Gamification in statistics education

Gamification in statistics education: A literature review

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Abstract. Today, the rapid growth of publicly available data reinforces the need for public understanding of statistics and data interpretation. These skills are important for data-based decision making at individual-level or even at societal-level. However, statistics have been accused as a complex educational topic. In the meantime, although gamification notes positive outcomes in education, regarding students' engagement, statistical literacy is sparsely mentioned as an examining context in the respective literature. This study makes the picture more coherent, conducting a review about the adoption of gamification in statistical literacy (N=257 studies). In general, the results are in favor of the use of gamification in statistics education. The few mentioned negative outcomes warn for further attention on its design and integration. Besides having a variety of statistical topics mentioned, lifelong learning is slightly investigated. Only half of the reviewed body of the literature presents empirical data, and narrative and board games are mainly used. Further research is proposed about the design of gamification, touching more topics of statistics and examining various motivational affordances, especially in lifelong learning.

Keywords: Education, Data Literacy, Statistics, Gamification, Forecasting.

1 Introduction

The information age that we live in, is characterized by an exponential growth of production, storage and analysis of data. Data can provide useful insights in terms of decision-making and raise social awareness by providing a data-based worldview. Consequently, citizens need to be engaged in data interpretation and basic statistics skills. In this context, the dissemination of statistical literacy is a challenge for teachers, researchers and practitioners [61]. Statistical literacy, based on the research of [19], refers to the interpretation, evaluation and further communication of received statistical or data-based information. Therefore, it is interwoven with statistics education. On top of that, the importance of predictive analytics renders forecasting education crucial in business environments and economic curriculum [38]. However, both statistics and forecasting topics, remain onerous subjects even for students in the respective majors, due to their complexity [63, 2].

Gamification is defined as the integration of motivational affordances into services to create gameful experience [25]. It is increasingly used in education, with mainly reported positive results [54, 59, 37, 30]. A lot of educational gamifed applications are

widely used inside and outside of universities, in various educational levels and subjects [59]. Statistics education is not an exception. Recently, a few initiatives which intend to raise people's awareness about its scientific and social aspects have arisen[51]. However, there are no guidelines regarding the effective integration of gamification in statistics education.

In this study, we aim to review and synthesize the literature that uses gamification in education of statistics, forecasting and data literacy regarding the taught subjects, the educational level, the used motivational affordances, and the target audience. Based on the behavioral and psychological outcomes, this study identifies gaps in literature, giving further recommendations in order to support public engagement in the important topic of statistics, data literacy and forecasting education.

2 Review process

Our study follows the guidelines for an effective literature review [64, 46]. We identify the purpose of our review, which is to investigate the outcomes of the use of gamification in education of statistics, along with taught subject, target audience and propose further recommendations. The steps of our methodology are illustrated in Fig.1.

2.1 Search terms and databases used

The literature searches were conducted in the Scopus database and in the Association for Information Systems (AIS) Electronic Library. We chose these databases, because they index context of thousands publishers including rigorous databases, namely: IEEE, ACM and Springer. The search for literature in the Scopus database was conducted using the following search query: *TITLE-ABS-KEY (((((predict*) OR (forecast*) OR (statistic*) OR (data)) W/1 (education OR literacy OR teaching OR (learn* W/3 outcome) OR (learn* W/3 student) OR ("learning effect") OR ("learning result*") OR ("learning objectives") OR ("learning aim") OR ("learning goals"))) AND (((game) OR (gamif*)))))*.

This search is composed of three main parts. Since this review focuses on statistics and forecasting education, firstly, we framed the specific context using the terms: "predict*, forecast*, statistic*, data" in combination with terms relevant to the educational process. Secondly, the part "game" OR "gamif*" was used to include games, game-based learning and gamification. Finally, the search fields were defined as title, abstract and keywords. The search was limited to English and to conference papers, articles, articles in papers, reviews and book chapters. We followed a similar procedure in the AISeL database.

The literature search was conducted on 10/2019 and resulted in a total of 257 papers. Applying the inclusion and exclusion criteria (section 2.2), upon titles and abstracts, we concluded to 61 candidate papers. Finally, going through the full papers and applying the same criteria, we concluded to a set of 49 papers (articles: 55.10%, book chapters: 4.08%, conference papers: 44.90%). There is an increase in published papers, during the last years and the list of all papers is available: https://tinyurl.com/y4agt26z.

2.2 Selection criteria

The inclusion criteria should reflect the purpose of this study in order to conclude to the appropriate studies. Thus, the reviewed papers had to: (i) describe a game, a gamified activity, or motivational affordances in the educational context relative to statistics or forecasting or data literacy (ii) contribute to this educational field (iii) include an abstract. In addition, we excluded papers which aim to improve forecasting accuracy in terms of machine learning algorithms or games' score predictions in sports, without any educational contribution. No further training was used, since the review screening was conducted by one author.

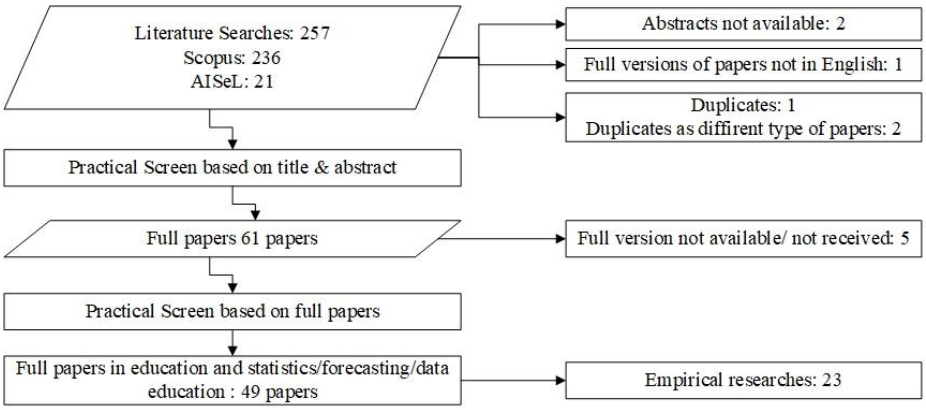

Fig. 1. The flowchart of the literature review process.

3 Analysis & results

Initially, our analysis focuses on the current state of the art. We present the specific subjects of courses, the respective target audience and the system used by the reviewed studies, which mention gamification interventions. Then, the reported motivational affordances and psychological and behavioral outcomes are identified and presented. Finally, the reviewed studies are categorized based on their reported impact. In the following analysis, we use bold to indicate the highest value, and italic for the second highest. Furthermore, for the sake of consistency, we use the same terminology as the research of [30].

3.1 Subject of statistics and system types employed

Teachers in a various subjects of statistics have used gamification to equip their audience with proper statistical background, as presented in Table 1. Gamification has been mainly used in introductory statistics courses, probably aiming to motivate students, due to the complexity that these courses entail [63]. The broad target audience and the various core systems used, show gamification's flexibility in the educational process.

Table 1. Mapping of gamification in statistics education by subject, system type and educational level of target audience.

Subject	No	%	Target Audience	No	%
Advanced statistics	4	8.16%	*Elementary education*	*4*	*8.16%*
Agriculture statistics	1	2.04%	High School	2	4.08%
Data analytics	3	6.12%	**Higher education**	**36**	**73.47%**
Data science	*5*	*10.20%*	Lifelong education	3	6.12%
Economics	1	2.04%	Not specific level	3	6.12%
Forecasting	3	6.12%	(blank)	1	2.04%
Introductory Statistics	**15**	**30.61%**	**Total**	**49**	**100%**
Medicine/nursery	4	8.16%			
Psychology	2	4.08%	**Core system used**	**No**	**%**
Risk management	1	2.04%	**Board game, Cards**	**15**	**30.61%**
SC/ IT	3	6.12%	Gamified related platforms used	5	10.20%
STEM	4	8.16%	Courses with/out online support	6	12.24%
Supply management	1	2.04%	**Exclusively developed system**	**15**	**30.61%**
Urban data literacy	1	2.04%	*Plugins for Learning Management Systems/platforms*	*7*	*14.29%*
(blank)	1	2.04%	(blank)	1	2.04%
Total	**49**	**100%**	**Total**	**49**	**100%**

3.2 Motivational affordances and outcomes

Most of the reviewed studies have employed an exclusively developed system embodying multiple motivational affordances with narrative/storytelling and full game (board or serious game) being the most commonly reported, according to Table 2. More recent studies tend to use points and a leaderboard in the gamified systems, which is in accordance with literature [30, 37]. However, only few studies explicitly described the reasons for using the respective motivational affordances.

Table 2 demonstrates the examined outcomes, based on reviewed studies. The psychological outcomes regarding the perceived effect of gamified experience on participants are examined [30, 21, 37], but are rarely supported by a quantitative analysis.

3.3 Results by type of studies

Table 3 lists the analysis methods of reviewed studies based on their results' frequency. The majority of them –solution, experience and validation papers [49, 59] – does not present strong empirical data. However, few of them demonstrate preliminary results or the authors' experiences as outcomes. Empirical researches are mostly in favor of

the use of gamification in statistics education. Noticeably, the reported negative oriented empirical researches indicate that gamification needs cautious design in order to be effectively used [17, 8, 22].

Table 2. Motivational affordances and reported outcomes in the reviewed body of literature.

Motivational affordances	No	Motivational affordances	No
Action language	1	**Narrative, storytelling, theme**	**16**
Adaptive difficulty	2	Peer rating	1
Assistance, virtual helpers	2	Performance feedback	5
Avatar, character, virtual identity	2	Physical cards	2
Badges, achievements, medals, trophies	3	Physical dice	4
Carnival games	1	Physical play board	8
Challenges, tasks, clear goals	5	Points, score, XP	6
Check-ins, location data	1	Progress, status bars	1
Competition	3	Quizzes, questions	5
Cooperation, teams, human interaction	7	Real world/financial reward	1
Customization personalization	2	Retries, health	1
Full game (board/commercial games)	*13*	Role Playing	2
Increasing difficulty	2	Social networking features	1
In-game rewards	3	Timer, Speed	5
Leaderboards, ranking	6	Virtual objects (augmented reality)	1
Levels	5	Virtual world, simulation	3
Psychological Outcomes	No	Behavioral Outcomes	No
Affective	**21**	*Engagement with the system*	*4*
Attitude	5	**Performance**	**16**
Cognitive	*9*		
Effort in use/ experience challenge	4		
Overall assessment of the use of the gamified system	4		
Psychological states, personality features	6		

4 Discussion

The majority of the reviewed studies is positively oriented about the integration of gamification into statistics education, which is in accordance to research literature [30, 37, 34]. In secondary education, a physical equipment or a board game have been mainly used in order to teach introductory statistics and data representation. The majority of gamified interventions has been noted in higher education, touching all of the men-

tioned subjects of statistics (see Table 1) and especially the strongly data-related subjects such as: data science, data analytics and forecasting. Although exclusively designed systems have been employed in these cases, there is no strong justification and common evaluation regarding the motivational affordances used and only half of the reviewed studies present empirical data [33]. On the other hand, lifelong learning of statistics has barely integrated gamification, using mainly courses with/out online support, about more advanced subjects (i.e. forecasting).

Table 3. Results of reviewed studies.

Types of research	Positive Oriented	Equally Positive & Negative	Negative Oriented	No specified	Total
Empirical	17	3	3	0	23
Quantitative	[62, 33, 57, 4, 7]		[44]		**6**
Qualitative	[36, 42, 66, 39] [29, 28, 20, 47, 14]		[63]		10
Mixed	[16, 58, 3]	[23, 43, 1]	[55]		7
Non-empirical	14	1	0	11	26
Solution, Validation, Experience Papers	[6, 27, 15, 50, 5] [12, 9, 35, 40, 45] [32, 41, 24, 53]	[56]		[26, 52, 10, 18] [48, 31, 34, 65] [13, 60, 11]	26

A variety of motivational affordances has been used in many subjects of statistics, ranging from introductory to advanced topics [34]. Nevertheless, the narrative/storytelling is the most popular affordances for teaching mainly basic statistics and data analytics topics. While a lot of different core systems have been employed to integrate the narrative context, exclusively developed systems are mainly reported. Full games and board games are the next commonly used motivational affordances. However, a few negative or mixed oriented studies mentioned these motivational affordances regarding the physiological outcomes (affective of systems and psychological traits) [22, 8]. This fact can be considered as a warning for cautious gamification design in statistics education, even though there is no consistency in the mentioned measure instruments [30].

Overall, based on the frequency of the examined variables –motivational affordances, core systems, subjects, target audience– along with the reported outcomes, gamification is gaining a stronger position in the field of statistics education. Not only most of the studies present positive outcomes, but also the variety of the used motivational affordances is spread in a plethora of systems and subjects of statistics, even in the most complex topics. These findings are encouraging for the use of gamification in statistics education, as it seems to have the potential to motivate a wide audience regarding this topic, promoting a data-based worldview [51], and eventually improving decision-making process even at societal-level.

Based on our analysis, a few gaps have been identified, giving direction for further research in the design of gamification, and the target audience. Since statistical literacy is necessary in order to interpret the data and get useful insights, gamification research

should further employ and evaluate the use of gamification strategies, through controlled experimental research method (i.e. achievement-related affordances, which have been mostly used in education with great results [30]). Additionally, consistency in the evaluation of the impact of gamification according to both behavioral and psychological outcomes, would straighten the creation of design guidelines. Considering the extensive use of exclusively developed applications and the trend to create freeware, the need for effective design guidelines per subject taught and target audience is crucial. In this direction, more empirical research should be conducted. Especially, further research should focus on the field of lifelong learning, by integrating a variety of motivational affordances into all the subjects of statistics, ranging from basic statistics up to more advanced topics (forecasting, machine learning), in order to achieve social awareness, regarding data-based social facts and trends [51].

4.1 Limitations

Although, the present study follows guidelines for a systematic literature review, the backward and forward step would benefit it. Our results are limited to the specific searches. However, this study focuses on the effectiveness of gamification in teaching statistics in a multidisciplinary ground and not generally on the use of gamification in education.

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