Based Lean

Based on the fundamentals of the Toyota Production System [21], the Lean philosophy can be described as a set of principles that aim to reduce waste, add value and maximize the results of an organization through a systematic process of continuous improvement [9, 22–24]. Lean goes beyond a set of tools and methods. It means going deeper into a learning cycle, experiencing improvements, reflecting, and internalizing your insights, resulting in lean improvement lessons [6, 24].

For the global and sustainable evolution of Lean, fundamental values such as building a culture of continuous improvement, people development, management for learning, and problem solving are expected to be maintained [25]. Lean practices must promote, in addition to greater customer satisfaction, an ideal environment for learning: without guilt, fewer errors, availability of information, growth, and respect for workers [26, 27].

Lean learning can also support the company's ability to sustain innovation and knowledge linked to improvements in quality, productivity, and operational efficiency. This is because an organization that learns to learn in a Lean format expands the capacity to continuously create the established results [28]. In this way, models based on mechanisms of association, collaboration, sharing and mutual learning stand out for the development of a Lean learning environment [29].

In a context where current and holistic production systems are valued, the principles and methods of Lean Production are currently seen as the best practices and essential for competitiveness [28, 30]. Therefore, there is a requirement for students well trained and prepared in Lean concepts to meet these new demands [9, 31]. Since many companies suspect that the new generation of professionals is not prepared in terms of knowledge and skills appropriate to the needs of the industry [26], it is noted the importance of institutions to adapt Lean for curriculum and use alternative methods of teaching to connect to real contexts [9, 32]. For Lean educators, the consensus is the meaningful approach to the practical components [33].

This consensus is the consistent approach to the practical components of teaching [8, 13, 33]. Simulation games are currently a popular resource among educators who aim to train workers or students on the principles of Lean Production [33]. The use of game elements in non-game contexts can be defined by Gamification, or also Serious Games [14]. It is a plus pedagogical technique used to enrich the students' experience [16].

Game-Based Lean is designated to use Serious Games as a good alternative to teach Lean while provide new and important skills to professionals. Skills such as critical thinking, teamwork, communication, responsibility, motivation, and global learning are results achieved by Serious Lean Games, once that allow students to make decisions

and solve problems based on the application of Lean concepts [13]. Alves et al. [5] provided some examples of the use of Serious Games, and considered a successful tool for the dissemination of Lean knowledge [10], as well as an important active teaching method applied to Lean Learning [8].

3 Research Methodology

For the research it was used a literature review that followed two phases. The first phase, identification, consists of finding the articles according to a topic, carried out in two different search databases: Scopus and Web of Science (WOS). These were selected as they have an ample coverage [34]. The search in the database of SCOPUS and WOS was carried out using the following search strings: ALL ("Bloom's Taxonomy" AND "Gamification" AND "Lean"), ALL ("Bloom's taxonomy" AND "Serious Game*" AND "Lean") and limited to the period from 2010 to 2021. This period was chosen as most publications about serious game assisted education appeared after 2009 [35]. Also, the search included articles, conferences, books, and book chapters. This search resulted in a total 32 articles.

The second phase consisted of filtering and excluding duplicated articles, using the Excel software, following the criteria explained next. Repeated studies within the databases were eliminated, studies published in WOS were maintained and those that were in Scopus were subtracted. To do this, all the files downloaded from the databases were grouped and duplicated files within were removed. In total, 22 articles resulted from this phase.

The analysis of the 22 articles allowed to discard eight papers applying some criteria: not having free access to full paper and considering only articles that are case studies approaching Bloom Taxonomy, Serious Games and Lean learning within universities or companies. With this, the authors want to answer to the question in the title of the paper: *Bloom Taxonomy, Serious Games and Lean learning: What do these topics have in common?* This means that the final selection resulted in 14 papers, which were deeply analyzed and made-up Sect. 4 of this study.

4 Results and Discussion

The 14 papers identified that have the keywords selected are in the Fig. 1. The deep analysis of all papers referred the three domains of Bloom Taxonomy, namely, cognitive, affective, and psychomotor. Some examples were the presence of the words problem-solving and confidence.

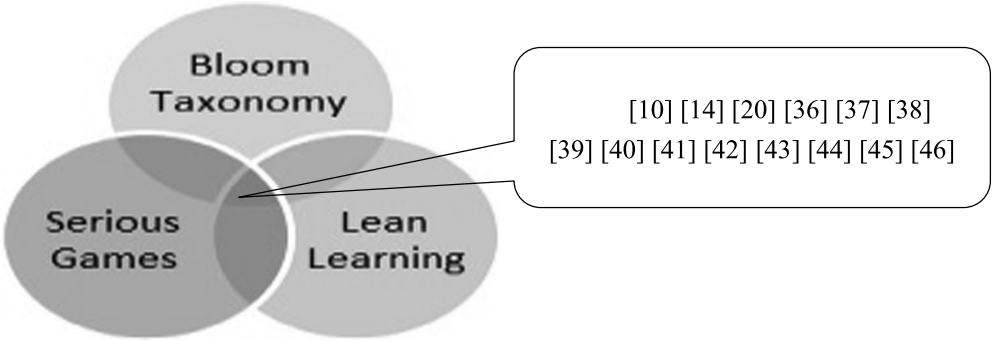


Fig. 1. Papers obtained from Scopus search.

Figure 2 and Fig. 3 shows respectively the countries and year from where the papers are. United States is the country with more publications (five papers), and considering the period of 2010 to 2021, the year of 2019 was the year with the highest number of publications. It is possible that papers discussing the three topics only appear in 2016.

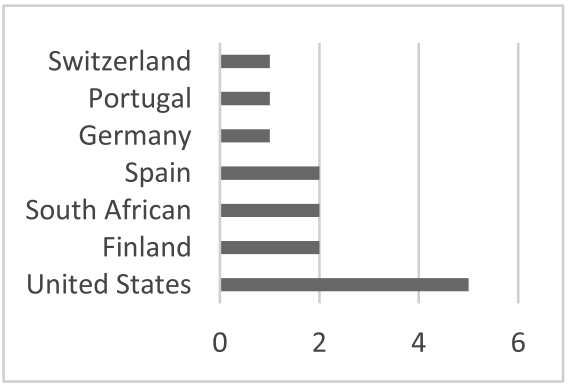


Fig. 2. Number of papers by Country.

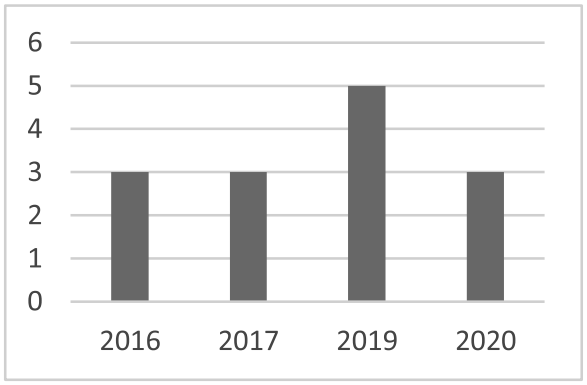


Fig. 3. Number of papers by year.

Table 1 presents the hierarchical levels applied in the Serious Games in the 14 papers selected. Through the content analysis of the papers, the authors identified elements indicating all the hierarchical levels in only three papers [14, 39, 46]. This confirmation was based on the "Create" level keywords (e.g., formulate, build, invent, compose, develop, etc.) found as a description and conclusions of the games activities made by the apprentices. For instance, Souza et al. [10] and Crocco et al. [36] did not achieve the Create level. This means that, during or after the game, nothing was said about solutions created by the apprentices as an outcome of the game.

The Serious Games activity described in the papers [37, 41, 42, 44, 45] did not achieve the "Analyze" level. The keywords for this level (e.g., classify, break down, categorize, criticize, simplify, associate, etc.) were not found. However, Ponticorvo et al. [42] confirmed, while playing the game, the user expressed herself through behavioral acts that involved her body, or other forms of interactions. And this same author also referred that the educational aspect involved allowed users to foster transversal skills through innovative approaches to teaching, learning, and assessment.

Table 1. Bloom Taxonomy hierarchical levels applied in the serious games or simulations.

Author	Remember	Understand	Apply	Analyze	Evaluate	Create
[10]	X	X	X	X	X	–
[14]	X	X	X	X	X	X
[20]	X	X	X	X	–	–
[36]	X	X	X	X	X	–
[37]	X	X	X	–	–	–
[38]	X	X	X	X	–	–
[39]	X	X	X	X	X	X
[40]	X	X	X	X	–	–
[41]	X	X	X	–	–	–
[42]	X	X	X	–	–	–
[43]	X	X	X	X	–	–
[44]	X	X	X	–	–	–
[45]	X	X	X	–	–	–
[46]	X	X	X	X	X	X

Although the sample is small and the results are limited, from this research, the authors inferred that Serious Games could help to achieve the highest order thinking level of Bloom Taxonomy. The three topics discussed are complementary in their usefulness to the Lean apprentices and their mentors.

5 Conclusions

This paper contributes to the scientific understanding of how Bloom Taxonomy, Gamification and Lean learning are connected within engineering contexts. The literature review performed returned 14 papers that discuss the three concepts. This means that the three have something in common. Serious Games are practical instructional educational tools useful for people to learn Lean that allowed them to reach higher order Bloom Taxonomy levels. Lean learning is guided by practical and objective elements, often instructed by active learning methods.

Furthermore, Game-Based Lean when reaching the levels of Bloom Taxonomy, it is expected the achieve of better student learning and critical thinking results and reduction of the learning cycle time and added value to Lean learning.

The limitations of the study consist in its qualitative nature and its reliance on a literature review that may raise some issues regarding the generalizability of results. This lack of generalizability contributes to the small sample obtained and the subjective interpretation. Still, the present study should encourage future analyses, expanding the implementation steps of Serious Games to enhance Lean learning in university and industrial environments.

In future work, it will be meaningful to understand the real gains of the Serious Games, i.e., how it contributes to adding value to the companies.

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