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A Bibliometric Analysis of Gamification Research

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ABSTRACT Gamification has rapidly emerged as one of the favorite persuasive technologies widely used with the aim of promoting a positive change in the user's behavior by means of including game-like elements in non-game contexts. As a research discipline, gamification is growing fast, maturing from basic and fundamental questions such as what and why gamify to more mature ones such as how to gamify, when and when not, and still facing empirical and theoretical challenges to prove the effects of its practice and consolidate the principles that guide meaningful gamification designs. The purpose of this paper is to conduct a bibliometric study to describe how gamification as a scientific discipline is structured and how it has evolved over time. To do this, we make use of bibliometric performance analysis and science mapping methods to display and analyze the intellectual, conceptual and social network structures of gamification research, as well as the evolution and dynamical aspects of the discipline. The results reveal the research fronts and intellectual structures of the field, the internal relationships among articles, authors and keywords, the existing networks of collaboration, the emerging trends, the hot topics, and the most influential authors, publications and sources. Together, they picture the intellectual landscape of gamification as a scientific field that will be useful for junior and senior researchers, practitioners, funding agencies and policymakers.

INDEX TERMS Bibliometrics, computers and information processing, gamification, science mapping, scientometrics.

I. INTRODUCTION

In 2011, Gamification was defined as ''the use of game design elements in non-game contexts'' [1]. Since then, it has rapidly emerged as one of the favorite persuasive technologies widely used with the aim of promoting a positive change in the user's behavior by means of including game-like elements in non-game contexts. The effect most frequently pursued with gamification is an improvement in the user's engagement and their intrinsic motivation towards the development of specific actions, typically considered boring or uninteresting. Initially applied in the business and marketing domains [2]–[5], its popularity rapidly spread to different application domains in which human interaction is present such as healthcare [6], [7], education [8]–[10], recruitment [11]–[14], energy saving [15]–[20], project management [21]–[23], safe driving [24]–[27], crowdsourcing [28]–[32] and software development [33]–[37].

After five years of gamification research, in 2015 Vermeulen *et al.* started to discuss the maturing of gamification as an academic research object [38]. In their work, they analyzed the main challenges of the discipline and proposed the use of activity theory [39] to address the ''theoretical deficiencies of contemporary gamification''. In June 2017, Nacke and Deterding went deeper into the conception of gamification as a research discipline and collected the signs of its growing maturity by editing a special issue of the Computers and Human Behavior journal [40]. The following year, Landers *et al.* defined the ''gamification science'' as ''a subdiscipline of game science'' and established the goals for gamification scientists and practitioners [41]. More recently, in 2019, Rapp *et al.* edited a special issue on the current and future trends in gamification research for the International Journal of Human-Computer Studies [42]. These studies share a common approach towards gamification as a research discipline. A discipline that is growing fast, maturing from basic and fundamental questions such as *what* and *why* gamify to more mature ones such as *how* to gamify, *when* and *when not*, and still facing empirical and theoretical challenges to prove the effects of its practice and consolidate the principles that guide meaningful gamification designs.

During the last years and in parallel with the increasing number of primary studies describing the results of

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gamification experiences, the number of literature reviews summarizing the knowledge in gamification and identifying research gaps has also increased. Generally, four different approaches are used to conduct literature reviews: a) narrative, b) systematic, c) meta-analytic and d) bibliometric [43], [44]. The first two approaches are very frequent, especially the systematic one commonly used to identify a research gap that justifies a research project or a doctoral work. Most of the literature reviews conducted in the field of gamification fall into this type of studies. However, the fact that they are mostly qualitative studies leads to the two traditional weaknesses found in this type of works, which are: the level of completeness of the study in terms of covering all the available and relevant literature, and the impossibility of replication, which is something fundamental for a research work [45].

The other two approaches to address literature reviews offer a complementary strategy under the form of quantitative studies. A meta-analysis study consists on applying statistical methods to find relationships or identify patterns in the findings of a large collection of works. There have been some meta-analyses conducted in the gamification field. For example, in the last two years a meta-analysis was the approach selected to synthetize either the effects of gamification on cognitive, motivational and behavioral learning outcomes [46], the earlier quantitative studies in gamification [47] and the effects of gamification on student's academic achievements [48].

Bibliometric studies make also use of statistical methods to ''measure the 'output' of individuals/research teams, institutions, and countries, to identify national and international networks, and to map the development of new (multidisciplinary) fields of science and technology'' [49]. Traditionally used to measure the scientific performance of an individual, a group, a university or a country based on the number of citations, Bibliometrics is becoming popular as a means of scientifically discovering patterns in the knowledge collected in the body of literature, revealing emerging trends in a research field and analyzing the underlying structures of research, its evolution and dynamical aspects. Consequently, in bibliometric analysis two main procedures can be distinguished: a) performance analysis, which uses bibliographic data to measure the research activity of individuals, groups, organizations or countries and their impact, and b) science mapping, which focusses on visualizing the structure and dynamics of a research field [50].

There have been numerous bibliometric studies conducted in different fields of research such as information processing and management [51]–[53], medicine [54]–[56], computer science [57]–[59] and policy-making [60]–[62]. In order to find if and which bibliometric studies had been done in the field of gamification research, we conducted different searches in digital databases such as IEEE Xplore, Science Direct, Scopus, WoS, Springer Link and Wiley Online Library. The results of these searches showed a very small number of such bibliometric studies on the research field of gamification. Two of them aimed at describing the evolution of research in the gamification of education [63], [64]. By integrating bibliometric and text-mining analysis, their authors analyzed the works published in the period 2010–2014 describing applications of serious games, game-based learning and gamification in education. Their main findings included the presence of four main themes of research and the identification of future research lines in the field of games and the gamification of learning. The extent to which gamification is being used in accounting education was the main aim of another bibliometric study [65]. The research field was structured into five main themes of research enabling the identification of research gaps and future research lines in the area of gamification in accounting courses. It is important to note that the three works described above were coauthored by a core group of two authors with interest in describing the research landscape of gamification in education, in general, and in the accounting education in particular. In a close but different field than gamification, Stehmann has recently published a bibliometric study to describe the structure of research in online gambling and gaming literature and identify future research lines in that particular field [66]. Finally, the work authored by Harman *et al.* makes use of citation network analysis to ''explore the changes in scholarly interest'' in gamification [67]. This study dates from 2014 and analyzes the citation network of the gamification works published between 2010 and 2013. Their analysis led to conclude that gamification was a growing topic that deserved more research and that citation analysis helped to understand the evolution of the research discipline.

As shown, the gamification research has not been analyzed completely under the perspective of a research discipline, including all the domains in which it has been applied. We found there is a lack of analysis of topics such as the research fronts and intellectual structures of the field, the internal relationships among articles, authors and keywords, the existing networks of collaboration, the emerging trends, the hot topics, and the most influential authors, publications and sources, among others. This is the gap our work aims to fill.

Consequently, the purpose of this paper is to conduct a bibliometric study to describe how gamification as a scientific discipline is structured and how it has evolved over time. To do this, we make use of performance analysis and science mapping methods to display and analyze the intellectual, conceptual and social network structures of gamification research, as well as the evolution, performance and dynamical aspects of the discipline.

Our paper contributes to the literature in the two following ways:

a) Unlike previous reviews of the literature, it covers the complete gamification research domain, eliciting its conceptual, intellectual and social network structures.

b) Its conclusions are based on quantitative data rather than qualitative analysis.

Our work shares part of the spirit of the study made by Harman *et al.* [67] in the sense that citation networks are used to reveal the relations between the relevant works in gamification research and its historical evolution. However, the differences between both studies are highly significant, regarding: a) the aims: Harman *et al.*'s work aims at proving four hypotheses closely related with the analysis of the scholarly interest in gamification during the four years included in their study. Our study has broader aims, aiming at describing the research performance and finding and visualizing the conceptual, intellectual and social network structures of gamification research; b) the timespan of the studies differs considerably: whilst Harman *et al.* analyzed the works published in the range (2010-2013), in this work the range (2011-2019) is explored and therefore, our conclusions are based on up-to-date information; c) the search processes used to build the dataset for the studies are also noticeably different. Whereas Harman *et al.* searched only for works having the word ''gamification'' in the Title field, we have searched for that word and its variations, such as ''gamified'', ''gamifying'', etc., in the Title+Abstract+Keywords fields. Moreover, Harman *et al.*'s dataset contained 1,144 publications resulting from searches conducted in Google Scholar, amazon.com and a curated academic library collection, whereas our dataset contains 4,706 publications indexed in the core collection of the Web of Science. Our search process has allowed us to locate more relevant works, some of them were even published at the time of Harman *et al.*'s study, but not included in the dataset of their review; d) the methods: the analysis of the co-citation network is the only method used to address the aims of Harman *et al.*'s work. In our study, eight different performance and science mapping methods have been used to support our findings and conclusions; e) the findings: Harman's *et al.*'s analysis provides evidence of the growing research interest on the topic of gamification by analyzing performance and network metrics on the co-citation network, and as future research highlights the need to keep on monitoring and analyzing this research field to get a deeper understanding of its organization, as well as using other search strategies to extend the size of the dataset. Their study does not cover aspects such as the conceptual structure of the field, the relevant publications, the intellectual and author's collaboration structures, etc., which are covered in this study, together with the proposal for a future research agenda based on our findings. Therefore, to the best of our knowledge, our work is the first effort towards providing an up-to-date evidence-based description of gamification as a research discipline.

This work will be of interest for different audiences:

a) For junior researchers, as it identifies the most relevant literature, authors and topic evolution of the discipline and facilitates gaining insight into the most relevant and appropriate topics scientifically identified.

b) For senior researchers, as it synthesizes existing knowledge and provides scientific evidence of research gaps as well as revealing the collaboration networks active in this research discipline.

c) For practitioners, as it identifies the most relevant contributions in the field, the hot topics and the future prospects of the field.

d) For funding agencies and policy makers, as it can be used to help in decision-making on research project funding on the basis of relevance in the field.

The rest of this paper is structured as follows: Section 2 describes the methodology and the dataset used to conduct the study; Section 3 shows and discusses the results of the study; Section 4 describes the limitations of this study and, finally, Section 5 summarizes the paper and suggests a future research agenda based on the findings of this study.

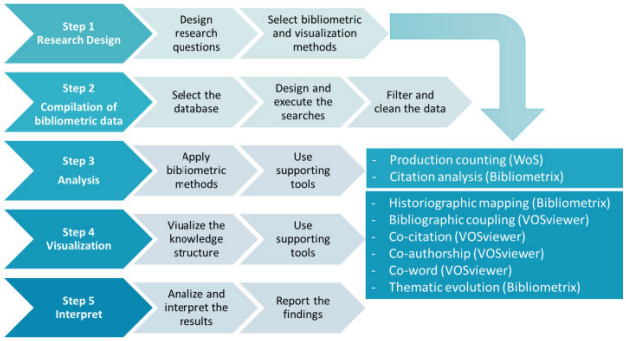

FIGURE 1. Steps of the process followed to perform this bibliometric study.

II. DATA AND METHODS

According to Aria and Cuccurullo [68], the science mapping process and tools were described by Börner *et al.* [69] and Cobo *et al.* [50]. Later, after analyzing 81 bibliometric studies in management and organization and the bibliometric methodology literature, Zupic and Čater [70] recommended a standard workflow to conduct bibliometric studies comprising the following five rigorous steps: study design, data collection, data analysis, data visualization, and interpretation. Our study follows this science mapping workflow method, as recommended in [68]. Fig. 1 shows an overall summary of these steps. A description of the aims and activities performed at each step follows:

- Step 1. Research design. This step aims at describing the research questions for the study and identifying the appropriate methods to answer each research question. The main aim of our study is to describe how gamification as a scientific discipline is structured and how it has evolved over time. To address this aim, the following studies have been conducted:
  a. Descriptive analysis: A descriptive analysis provides useful information about the production and evolution of research from the perspective of author's, institution's and country's performance. It helps find out who the most productive or influential authors

are, the most cited publications and the most influential journals. By tracking the evolution of those metrics over time, it provides researchers with snapshots of the evolution of the field

b. Intellectual structure analysis: The analysis of the intellectual structure of the field reveals how its theoretical framework has been built. By interpreting the nodes and links of different types of networks, it helps researchers find out how the works published have influenced the evolution of the research field.
c. Social network structure analysis: The analysis of the collaboration structure of the relevant authors in a field helps uncover consolidate groups of research.
d. Conceptual structure analysis: The conceptual structure analysis is used to locate the research front of a field as well as its evolution along time.

For each type of study, we defined a set of research questions together with the appropriate methods to answer them. TABLE 1 shows our research questions as well as the justification for each one. It also groups them into the different categories of analysis performed according to the previous classification. A brief description of the methods applied to answer our research questions follows:

a. Production counting: Consists on measuring the author's performance by means of the number of articles authored and co-authored. In our study, the preferred counting method has been the full-counting one, which gives full credit to each contributing author of a publication [71].
b. Citation analysis: Consists on analyzing the citation rate of the articles as a way of measuring the impact of the work of researchers in the research community [72].
c. Co-citation analysis: Co-citation of two articles happens when they are both cited in a third article. Analyzing strong co-citation links help discover the articles with significant connections to a research field, which, therefore, constitute the core publications for that field [73]. The relations between cited-references can be plotted using a co-citation network, which helps visualize clusters and strengths of co-citation links.
d. Bibliographic coupling: Bibliographic coupling occurs when two articles reference a common third article. The higher the number of common references, the higher the probability that those two articles treat the same subject [74].
e. Historiographic mapping: A historiograph is an oriented graph that helps visualize the chronological evolution of the intellectual base of a discipline. It makes use of direct citation data among the papers included in a dataset [75].
f. Co-authorship analysis: Helps visualize how authors in a particular field collaborate with each other to produce new research. It is visualized through a network that enables the discovery of established research groups and pivotal authors linking different groups [76].
g. Co-word analysis: Co-word analysis helps discover links among research concepts by means of term co-occurrence. Words that appear together in an abstract, title or as keywords will be closely related in a network. It is useful to visualize clusters of research [77].
h. Thematic evolution analysis: Helps to detect research themes and their evolution through different periods of time by means of a longitudinal co-word analysis and thematic/strategic mapping [50], [78].

- Step 2. Compilation of bibliometric data. The aim of this step is to build the dataset that is going to be used for a bibliometric study. Decisions such as which database is going to be used to extract the data, which search strings will be used, the timespan for the searches, etc. have to be made at the beginning of this step. Once decided, the searches are to be performed and the resulting data downloaded. The decisions made at this step are crucial for the results and validity of the study since they define the scope of the dataset that will be used for the analysis. To build a representative dataset of the gamification literature, we used Web of Science (WoS). The reason for choosing this database is that it is the most widely recognized and frequently used database for the analysis of scientific publications [59], [79]. The search strategy aimed at retrieving the publications in English recorded in the core collection of WoS containing any variation of the term ''gamification'', such as ''gamify'', ''gamifying'', etc., in the title, abstract or author keywords. Author keywords were preferred over Keywords Plus since the keyword ''gamification'' was found to be automatically added to papers describing videogames or games experiences, which are not cases of gamification experiences as defined in [1]. The configuration of the search process is detailed in TABLE 2. The original dataset was retrieved from WoS on October, 2020 and contained 4,757 publications. This dataset was cleaned to remove the publications that were not relevant for this study because they were clearly in a different field than gamification. A small number of publications were also removed for the following reasons: a) they were duplicates, b) they missed important data fields such as the author names, and c) their publication date was out of the time period of the search. At the end of this process of cleaning the original dataset, the final one contained 4,706 publications. The final dataset was exported to different file formats to be processed by the tools used in this study.
- Step 3. Analysis. In this step, the bibliographic methods are applied in order to generate information to answer the research questions. Different software tools can help generate the necessary insights from the dataset. In this

TABLE 1. Research questions for our study.

DESCRIPTIVE ANALYSIS
RQ1. Which is the publishing trend of gamification related publications? The volume and evolution of the publications and their citations is useful to the researcher to know how the field has evolved and provides them with information that helps interpret other analysis aimed at predicting future themes of research. Methods: a) Production counting, b) Citation analysis
RQ2. Which countries/institutions have contributed to gamification research? Knowing which countries, institutions, and research centers contribute most and receive most citations help researchers to make decisions about international project proposals or cooperation agreements at the educational and research domains. Methods: a) Production counting, b) Citation analysis
RQ3. Which are the influential publications in the gamification field? Being aware of the most relevant publications in the field is essential for a researcher as they are the foundations for the research discipline. Additionally, knowing which topics have been studied in these seminal works may help find out gaps in the literature that deserve further work. Method: Citation analysis
RQ4. Which are the influential journals in the gamification field? Being familiarized with the journals that frequently publish works in the field and receive the highest number citations is key for a researcher to decide where to contribute their research results. Methods: a) Production counting, b) Citation analysis
RQ5. Who are the top authors in gamification research? As a complement to knowing the most influential publications, being aware of the authors that most contribute to the field and have received the highest number of citations is essential to know which authors to follow to keep updated with the latest advances, and to make decisions about international collaboration. Methods: a) Production counting, b) Citation analysis
INTELLECTUAL STRUCTURE
RQ6. Which are the research front and the intellectual base of gamification research? Knowing the intellectual base of a discipline allows researchers to be aware of the conceptual structure of such discipline. Being aware of the theoretically framework of the discipline is essential to conduct quality research. Methods: a) Bibliographic coupling, b) Co-citation analysis
RQ7. How has the knowledge in the field been constructed over time? The evolution of the intellectual base of the field helps the researcher find out the chronological distribution of the publications and their intellectual linkages in a historical order. Being aware of the historical evolution of a field also helps distinguish more regular and developed groups of research. Method: Historiographic mapping
SOCIAL NETWORK STRUCTURE
RQ8. What are the authors' collaboration structures? The authors' collaboration structures reveal how the most relevant authors relate to others to build the knowledge of the field. Knowing these structures is important to find regular groups producing relevant research that needs to be followed and can be contacted for collaborative research. Method: Co-authorship network
CONCEPTUAL STRUCTURE
RQ9. What is the conceptual structure of the gamification research? Being aware of the conceptual structure of the field helps researchers to be aware of the topics of research addressed. It can also provide valuable information to identify new research topics in the field. Method: Co-word analysis
RQ10. How has the research focus evolved over time? Analyzing the chronological evolution of knowledge in the field helps the researcher identify the origins, evolution and relationships among the themes of research in the field. It also provides the researcher with valuable information about potential gaps in the field that deserve more research attention. Method: Thematic evolution analysis

TABLE 2. Search configuration in WoS.

Search terms	(TI=(gamif*) OR AB=(gamif*) OR AK=(gamif*)) AND Language=(English)
Document type	PROCEEDINGS PAPER OR BOOK OR ARTICLE OR REVIEW OR BOOK CHAPTER
Time Period	1900-2019
Indexes	SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC.

study, in addition to conventional spreadsheets for simple statistical analysis, and a reference manager, the following tools have been used:

- Bibliometrix R-package 3.0.0: An R-package for quantitative research in scientometrics and bibliometrics developed by Aria and Cuccurullo [68].
- VOSviewer 1.6.15: A software tool for constructing and visualizing bibliometric networks developed by van Eck and Waltman [80].

Our tool selection is based on the recent analysis of the tools for bibliometric studies performed by Moral-Muñoz *et al.* [81], which concludes that bibliometrix is the tool that ''contains the most extensive set of techniques'' and highlights the network visualization capabilities of VOSviewer. Accordingly, we have used bibliometrix as the preferred tool for most of our bibliometric analyses and VOSviewer for the analyses than require network analysis and visualization.

Accordingly, the descriptive, historiographic and thematic evolution analyses were conducted using the bibliometrix R-package. To this end, our dataset, as a set of WoS downloaded files, was loaded and converted into an R bibliographic data frame using the *convert2f()* function. From there, different bibliometrix functions were used to obtain different bibliometric measures. The results of these analyses were exported to MS-Excel for improved graphical representation. The network analyses were performed and graphically represented using VOSviewer. TABLE 3 lists the functions used to answer each of our research questions, a brief description of their functionality and the parameter setting used. We refer the reader to the bibliometrix and

TABLE 3. Bibliometrix and VOSviewer functions and parameter configuration.

Research Question	Function	Description
BIBLIOMETRIX FUNCTIONS		
RQ1-RQ5	*biblioAnalysis()*	Returns an object of class bibliometrix, containing main bibliometric measures.
	summary()	Summarizes the main results of a bibliographic analysis.
	citations()	Identifies the most cited references or authors.
RQ7	*histNetwork()*	Creates a historical co-citation network from a bibliographic data frame.
	histPlot() • *n=30*	Plots a historical citation network.
RQ10	*thematicMap()* • *field= "DE",* • *n=250,* • *minfreq=5,* • *stemming=FALSE,* • *size=3* • *n.labels=2,* • *repel=TRUE*	Creates a thematic map based on co-word network analysis and clustering, as proposed in [50].
VOSVIEWER FUNCTIONS		
Common configuration for all analyses: • *Type of data: Map based on bibliographic data.* • *Data Source: Data from bibliographic data files* • *Counting method: Full counting* • *Layout and clustering. Default options recommended by VOSviewer for each type of analysis*		
RQ6	**Bibliographic coupling:** • *Type of analysis: Bibliographic coupling* • *Unit of analysis: Documents* • *Min. number of citations of a document: 0* • *Number of nodes to select: All (4706)* **Co-citation analysis:** • *Type of analysis: Co-citation* • *Unit of analysis: Cited references* • *Min. number of citations of a document: 20* • *Number of nodes to select: All (870)*	
RQ8	**Collaboration network:** • *Type of analysis: Co-authorship* • *Unit of analysis: Authors* • *Min. number of documents of an author: 2* • *Min. number of citations of an author: 10*	
RQ9	**Co-word analysis:** • *Type of analysis: Co-occurrence* • *Unit of analysis: Author keywords* • *Min. number of occurrences of a keyword: 5* • *Number of keywords to select: 300*	

TABLE 4. Main information of the publications in the dataset.

Documents	4,706
Sources (Journals, Books, etc.)	2,241
Keywords Plus (ID)	2,560
Author's Keywords (DE)	9,222
Timespan	2011:2019
Average citations per documents	5.884
Authors	12,078
Author appearances	16,250
Authors of single-authored documents	559
Authors of multi-authored documents	11,519
Documents per Author	0.39
Authors per Document	2.57
Co-Authors per Documents	3.45
Collaboration Index	2.84
Single-authored documents	651

VOSviewer main publications [68], [82], and technical documentation [83], [84], respectively, for further information about the functionality, implementation and performance of these functions.

- Step 4. Visualization. Step 4 is highly related to the previous step and aims at producing the visualization of the analysis data generated to facilitate its understanding and interpretation. In this study, we have used the above mentioned tools as analysis as well as visualization tools.
- Step 5. Interpretation. The last step of a bibliometric study is the interpretation of the analysis data obtained. To interpret the results, it is necessary to carefully examine the articles in the dataset to check the validity of the conclusions reached. The final aim of this step is to summarize and communicate the main findings and conclusions of the study by means of this scientific article.

III. RESULTS AND DISCUSSION

In this section, we provide and discuss the answers to the research questions of this study.

A. RQ1: WHAT IS THE PUBLISHING TREND OF GAMIFICATION RELATED PUBLICATIONS?

As mentioned before, the dataset for this study contains the data of 4,706 publications. TABLE 4 provides detailed summary information about our dataset.

There have been 2,241 different sources of publications of gamification research. The majority of the publications are conference papers (63%), followed by journal papers (32%). Far from these two types, we can find a small number of contributions in the form of book chapters (3%) and reviews (2%). Authors have used a total of 9,222 keywords to describe their research, which has reached an average

number of citations close 6. Regarding the number of authors, 12,078 authors have authored or co-authored 4,706 publications, with a collaboration index of 2.84.

Fig. 2 shows the yearly number of publications (TP) and the growth rate, measured as the ratio of the number of publications of two consecutive years. The first publications in this research area appeared in 2011. Since then until 2019, the annual percentage growth rate is 87.78%. The evolution of the number of publications reveals a fast growing of the field during the first four-year period (2011-2014), where the number of papers published in one year is approximately six, three times and twice the publications of the previous year, respectively.

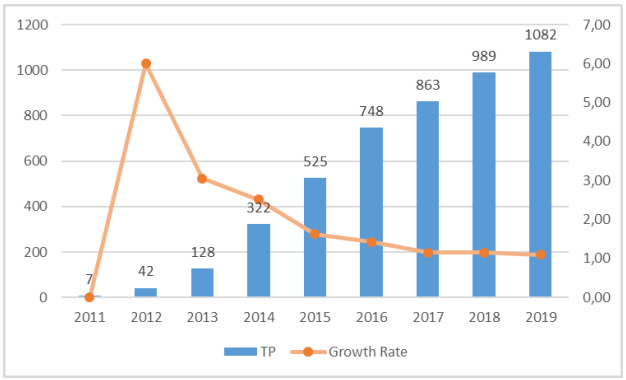

FIGURE 2. Publishing trend in gamification research.

Fig. 3 shows the total number of citations of publications per publishing year (TC) and the average number of citations per publication and year (Avg Cit Per Year). In general, the average number of citations of the publications in the dataset is 5.884. The articles published in the central period of the study (2014-2017) have reached the maximum number of citations, being the works published in 2015 the most cited ones (5,503 citations). In terms of the average number of citations per publication and year, the papers published in 2013 hold the highest value, as they have received 2.77 citations per year.

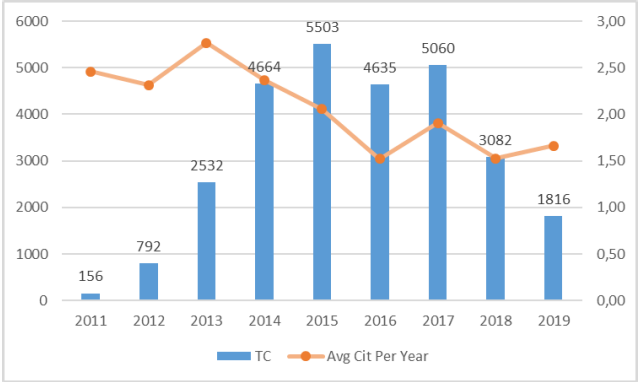

FIGURE 3. Total number of citations and average citations per publication and year.

The distribution of citations among the publications is not homogeneous. Out of 4,706 publications, only 2,824 have been cited at least once. This means that only approximately 60% of the research in the dataset has produced some kind of impact in the gamification research community.

B. RQ2: WHICH COUNTRIES AND ORGANIZATIONS HAVE CONTRIBUTED TO GAMIFICATION RESEARCH?

Fig. 4 shows the top 20-most contributing countries in terms of number of publications. In this figure, each publication has been allocated to the country of its corresponding author. Out of the 85 different countries in the dataset, the most productive ones are USA (566), Spain (417), Germany (319), United Kingdom (309) and China (192). This figure also shows the international collaboration intensity of each country. United Kingdom and Germany are the most internationally collaborative countries, as they have the highest level of Multiple Country Publications (MCP), with 76 and 64 internationally collaborative publications, respectively. This figure reveals that international collaboration in this field is not very high since the number of Single Country Publications (SCP) of the top-20 most productive countries is much higher than the number of their MCPs ones. In fact, the ratio of MCP in this top-20 group is not higher than 33% of the respective countries' production.

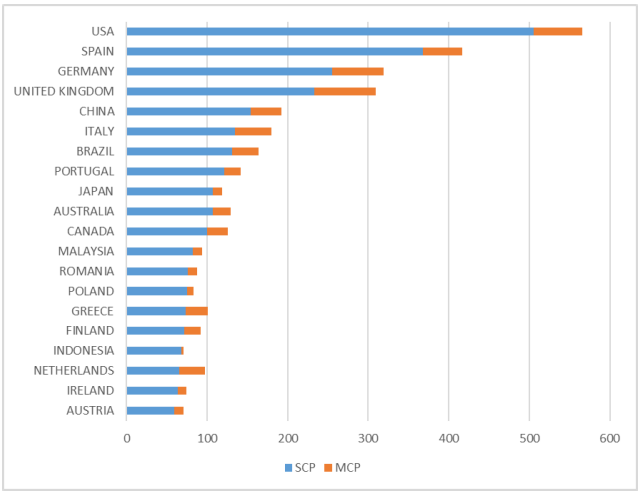

FIGURE 4. Top-20 most contributing countries.

It cannot be said that the most productive countries are also the most influential ones, if we consider the number of citations received by their publications. Fig. 5 shows the data of the top-20 most cited countries. As it can be seen, the works published by USA, Spain and Finland top the list. Together with these three countries, Canada, Germany, UK and China close the group of countries receiving more than 1,000 citations. However, if we pay attention to the average citations received by publication, the results are quite different.

Fig. 6 shows the top-20 countries with the highest number of average citations per publication. This figure reveals that Finland, the twelfth country in terms of production and the third country in total number of citations, leads the list with an average of 27.8 citations per publication. Far from that value,

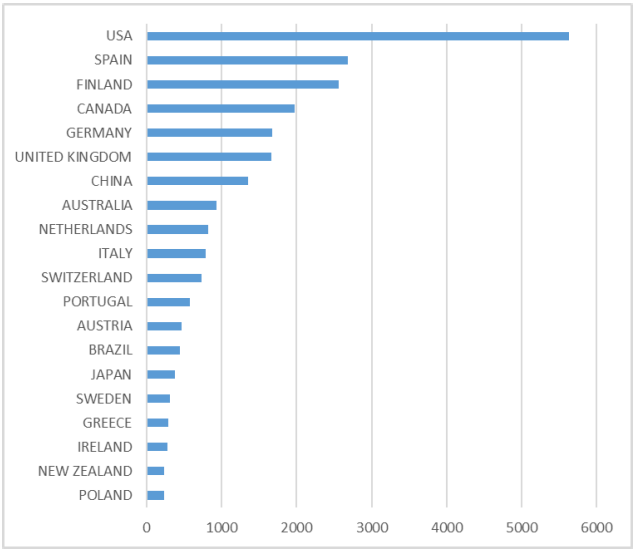

FIGURE 5. Top-20 most cited countries.

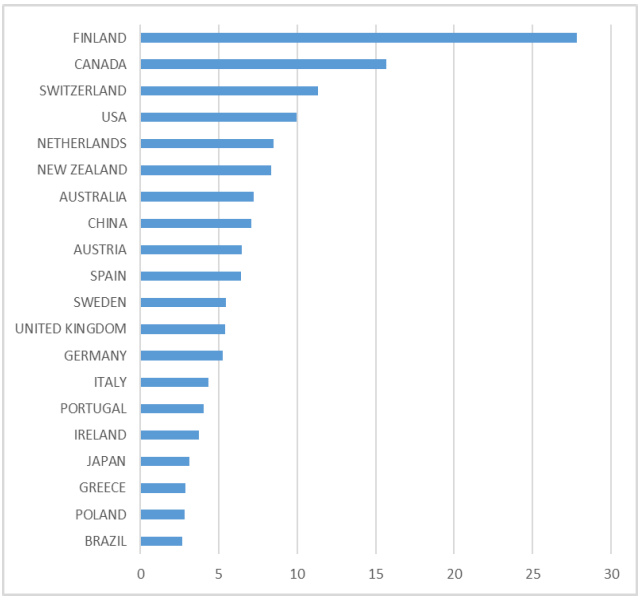

FIGURE 6. Top-20 most influential countries (average citations per publication).

Canada and Switzerland follow with 16.68 and 11.32 average citations per publication. USA, which topped the lists of most productive and most cited countries, receives only an average of 10 citations per publication, and Spain, which was second in terms of world production and citations, falls to the tenth position with an average of 6.4 citations per publication.

Fig. 7 scales down to the level of the ten most-active organizations. For each organization, its number of publications (TP) and h-index are shown. A total of nine universities and one associate laboratory top this list.

Universidad Politécnica de Madrid (Spain) is the most contributing organization, with 45 publications, followed by the INESC (Institute for Systems and Computer Engineering,

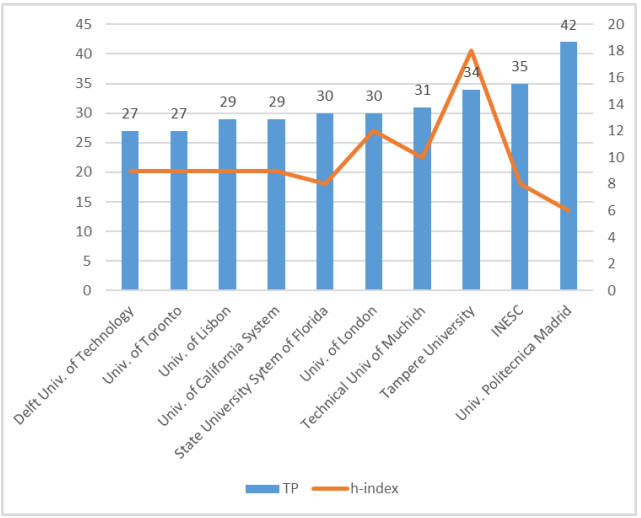

FIGURE 7. Top-10 most influential organizations (number of citations).

Technology and Science) (Portugal), and the Tampere University (Finland), with 35 and 34 publications, respectively. The Delft University of Technology (Netherlands) and the University of Toronto (Canada) close the list of most contributing organizations, with 27 publications each. When the influence that the research in gamification carried out in these organizations is measured in terms of their h-index, the results reveal that the organization producing the most influential research is the Tampere University, with an h-index of 18. The 34 publications from this university have reached 2,230 citations, with an average of 65.59 citations per publication.

The University of London is the second institution producing relevant research with an h-index of 12. Their 30 publications have reached 581 citations, with an average of 19.37 citations per publication. The group of the top-three most influential organizations is closed by the Technical University of Munich, with an h-index of 10, whose 31 publications have received a total of 285 citations, with an average of 9.19 citations per publication. The organization producing the least influential research is also the most contributing one. With an h-index of 6, the 42 publications from the Universidad Politécnica de Madrid have only received a total of 151 citations, which gives an average of 3.6 citations per publication.

Although different topics of gamification have been explored in the gamification research conducted in these organizations, the application and impact of gamification in: a) education, mostly online education, MOOCs, STEM education, and language learning, and b) healthcare, mostly e-health, exercising and wellness, mental health and particular disorders, such as Diabetes, have been the most frequently studied topics across these organizations. In the topic of healthcare applications of gamification, the University of Toronto stands out for their research mostly focused on the application and impact of gamification in mobile health and medical training. Marketing applications of gamification,

such as, customer engagement, crowdsourcing and mobile marketing, have also been studied at INESC, Tampere University, Delft University of Technology, University of Florida and the University of London. The relations of gamification and energy efficiency and smart cities in general have also attracted the attention of researchers from the University of California, INESC and the University of London, whereas how gamification can help improve our driving behavior has been explored at the University of Munich. Finally, the theoretical principles of gamification have been the topic of highly-cited research conducted mostly at the Tampere University and the University of London. Finally, the use and application of gamification in education has been explored in the works of the universities of Lisbon and Politécnica de Madrid, which has also investigated gamification for software process improvement.

C. RQ3: WHICH ARE THE MOST INFLUENTIAL PUBLICATIONS IN THE GAMIFICATION FIELD?

When studying a particular research field, highly cited papers are of importance because they have influenced and attracted the interest of the researchers of that particular field. To locate the most influential publications in the gamification field, we have made use of the H-Classics approach developed by Martínez *et al.* [85]. Based on H-index [86], this approach combines measures of the number of papers and the impact of those papers to help to unbiasedly locate highly cited papers, aka citation classics, within a research field. According to [85], ''H-Classics of a research area A could be defined as the H-core of A that is composed of the H highly cited papers with more than H citations received''. Accordingly, once the dataset for the study is set, the process to determine H-Classics requires to compute the H-index of the set of publications in the dataset and then recover the H highly cited papers.

In our study, the H-index of the publications in the dataset is 61, as provided by WoS. Appendix I shows the 61 most cited publications in the dataset. For each publication, together with its basic information, such as its title (TI), authors (AU), publication year (PY), and digital identifier (DI), its total number of citations (TC) and average number of citations per year (AVG CIT) are listed. The majority of the highly-cited publications have been published as journal articles (75.5%). Computers in Human Behavior, and Computers & Education are the scholarly journals that have published the higher number of highly-cited works, with 8 publications each. The most influential publication, with an average of 125.14 citations per year, is a literature review of empirical studies on gamification conducted by Hamari *et al.* in 2014 and published in the proceedings of the Hawaii International Conference on System Sciences (HICSS) [87]. This review analyzed the existing literature to find empirical evidence of the effects of gamification. It concluded that gamification provides positive effect, but such effect also depends on the context in which gamification is implemented. Thirty-three more works in this list fall also in the category of literature reviews performed as surveys, systematic literature reviews, mapping studies, and informal reviews. All of these works analyze the existing publications to find empirical evidence of the effects of gamification in health applications [6], [7], [88]–[90], advertisement [91], its applications and effects in education [92]–[102], the relations among game design elements, user types and gamification design [103]–[107], the applications of gamification in software engineering [108], marketing [5], [109], [110], services [111], and tourism [112], and the gamification theoretical foundation and practical effects [113]–[115].

The remaining publications describe empirical experiments carried out in real settings in order to assess different aspects of gamification, mainly its educational effectiveness, and the effects of the different gamification elements. Seventeen of those works describe experiments carried out in educational contexts [8], [116]–[131]. Those experiments mainly aim at describing the effects of gamification in, generally, university students' motivation, engagement and cognitive performance as well as analyzing the effects of different gamification elements. The remaining publications describe experiences of gamification applied in non-educational contexts, such as healthcare and wellbeing [132]–[136], trading services [137], [138], house renting [139], handling of materials and supplies [140], marketing [141], online surveys [142], and image tagging [143].

D. RQ4: WHAT ARE THE INFLUENTIAL JOURNALS IN THE GAMIFICATION FIELD?

TABLE 5 lists the journals that publish highly cited and therefore influential gamification works. For each journal, its total number of gamification publications (TP), total number of citations achieved by those publications (TC), and the h-index are shown. The journals are ordered according to TC. As this table shows, Computers in Human Behavior is the journal with the highest number of publications (52) and the highest number of citations (2,168). The next journal, Computers & Education, reaches also a high number of citations, close to 2,000, with half the publications (26). Both journals group almost a quarter of the publications published in the top-20 most influential journals. Attending to the h-index of these influential journals, apart from Computers in Human Behavior and Computers & Education, JMIR Serious Games, and Simulation and Gaming have an h-index higher than 10. The remaining journals are all in the range of 5 to 7 in their h-index.

E. RQ5: WHO ARE THE TOP AUTHORS IN GAMIFICATION RESEARCH?

To analyze the most active and influential researchers in gamification research, TABLE 6 and TABLE 7 list the top-10 authors in number of authored publications and citations received, respectively.

If we attend to the top contributing authors (TABLE 6), Hamari tops the list with 28 publications in the dataset. Additionally, his publications have received the highest number of

TABLE 5. Top-20 most-influential Journals in gamification research in terms of total citations.

Journal	TC	TP	h-index
Computers in Human Behavior	2,168	52	24
Computers & Education	1,988	26	17
International Journal of Human-Computer Studies	623	16	7
Educational Technology & Society	439	10	6
JMIR Serious Games	393	22	11
Simulation & Gaming	391	18	10
International Journal of Information Management	221	8	6
International Journal of Emerging Technologies In Learning	214	20	7
Games For Health Journal	207	17	7
Personal and Ubiquitous Computing	191	10	7
JMIR Mhealth and Uhealth	188	14	6
Multimedia Tools and Applications	164	12	7
International Journal of Serious Games	114	23	6
Plos One	112	12	5
Sustainability	101	22	5
International Journal of Game-Based Learning	90	18	6
Frontiers In Psychology	90	12	5
IEEE Access	69	16	5
Eurasia Journal Of Mathematics Science And Technology Education	62	11	5
JMIR Research Protocols	61	11	6

TABLE 6. Top productive authors in gamification research (criterion: number of publications).

ORDERED BY TP				
Author	**TP**	**TC**	**h-index**	**PY_start**
Hamari, J	28	2400	18	2013
Kim S	16	54	5	2014
Marti-Parreño J	16	77	4	2015
Isotani S	15	91	6	2014
Kruger A	14	34	4	2015
Nacke LE	14	194	7	2016
Altmeyer M	13	33	4	2015
Lessel P	13	33	4	2015
Ali R	12	105	6	2014
Arnab S	12	15	3	2016
ORDERED BY TC				
Author	**TP**	**TC**	**h-index**	**PY_start**
Hamari J	28	2400	18	2013
Nacke LE	14	194	7	2016
Ali R	12	105	6	2014
Isotani S	15	91	6	2014
Marti-Parreño J	16	77	4	2015
Kim S	16	54	5	2014
Kruger A	14	34	4	2015
Altmeyer M	13	33	4	2015
Lessel P	13	33	4	2015
Arnab S	12	15	3	2016

citations. With an average of 85.7 citations per publication, and an h-index of 18, the difference with the rest of the top contributing authors is highly significant. His interests cover a wide range of gamification topics. His most cited publications aim to show empirical evidence of gamification effects by reviewing the literature or describing the results of experiences conducted in the domains of gamifying services, economics, crowdsourcing at work, physical activity, e-sports

TABLE 7. Top influential authors in gamification research (criterion: number of citations).

ORDERED BY TP				
Author	**TP**	**TC**	**h-index**	**PY_start**
Hamari J	28	2400	18	2013
Koivisto J	8	1586	8	2014
De-Marcos L	5	886	5	2013
Dominguez A	3	791	3	2013
Fox J	3	509	3	2014
Pages C	2	754	2	2013
Saenz de Navarrete J	2	754	2	2013
Martinez-Herraiz JJ	2	576	2	2013
Sarsa JJ	1	844	1	2014
Fernandez-Sanz L	1	539	1	2013
ORDERED BY TC				
Author	**TP**	**TC**	**h-index**	**PY_start**
Hamari J	28	2400	18	2013
Koivisto J	8	1586	8	2014
De-Marcos L	5	886	5	2013
Sarsa JJ	1	844	1	2014
Dominguez A	3	791	3	2013
Pages C	2	754	2	2013
Saenz de Navarrete J	2	754	2	2013
Martinez-Herraiz JJ	2	576	2	2013
Fernandez-Sanz L	1	539	1	2013
Fox J	3	509	3	2014

and information systems. He has also explored the principles of gamification design and the effect of gamification elements such as badges, and compared gamification with games.

To analyze the most influential authors in terms of citations received, TABLE 7 lists the top-10 authors with the highest number of citations, disregarding the number of publications they have authored. Again, the list is topped by Hamari, whose works have received the highest number of citations, followed by one of his co-authors, Koivisto. One factor that is interesting to note is that among the top-10 highly cited authors, there are authors that have published a small number of contributions in the field. Two authors have published one single work and three authors, only two. However, those works reached a high number of citations. This data could suggest that among the top cited authors in gamification research there maybe authors that are not regularly contributing to the area, but published one or two works that have been widely cited. The vast majority of the most-cited authors started publishing in the topic of gamification in the period 2013-2014.

Fig. 8 shows the top-10 most productive authors over time. The horizontal line represents an author's timeline. The bubble size is proportional to their number of contributions in a particular year and the color intensity is proportional to their total number of citations. In this group, the earliest publishing author is also the most influential one as seen before, Hamari, whose first publication appeared in 2013.

In 2014, he published four articles, being one of them the most cited work in gamification research. The following years, he contributed two or three articles every year, except in 2017, in which the number of papers he published was

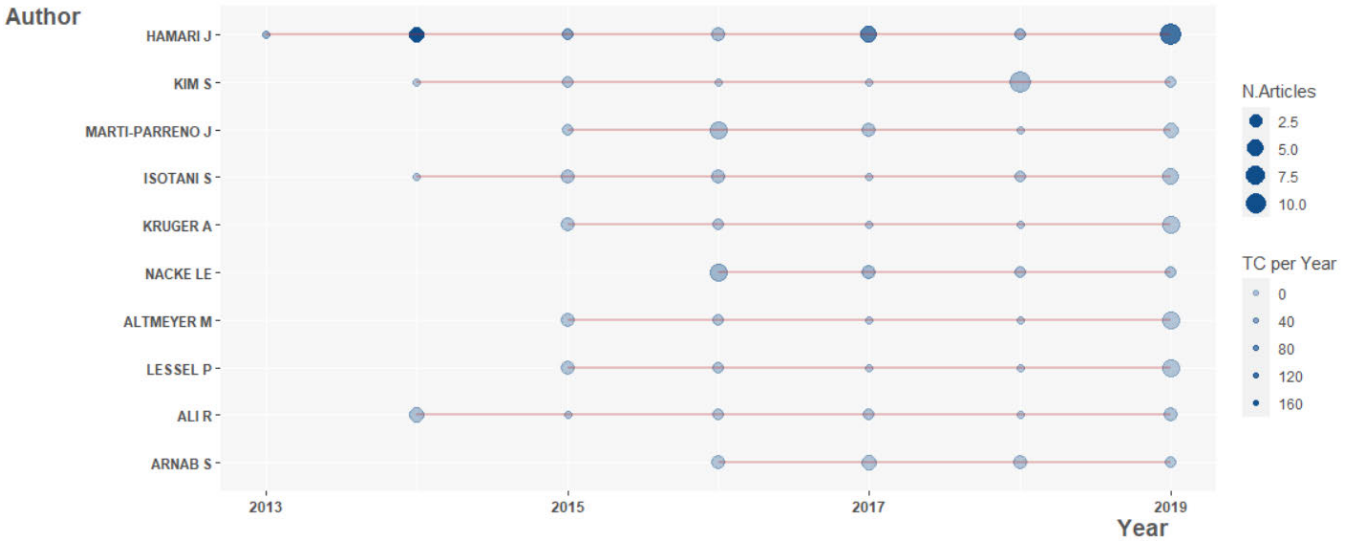

FIGURE 8. Most-productive authors' production over time.

5 and 2019, in which his total contributions to the field have been 11. Kim and Isotani, exploring the gamification of learning, and Ali, studying the use of gamification in requirement engineering and the enterprise environment have followed similar publishing paths. The three of them started publishing in 2014 and have contributed every year. Marti-Parreño, and the team formed by Altmeyer, Kruger and Lessel share also a similar path starting to publish in 2015 and contributing regularly between one and three papers until 2019. Marti-Parreño's works are in the educational use of gamification, while Kruger, Altmeyer and Lessel have explored its applications in advertisement, physical exercise and user types. They reached their highest number of contributions in one single year (7) in 2019.

Finally, Nacke and Arnab both started publishing in 2016 and have contributed regularly since then. Nacke's works are focused on personality and gameful design, and Arnab's ones on gamification of education and energy saving. Both authors have a decreasing pattern in their number of works published by year and reached their minimum number (2) in 2019.

However, with 4 publications in 2016, Nacke is the author with the highest number of publications in his first year of publishing in this field, whereas Kim and Hamari are the authors contributing the highest number of publications in one single year, with 11 publications in 2018 and 2019, respectively.

F. RQ6: WHICH ARE THE RESEARCH FRONT AND THE INTELLECTUAL BASE OF GAMIFICATION RESEARCH?

To understand the structure of a research field, citation analyses have been traditionally used. Citation analyses employ citation counts as a measure of similarity of publications. They can be decomposed into bibliographic coupling and co-citation analyses. Bibliographic coupling uses as a similarity measure the number of common references that are cited by two documents, whereas in co-citation the measure of similarity of two publications depends on the number of documents that cite them both. Since bibliographic coupling follows a retrospective approach by studying citing documents and co-citation follows a forward-looking by studying cited documents, both analyses can complement each other [144]. In this work, we follow this complementary approach to describe: a) the research front of gamification research by analyzing the citing publications (bibliographic coupling analysis), and b) the intellectual base of gamification research by analyzing the cited references (co-citation analysis).

Bibliographic coupling analysis – Research front Bibliographic coupling helps to find the research front of a field, that is, how the research literature on a field is being self-organized by its authors [145]. One of the advantages of bibliographic coupling is that it makes it possible to find conceptual connections between publications that did not have time to be cited yet because they are very recent [144]. For that reason, we did not set any threshold regarding the minimum number of citations to obtain the bibliographic coupling map shown in Fig. 9. In this representation, the size of a node is proportional to the number of citations received by the publication. A link between two nodes means that those two nodes cite common references. Their coupling strength is higher the more citations to other documents they share.

The publications were clustered into 9 clusters. The color of the node shows the cluster of the publication. An analysis of the main topics covered, the citations and the evolution of the publications in each cluster follows:

- Cluster 1, in red, is the most-populated one. It groups 2,126 publications. The topics covered by the publications in this cluster explore the general use and applications of gamification in different contexts, but with

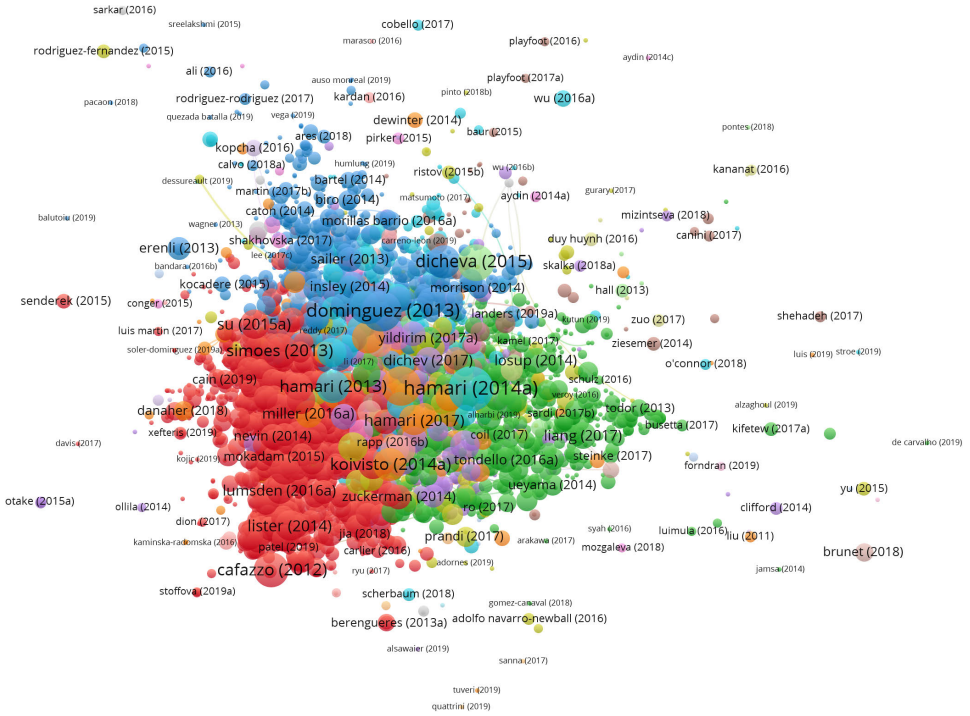

FIGURE 9. Bibliographic coupling map.

a clear preference for the educational, and health and wellness ones. Very frequently, the use of gamification in these contexts is supported by mobile technologies. The pattern of publication follows a clear growing trend along the years 2011-2019, which reveals the increasing interest in conducting studies on the applications of gamification. The publications in this cluster accumulate 10,964 citations with an average of 5.16 citations per publication. The most cited paper in this cluster describes a pilot study of a mobile-health intervention for the management of type 1 diabetes in adolescents [136] (282 citations). It concludes that the use of gamified incentives improved the frequency of blood glucose monitoring in that population, whose level of satisfaction with the application anticipated a continuous and future use once the pilot study was over. The main features of a social gamification framework for a K-6 social learning environment are explored in the second most-cited publication of this cluster [124] (271 citations). This publication describes an on-going process aimed at adding gamification to a social learning platform supported by mobile technologies. The third most-cited paper describes an analysis of 132 gamified apps related to physical activity and diet and their potential to impact health behavior [88] (150 citations). Although at the time this work was published (2014), there was a widespread use of gamification in the heath context under the form of mobile apps, the conclusions of this analysis insist on the importance of a stronger adherence of these applications to professional guidelines and industry standards.

- Cluster 2, in green, groups 573 publications, which share a common interest in exploring the relation between gamification elements and the effects they produce regarding different factors of personality. The trend of publications in this cluster grows continuously from 2011 to 2018. In 2019, for the first time, the number of publications is slightly smaller than in the previous year. The number of citations accumulated by the publications in this cluster reaches 2,931, with an average of 5.11 citations per publication. A study exploring the use of external rewards on students' motivation, engagement and learning is the most cited work in the cluster [118] (107 citations). Their results confirmed that the use of external motivators had a positive impact on students' understanding, but no impact on disciplinary engagement was found. Another study about the impact of different types on achievement badges in an online learning environment was explored in the second most-cited publication [127] (90 citations). The conclusions of their study confirm that rewarding student achievements with badges affect their behavior even if the badges have no impact on the grading. Furthermore, they found evidence about the relation between different badge types and students' personality and behavior. The impact of badges on accommodation, reviews and ratings in the Airbnb platform was explored in the third most-cited publications [139] (83 citations). By analyzing the data

related to the operation of the platform in Hong Kong, the authors could conclude that guests were more prone to book and spend more time in the accommodation provided by the hosts who had been awarded the ''Superhost'' badge, and also, to more frequently give reviews and higher ratings to such hosts, revealing a clear influence of that badge on the behavior of guests.

- Cluster 3, in blue, groups 483 publications, with a shared interest in the application of gamification in education. A particular feature of the publications in this cluster is that many of them provide non-concluding findings about the benefits of gamification in the classroom and they reinforce the need to keep on conducting experimentation. The number of publications in the cluster grows continuously until 2016. From that year on, the number of publications per year remains in a constant value. The accumulated number of citations of the publications in this cluster is 539, with an average of 1.11 citations per publication. The most-cited publication in this cluster is a study conducted to determine if gamification increases motivation and engagement of a group of university students [116] (539 citations). They concluded that more research was needed. Even though the students had a higher motivation and reached better scores in general, their performance in particular assignments, such as the written ones, and their level of participation in class activities was lower than the students who did not follow a gamified course. A longitudinal study on the effects of gamification in the classroom is also the main aim of the second most-cited publication [93] (415 citations]. Their experimentation showed negative results about the use of gamification in the classroom. It was found that students were less motivated, satisfied and empowered after the experience. Because of their lower motivation, the final scores of the gamified group were also lower. Another experiment comparing a gamified and non-gamified group of students was conducted on the third most-cited publication [117] (215 citations). In this case, the results also prove that the gamified group had a more positive attitude and achieved a better academic achievement for practical assignments. However, their results in knowledge assessment were lower than the non-gamified group.
- Cluster 4, in yellow, groups 249 publications. The publications in this cluster explore the topic of engagement and incentives. The number of publications raises year after year until 2015. After this year, the number of publications remain constant, though with some fluctuations. The publications accumulate 143 citations, with an average of 0.57 citations per publication. The most-cited publication is an introductory work to the field of gamification in e-learning, describing its main aims, elements and expected results in terms of increasing engagement [96] (539 citations). Kawajiri *et al.* [146] (58 citations) explored the use of gamification in steered crowdsourced applications as an alternative to incentive design in crowdsensing. They concluded that gamification in steered crowdsourcing helped to faster deployments with half of the data than non-steered crowdsensing needed. The third most-cited publication explores the use of cooperative, competitive and hybrid social incentives in the context of physical activity apps [147] (57 citations). Their findings reveal that cooperative and hybrid incentives provided better results than competition in terms of motivating users toward physical exercise.
- Cluster 5, in purple, groups 230 publications, which address the topic of understanding the effects of gamification by scientifically proving its impact on the intrinsic motivation of participants in different contexts, being the educational context the most frequently one studied. They accumulate 1,497 citations, with an average of 6.50 citations per publication. The publications in this cluster are more recent ones, dating from 2014 and growing regularly until 2019, year in which the highest increment is reached. The most-cited publication describes an empirical experiment conducted to analyze the effects of individual game elements on intrinsic motivation and need satisfaction [143] (143 citations). The authors could prove that points, levels and leaderboards increase user performance, but they act as external motivators. No evidence was found to prove that they affect intrinsic motivation, need satisfaction or work quality. In the second most-cited publication, Landers presents a psychological theory of gamified learning [115] (120 citations) and provides ''recommendations for the rigorous, scientific study of gamification''. The analysis of the motivational mechanisms of gamification when applied in learning contexts is addressed by the third most-cited publication [99] (92 citations). Dichev and Dicheva conducted a literature review to find empirical evidence about the motivational effect of gamification in educational settings. Among their conclusions, they highlighted the fact that there was a lack of quality studies providing scientific evidence about the long-term benefits of gamification in education and the limited methodological knowledge about how to gamify different educational contexts.
- Cluster 6, in turquoise, groups 215 publications that address that analyze the impact of gamification in professional settings. The publications included in this cluster date from 2012 to 2019. They have a continuous growth until 2016, year in which the maximum value in number of contributions in one single year is reached. The following year the number of publications drops to similar values of 2015 and remains constant until the end of the period. The publications accumulate 2,558 citations, with an average of 12 citations per publication. The most-cited publication in our dataset leads the most-cited publications in this cluster [87] (844 citations). This work consists on a literature review of empirical studies conducted on gamification to find

out whether gamification works. The authors conclude that even though the majority of the studies they analyzed concluded that gamification did work, the results highly depended on the context and the participants and that, therefore more methodologically-grounded research was needed to prove such an affirmation. In the second study, Hamari conducted a field experiment to find the relations between badges and user behavior in a trading service [137] (230 citations). He could not conclude that by implementing gamification mechanisms an improvement in the users' activity could be achieved, but he could prove that the activity of those users who regularly checked about their and others' badges, increased their level of activity. The benefits of gamification when applied in a business context is the aim of the third most-cited publication in this cluster [103] (141 citations). The definition and the psychology behind the concept of gamification and a motivational design framework and guidelines about how to use it are introduced to readers from the business sector, supported on the information provided in empirical works that show the benefits of gamification in non-business contexts.

- Cluster 7, in orange, groups 169 publications related to motivational design in different contexts such as marketing, professional development, energy saving and effective driving. The publications accumulate 476 citations, with an average of 2.82 citations per publication. They range from 2011 to 2019, with a growing trend until 2016. Since then, there seems to be a gradual decline in the number of contributions in this cluster. The most-cited publication is a survey on gamification literature aiming at defining and describing gamification from the empirical findings published [113]. This work concludes that gamification can be classified as another element inside the bigger effort of improving the user experience of interactive systems (476 citations). How demographic differences impact on the perceived benefits of gamification is the subject of study of the second most-cited publication [95] (236 citations). From the analysis of the usage data of an exercise gamification service, the authors could conclude that there was evidence that the perceived benefits of gamification declined with time and that the participant's demography is correlated not only with the perceived benefit of gamification, but also with its effect over time. The third most-cited publication in the cluster reinforces the thesis that gamification is only effective when special care has been applied to select specific game elements to address particular psychological needs and effects [140] (201 citations).
- Cluster 8, in brown, groups 159 publications on the particular relations between gamification and software engineering, being it a) the applications of gamification to improve either professional software engineering or software engineers training, or b) the application of software engineering principles to engineer gamified software. These publications range from 2013 to 2019 and accumulate 46 citations, with an average of 0.30 citations per paper. The most-cited publication proposes a method for developing gamified software that was evaluated positively by gamification experts [148] (46 citations). The most valuable contribution of this framework is the fact that integrates the knowledge in literature about gamification engineering in one single holistic proposal. The next-most cited publication describes the development of a gamified ERP (Enterprise Resource Planning) system and the results of its application on ERP training in terms of improving users' learning and satisfaction [149] (27 citations). Another framework for gamifying organizational change management of software process initiatives is presented in the third most-cited publication [150] (27 citations). In this case, the framework is grounded on the motivational elements of software engineering professional and theoretically validated with a group of practitioners.
- Cluster 9, in fuchsia, groups 86 recent publications mostly related to experiences in gameful design. They date from 2014 to 2019, with a growing trend along the period. The number of accumulated citations is 59, with an average of 0.68 citations per publication. The most-cited publication conducted a randomized controlled trial to prove that gamification together with online social support improves the levels of physical activity and empowerment of patients with Rheumatoid Arthritis [151] (59 citations). Positive results on motivation and student's performance when using gamification in a computer programming course were reported in the second most-cited publication [152] (37 citations). The next paper in number of citations surveys the literature to highlight the differences between gamification and gameful design and summarizes the theoretical foundations of gamification [153] (28 citations).

TABLE 8 shows the 5 most-highly coupled publications in the network, which occupy central positions as are connected with publications from different clusters. Two of the most connected publications correspond to literature reviews conducted in 2019 and 2015. The first one, and the publication with the highest link strength, was published in 2019, although the study was conducted on a dataset obtained in 2015 [114]. The study analyzes the research model and empirical results of 819 publications reporting gamification research. Their conclusions include the need of a more solid theoretical foundation for gamification empirical research and propose 15 recommendations for a future gamification research agenda. The second review study dates from 2015 and consists on a survey of the gamification literature to define and describe the term ''gamification'' as used in the empirical research published. In their conclusions, the authors suggest having found enough evidence that gamification is a distinctive effort for improving user experience

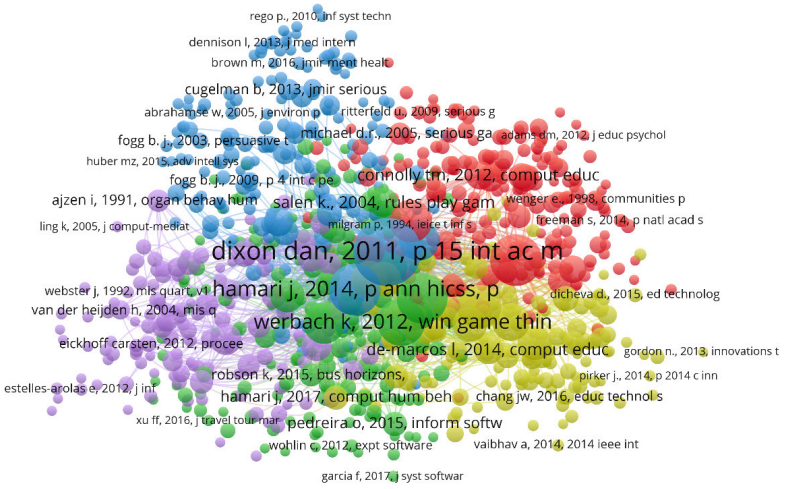

FIGURE 10. Co-citation network.

TABLE 8. Top 5 Most-highly coupled publications.

Publication	Cluster
Koivisto J, Hamari J, 2019, The rise of motivational information systems: A review of gamification research. Int. J. Inf. Manag v45. doi 10.1016/j.ijinfomgt.2018.10.013	5
Aldemir T et al, 2018, A qualitative investigation of student perceptions of game elements in a gamified course. Comput. Hum. Behav.v78. doi 10.1016/j.chb.2017.10.001	9
Seaborn K, Fels, DI, 2015, Gamification in theory and action: A survey. Int J Hum-Comput St, v74, p14, doi 10.1016/j.ijhcs.2014.09.006	7
Xi N, Hamari J, 2019, Does gamification satisfy needs? A study on the relationship between gamification features and intrinsic need satisfaction. Int. J. Inf. Manag v46.doi 10.1016/j.ijinfomgt.2018.12.002	5
BilginCU, Gul A 2019, Investigating the Effectiveness of Gamification on Group Cohesion, Attitude, and Academic Achievement in Collaborative Learning Environments, TechTrends v 64. doi 10.1007/s11528-019-00442-x	3

with interactive systems, different from games and serious games [113].

Two more publications study the gamification effects on the educational context. The second publication with the highest link strength describes the results of a qualitative investigation to find out the impact of different game elements when applied in an educational setting and provides recommendations about how they should be designed and implemented [154]. The other publication describes an experience using gamification as a means to improve learners' collaboration when working in groups [155]. In their conclusions, the authors confirm that gamification did have a positive impact on group cohesion and learner's achievements. However, no evidence was found to prove that it provoked any changes on learner's attitude towards collaborative learning environments. Finally, an empirical study to find empirical evidence on the impact of different gamification elements on different dimensions of intrinsic needs [156]. The study was based on the analysis of the user interactions with a platform of gamified services. The authors concluded that gamification has a positive effect on intrinsic need satisfaction of users, particularly on autonomy and competence needs satisfaction.

Co-citation analysis – Intellectual base

Fig. 10 visualizes the co-citation network of the publications in the dataset revealing the relations between the references that are often cited together. In the network, each node represents a reference that has received at least 10 citations by the publications in our dataset. The size of the node is proportional to the number of citations received. An edge connecting two nodes indicates that those two references were cited together by a publication in the dataset. The size of the node is proportional to its number of citations. Its color represents the cluster it belongs.

The references have been grouped into the following five clusters:

- Cluster 1, in red, is the most populated cluster, grouping 211 references published between 1970 and 2016. With a majority of the references published in journals in the field of education, this cluster collects the referenced knowledge in the use and applications of gamification in education. The five most-cited references in this cluster are three books followed by two journal articles. A book providing guidance about how to create meaningful learning experiences based on the values of game-based thinking and mechanics [157] (515 citations) occupies the first position in this list. How to use the power of game-based thinking to change business, education and nonprofit worlds is the aim of the second most-cited publication of this cluster [158] (327 citations). The next most-cited publication is the book introducing the psychological notion of *Flow* as the emotional state achieved by people when performing activities that

balance skill and challenge [159] (135 citations). The notion of Flow and its nine dimensions, as described by Csikszentmihalyi have frequently been used as a reference model to measure the experience of learners performing gamified activities. The last two positions in this list are occupied by two journal articles. The first one describes the results of a systematic literature review on the impact of gamified activities on young learners in terms of learning, skill enhancement and engagement [160] (120 citations) and the second one proposes a model for the design of effective instructional games [161] (104 citations).

- Cluster 2, in green, groups 198 references published between 1971 and 2018. The references have been published in marketing and services journals, which suggests that this clusters groups the knowledge about the applications of gamification in professional contexts, mainly marketing and trading services. The most-cited one is a book describing how to use game mechanics to improve customer loyalty [162] (497 citations). The next reference is also a book addressing how the design principles behind game-thinking can help businesses to motivate their employees and customers [163] (424 citations). The third position is occupied by a journal article describing the results of survey aimed at finding empirical evidence for the definition of the term ''gamification'' and proposing its classification as a factor to help improve the user experience with interactive systems [113] (300 citations). The next most-cited reference in this cluster is a conference paper proposing a definition for gamification closely linked to the marketing service industry [5] (195 citations). In the last reference of this top-five list, we find a book aiming at stablishing a theoretical framework for the discipline of game design and game-based thinking [164] (131 citations).
- Cluster 3, in blue, groups 188 references, published between 1973 and 2017. The references in this cluster have been mostly published in medical journals as they describe experiences of gamification in the healthcare and wellness areas. The most-cited reference is a conference paper that analyzes the historical origins of gamification and has been widely used as the reference paper for its definition as the ''use of game-design elements in non-game contexts'' [165] (1002 citations). The second reference is another conference paper detailing the results of a systematic literature review of empirical studies on gamification aimed at finding empirical evidence of the effects of using gamification [87] (518 citations). The next reference is another conference paper [1] (282 citations) describing a tutorial on the basic principles and definition of gamification that shares a core group of authors with [165]. The following reference analyzes the results of four studies investigating the relations between game environments and the satisfaction of psychological needs [166] (127 citations). The last reference of these top five most-cited references in this cluster is a journal article describing an analysis of four meta-analysis studies examining the effects of extrinsic rewards on intrinsic motivation [167] (103 citations).
- Cluster 4, in yellow, contains 144 references, published between 1982 and 2018. The references in this cluster are mostly specialized in exploring the principles of game design and their application in gamification, frequently in the gamification of education. The top five most-cited references are all journal articles. The first two references describe the results obtained with two gamification experiments conducted in educational settings [93], [116], (333 citations and 230 citations, respectively). A journal article exploring the relations between the Self-Determination Theory and intrinsic motivation, social development and well-being is the third most-cited reference [168] (215 citations). How to apply social gamification in K-6 education is the aim of the following reference [124] (190 citations). Last, another journal article summarizing the results of a literature review discusses the ''classic definitions of intrinsic and extrinsic motivation in light of contemporary research and theory'' [169] (195 citations).
- Cluster 5, in purple, groups 129 references published between 1975 and 2019. The references have been mostly published in journals in the field of social psychology and share an interest in the motivational effects of gamification in different domains. The most-cited reference is a journal article describing the results of a field experiment of a gamified trading service [137] (154 citations). The next work is another journal article studying the relation between the demographic factors and the perceived benefits of gamification of the users of a physical exercise gamified service [95] (142 citations). The two following references come from the field of psychology containing, an empirical model of motivation grouping 10 motivation subcomponents [170] (100 citations), and a discussion of the Self-Determination theory concept of needs and its relation to other contemporary motivation theories [171] (100 citations). The last reference in this top-five list discusses how the social relations among the users of a physical exercise gamified service can predict their motivation towards physical exercise [132] (80 citations).

Finally, TABLE 9 lists the ten most-cited references by the publications in our dataset. As can be seen, they belong to cluster 1 (2), cluster 2 (3), cluster 3 (3) and cluster 4 (2). There are four books, three conference papers and three journal articles. They have been published between 2011 and 2015 and they cover the topics of game-design principles [158], defining gamification as a motivational element for interactive systems [1], [113], exploring its design and effects in the educational [93], [116], [157], marketing [162] and business [163] domains and providing empirical evidence of its effects [87].

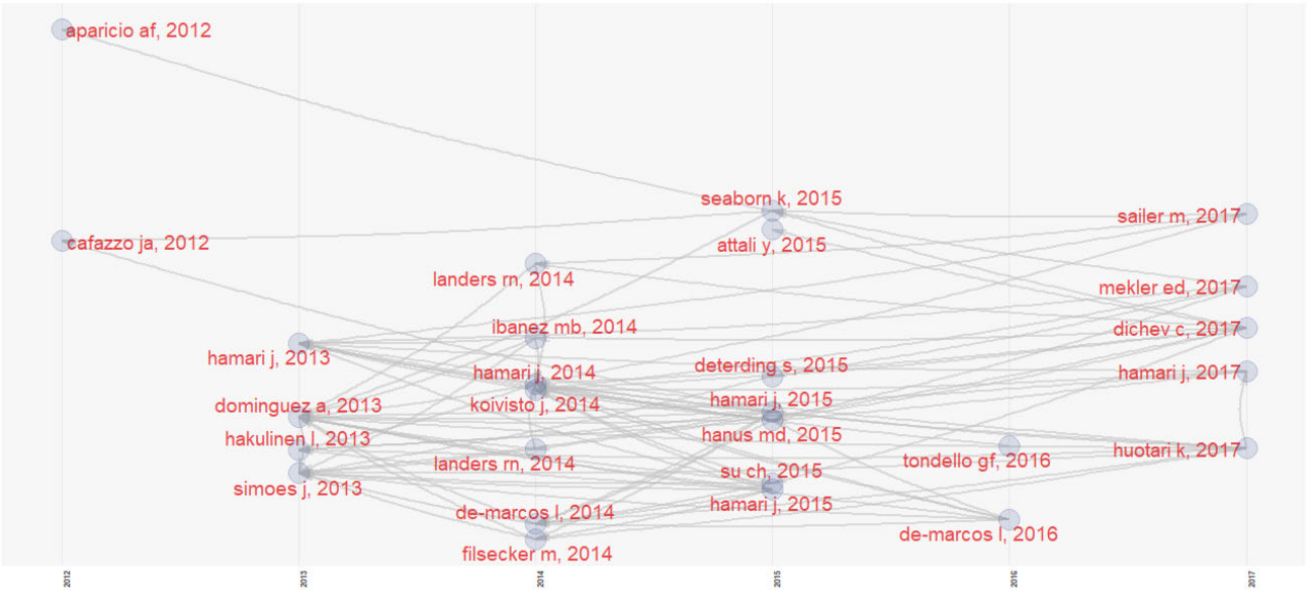

FIGURE 11. Historiographic structure of the gamification field.

TABLE 9. Ten most-cited references.

Publication	Cluster
Deterding S et al. 2011, From game design elements to gamefulness. 15 Int. ACM Mindtrek, doi:10.1145/2181037.2181040	3
Hamari J, 2014, Does Gamification Work? - A Literature Review of Empirical Studies on Gamification. Ann HICSS,p3025, doi: 10.1109/hicss.2014.377	3
Kapp KM, 2012, The gamification of learning and instruction: Game-based methods and strategies for training and education. Pfeiffer.	1
Zichermann G, Cunningham C, 2011, Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps. O'Reilly Media.	2
Werbach K, Hunter D, 2012, For the Win: How Game Thinking Can Revolutionize Your Business. Wharton School Press.	2
Dominguez A, et al. 2013, Gamifying learning experiences: Practical implications and outcomes. Comput Educ, v63, p380, doi 10.1016/j.compedu.2012.12.020	4
McGonigal J, 2011, Reality is Broken: Why Games Make Us Better and How They Can Change the World. Penguin LCC US.	1
Seaborn K, Fels, DI, 2015, Gamification in theory and action: A survey. Int J Hum-Comput St, v74, p14, doi 10.1016/j.ijhcs.2014.09.006	2
Deterding S et al, 2011, Gamification: Using game design elements in non-gaming contexts. CHI ea, p2425, doi 10.1145/1979742.1979575	3
Hanus MD, Fox J, 2015, Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. Comput Educ, v80, p152, doi 10.1016/j.compedu.2014.08.019	4

G. RQ7. HOW HAS THE KNOWLEDGE IN THE FIELD BEEN CONSTRUCTED OVER TIME?

Klavans and Boyack [145] suggested that direct citations are more accurate in representing a research front than bibliographic coupling and co-citation. Fig. 11 shows the direct citation network for the 30 most-relevant publications shaping the debate on gamification. The historiograph contains publications spanning from 2012 to 2017. In total, these publications have received 5,535 global citations. Of them, 3,143 correspond with local citations (LCS, Local Citations Score). This means that around 57% of the direct citations received by these publications have been made by the publications in our dataset reinforcing their decisive contribution to the field of gamification. In total, these publications have a Local Citation Score (LCS) ranging from 518 (reference [87]) to 40 (reference [118]).

The historiograph confirms the rapid evolution of the field in the first half of the period analyzed. From two relevant publications in 2012, the score duplicates in the following year with four publications in 2013, and almost again in the following one, with 7 publications in 2014 that remains the same in 2015, with also 7 relevant publications. The score drops down in 2016, reaching only two relevant publications, but raises to 5 publications in 2017. This evolution confirms that so far the years 2014 and 2015 have been the most productive ones in terms of relevant contributions. Recent publications from 2018 and 2019 have not reached enough citations yet.

Several publications have an important role in this network if we pay attention to the number of their intra-network citations, which means, the number of direct citations they have received from the publications in this selected group of relevant publications. These publications are Dominguez *et al.* [116], with 13 intra-network citations, Hamari [137] and Hamari *et al.* [87] with 10 intra-network citations each, Simoes *et al.* [124], with 8 and Koivisto *et al.* [95], with 6 intra-network citations. Having into consideration the number of publications in this network and the years of each publication, these publications have

reached an influential role in the gamification research, reaching 59%, 43%, 62.5%, 40% and 57.3%, of all their potential citations, respectively.

Another remarkable fact has to do with the speed of citations received by Hamari *et al.* [87]. With three vertical citations [95], [119], [120], it is the publication attracting more citations from publications of its same year. Two of these vertical citations come from two different teams, while the third one is a self-citation. Another publication, by the same author, [138] has another vertical citation by [5], although in this case is a self-citation since one of the authors participates in both publications.

The most researched topic across the years represented in the historiograph is the applications and effects of gamification in the educational domain, which have been studied by conducting different experiments. In 2013, aspects such as the effects of using a gamified plug-in into a learning platform [116], and using badges in online learning platforms [127], together with the impact of gamified social learning in a K-6 learning platform [124] were the object of study. In the next year, five out of the seven studies represented in the graph also explored gamification in the educational domain. Landers *et al.*'s works aim to describe and test a theory for gamifying learning [115], [120], and several experiences to motivate Computer Science students [119], compare gamification with social networking on e-learning contexts [117], and explore the effects of external rewards in student's motivation and performance [118]. In 2015, three works describing experiences of using gamification in the assessment of students performance [131], the effects of using a mobile gamified learning system on students motivation and achievements [123], and the results of a longitudinal study of the relation between gamification and student's intrinsic motivation [93] were published. In the following year, we find a work extending the comparison of gamification with social networking and games [101]. The exploration of the educational applications of gamification along this historiography is closed with a mapping study published in 2017, reviewing the literature to summarize the existing knowledge and the future prospects of using gamification in education [99].

Other less frequent topics have evolved also along this historiograph. Works progressing general studies and theories about gamification appeared in 2012, with a proposal of a method of analysis and application of gamification [172], followed by a literature review to show empirical evidence of the effects of gamification [87] in 2014, and a survey about the theory and action of gamification [113]. In 2017, a general work about how gamification motivates contributes to the analysis of the relation between gamification and motivation [140].

The interest in how to design effective gamification experiences led to research the relation between the different game elements and their particular effects, mostly on the motivation and engagement of the participants in gamified experiences. The first work in the historiography addressing this topic appeared in 2015, when Deterding *et al.* proposed a method for gameful design [104]. The following year, Tondello et al, proposed a survey to score user preferences and relate each of them with their most effective gamification element [107]. In 2017, Mekler *et al.* delve into the effects of different gamification elements on motivation and performance [143].

Finally, the evolution of the use of gamification to motivate the user's participation on gamified services of the well-being and trading domains as studied by Hamari *et al.* is also represented in the historiograph. In 2013, the results of an experiment on gamifying a trading service were reported [137], which was further explored in 2015 [111], and 2017 [138], and influenced the proposal of a definition of gamification more aligned with the service marketing literature in 2017 [5]. In parallel, the relations between demographic differences and the perceived benefits of a physical exercise gamification service were discussed in 2014 by Koivisto and Hamari [95]. The following year, the same authors further explored the applications of gamification in physical exercise by analyzing the effect of social influence in the attitude and motivation towards exercise [132]. Close to the wellness domain, the topic of gamification in healthcare is represented by a single publication in 2012, in which Cafazzo *et al.* describe the results of a gamified mobile application for the self-management of adolescent diabetes type 1 [136].

H. RQ8: WHAT ARE THE AUTHORS' COLLABORATIVE STRUCTURES?

An authors' collaboration network helps find out the existence of regular groups of authors collaborating to produce influential gamification research. To answer this research question, we analyzed the collaboration network of the authors in the dataset. There are 12,078 gamification authors in our dataset. To draw a meaningful and clear co-authorship map, we look at authors whose contribution to gamification is not anecdotic and have had some impact in the community. Setting a minimum level of contribution to the field is especially important in this dataset since almost 83% of the authors have published a single paper, and 33% of the authors have not received a single citation. For these reasons, we set a threshold to select the authors who have published two or more publications and have received 10 or more citations for their overall production. Since the average number of citations per publication is approximately 6 (see Table 2) this limit seems reasonable and not extremely restrictive. The number of authors meeting these thresholds is 2,089, which represents 17.3% of the total number of authors in the dataset.

To keep the network readable, Fig. 12 shows an overall view of the collaboration network of the 300 authors with the greatest total link strength, i.e. the total strength of the co-authorship links of a given author with other authors. Each author is represented by a node in the network. The size of the node is proportional to the number of publications of the author. The links among the nodes represent the collaboration relations among the authors. The nodes have been clustered into 53 clusters of collaboration. The color of the node

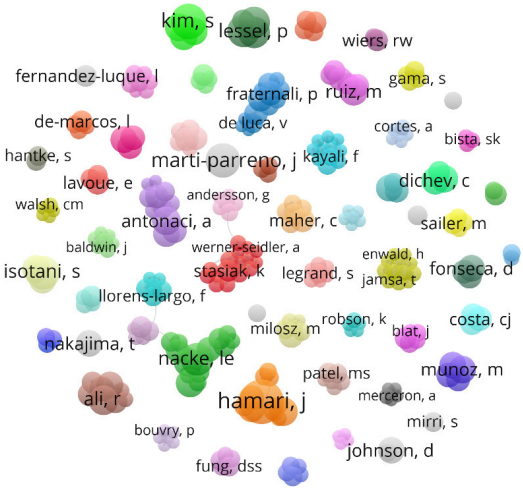

FIGURE 12. Authors' collaboration network.

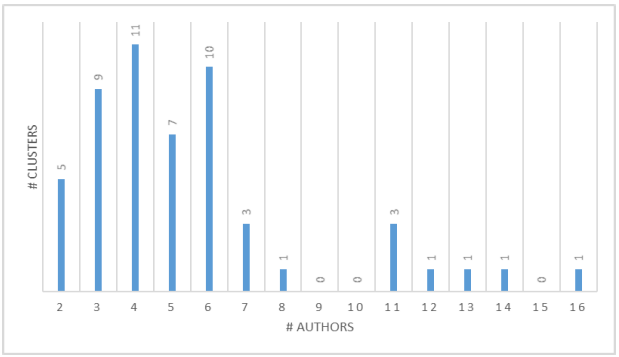

FIGURE 13. Size of clusters of author's collaboration.

represents the cluster of collaborating authors the author belongs. As Fig. 12 shows, the clusters of collaboration have different sizes and are mostly disconnected from other clusters. This structure suggests that there are regular structures of collaboration on certain topics of research (intra-cluster collaboration) but there is not much collaboration across different topics of research (inter-cluster collaboration).

To conduct an analysis of the intra-cluster research, we first analyzed its general structure and then studied the research conducted inside each cluster of collaboration. Fig. 13 shows the number of clusters found for each size of group of collaborating authors. As shown, the size of the intra-cluster collaboration networks ranges from 2 to 16 authors. The most frequent size of an intra-cluster collaboration network is four authors (11 clusters), followed by 6 authors (10 clusters) and three authors (9 clusters).

The level of inter-cluster collaboration is very low. Only wo collaboration structures between two different clusters were found. Fig. 14 shows the first collaboration structure.

In this case, between cluster 1 (mental health, young people) and cluster 18 (mental disorders). The link between these two clusters is materialized through a joint publication by Donker (cluster 1) and Carlbring (cluster 18) describing the effectiveness of a gamified virtual reality app on preventing acrophobia [173] (3 citations).

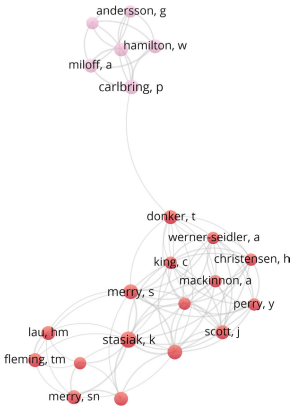

FIGURE 14. Collaboration structure between Cluster 1 and Cluster 18.

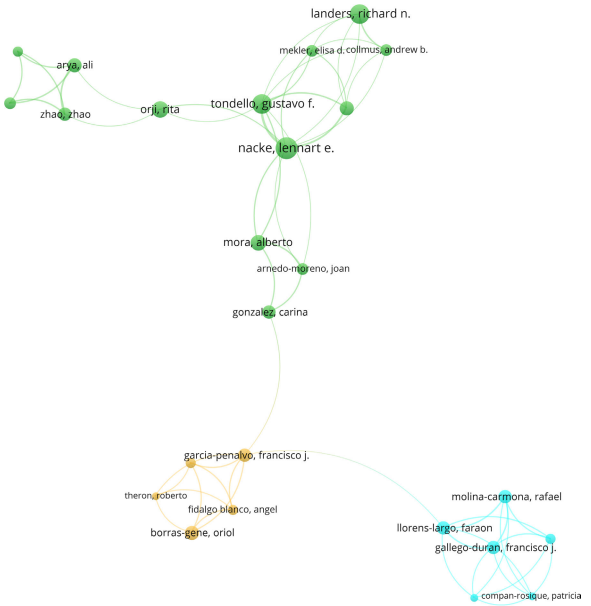

FIGURE 15. Collaboration structure between Cluster 1, Cluster 19, and Cluster 22.

The second collaboration structure is shown in Fig. 15 and links Cluster 2 (user types and personality), Cluster 19 (learning process), and Cluster 22 (MOOCs). The author Garcia-Penalvo (Cluster 22) is the author bridge between the three networks, since there are no publications joining authors of the three clusters, but pairs of them. The use of gamification for promote diversity in computer science studies is the result of collaboration of Garcia-Penalvo and Gonzalez (cluster 2) [174] (3 citations). The collaboration of Garcia-Penalvo with Llorens-Largo (cluster 19) led to propose an educational service-based ecosystem that supports the gamification of the learning processes [175] (20 citations).

I. RQ9: WHAT IS THE CONCEPTUAL STRUCTURE OF THE GAMIFICATION RESEARCH?

A total of 9,222 author keywords (DE) have been used to describe the publications analyzed. Fig. 16 shows the 20 most-frequent ones. If we focus on what these most frequent keywords tell us about gamification research,

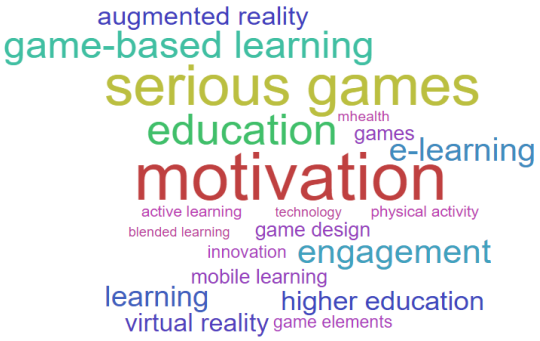

FIGURE 16. Word cloud of the most frequent keywords.

we could say that the most frequent keyword, *motivation*, confirms that the research on this field is mostly focused on the motivational effect of gamification.

In this group of most frequent keywords, forty-five percent of them are related to the educational scope, *serious games*, *education*, *game-based learning*, *learning*, *e-learning*, *higher education*, *mobile learning*, *blended learning*, *active learning*, revealing one the most explored domains of application. Technologies such as *augmented reality* and *virtual reality* seem to be present in many of the experiences published. Improving the *engagement* of the participants in gamified experiences is also among the frequent aims of these experiences. In addition to the educational scope, gamification has also been frequently explored in the health one, particularly in the *mhealth* domain, closely linked with the promotion of the *physical activity*. In both fields, gamification is seen as an *innovation* that seems to export the benefits of *games, game elements* and *game design* to the educational and health domains.

To find the conceptual structure of gamification research, we performed a co-word analysis of the author's keywords, which were mapped and clustered into a word co-occurrence map. In this map, shown in Fig. 17, each node represents a keyword. The larger the size of the node, the larger the frequency of the keyword. Nodes are connected by links. The wider the link, the stronger the link of co-occurrence between the two keywords.The color of the node indicates the cluster the node belongs. To keep the figure readable, only the 300 nodes with the highest degree are represented.

The following five clusters were identified:

- Cluster 1, in red, is the most-populated one. It groups 94 keywords. The most frequent keywords in this cluster are *games* and *game design*, which are highly influential factors towards gamification design. The analysis of the remaining keywords in the cluster reveals that this cluster groups publications aiming to design gamification experiences that have a positive impact on the user experience and provoke a change in their behavior. Most of the applications of gamification described in the publications of this cluster address the healthcare and wellbeing domain, and, in a much lesser frequency, the cultural one. In the area of healthcare and wellness is common to use *games*, and *videogames* as a way to promote a *behavior change* in *children* and *adolescents* towards *physical activity* [134], [176], [177], and *mental health* interventions [178], [179]. Gamification experiences in this cluster are usually classified as a type of *persuasive games* [180], [181], and are frequently implemented within *mobile applications* making use of *smartphones* and *wearable* devices within the contexts of *e-health* and *m-health* [182]–[185]. The change in behavior towards physical exercise in people suffering from different health conditions is frequently promoted by their participation in *exergames* and the use of mechanics of *competition* [186]–[188]. Additionally, in this cluster, a group of keywords related to human-computer interaction such as *user-centered design* and *usability* reveals the interest in designing these applications to improve the *user experience* and *user engagement* under the principles of *game design*, *co-design* and *gameful design* [189]–[193]. Indeed, the closeness of the *game design* node to the central position in the network reveals its critical importance in gamification research. Closely related, the links between gamification design and *personality* have been also explored [194]–[196], as the improvement of the user experience by applying game-design principles is not only studied for the cases of health applications, but also to improve cultural experiences such as learning about and experiencing *cultural heritage* [30], [197]–[199].
- Cluster 2, in green, groups 75 keywords. The most frequent keyword, *motivation*, characterizes this cluster which groups together the publications focused on the relations between gamification and *motivation*, and *engagement*. In this cluster, we can find studies focused on analyzing how gamification as an *educational technology* boosts *motivation* [116], [123], [140], [200]. Some works go further in analyzing the relation between gamification and motivation, particularly, *intrinsic motivation* and *engagement* [93], [143], [201], [202]. Many works describe experiences focused on the educational use of gamification, which is frequently described as *gamified learning*, conducted in formal and non-formal contexts [115], [203]–[205], and making use of technologies such as *augmented reality* [206]–[208], and *virtual reality* [209]–[211]. Several works address the use of gamification as a *technology* to innovate and improve engagement in *language learning* [212], [213]. In this context, *kahoot* is used as a digital tool implementing *game mechanics* to give support to *formative assessment* and *feedback* in educational processes [214]–[217]. *Simulation* is a common element present in different levels and contexts of gamified learning initiatives. [218]–[220]. Moreover, principles from *psychology*, the evaluation of participant's *performance* and the *personalization* of the gamification [221]–[223] are also themes explored in this cluster. In this sense, several works address the relation between the different *game elements* and their impact on *learning* [224], [225].

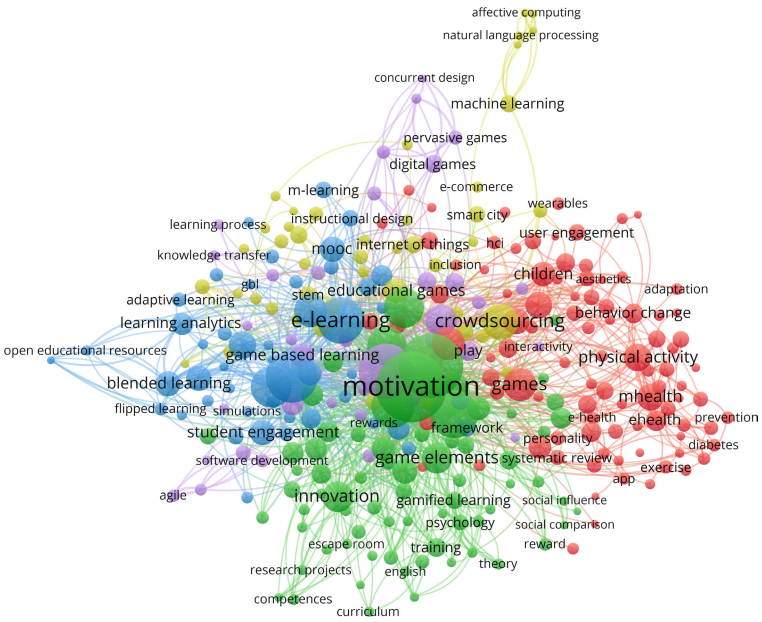

FIGURE 17. Word co-occurrence map.

- Cluster 3, in blue, groups 48 keywords. In this cluster, the works predominantly explore the educational uses of gamification in *higher education*, within *e-learning* and *mobile learning* contexts, such as *MOOCs*. The keywords describe publications related to the application of gamification within the context of *e-learning* [96], [226], [227] and MOOCs [228]–[231], where *social learning* is an important component [232], [233]. These gamified learning experiences are frequently explored within the context of *higher education* [234]–[236], commonly in ICT-related subjects [237], [238]. Connected to the node of *higher education*, several nodes describing different pedagogical approaches can be found. These works describe different experiences carried out at this educational level integrating gamification with *active learning* [239]–[241], *blended learning* [242]–[244], *collaborative learning* [245]–[247], *and flipped classroom* [19], [248], 249] aiming to improve the student's motivation and engagement. In this cluster, there is also an interest in comparing the results of gamified learning and *game-based learning* [250]–[252]. The *evaluation* of the results of using gamified learning initiatives is explored by measuring *learning analytics* [253]–[255]. In the gamified experiences described in this cluster, *badges* are frequently used to award the progress of the participants in the experience. Its use and effects have been analyzed in several works [97], [256], [257]. The Self-Determination Theory (SDT) [258] has been the most frequent motivational theory used [259]–[261] to provide the theoretical basis for these experiences.
- Cluster 4, in yellow, groups 45 keywords. The most frequent one is *crowdsourcing*, followed by keywords such as *social networks, citizen science, programming, stem, machine learning* and *internet of things*. The analysis of the remaining keywords and the position of the nodes in the network suggests that this cluster mostly explores two areas of application of gamification that share as a common element the use of gamified social networks to encourage participants' engagement. The first area of application deals with the use of gamification to boost participation and engagement in *crowdsourcing* platforms [262], [263], with an important number of works addressing topics related to *citizen science* [264]–[266] and the *internet of things* [267]–[269]. Connected with the *crowdsourcing* node, we can see a *machine learning* node that connects the crowdsourcing works with the application of *natural language processing* techniques such as *sentiment analysis* of the comments provided in *youtube* to build a gamified crowdsourced *recommender system* to improve content recommendation [270], [271]. Encouraging the participation of the users of crowdsourcing platforms is frequently based on gamifying their involvement in *social networks* [272], [273]. Precisely, the use of gamification and social networks links to the other area of application explored in this cluster, which is the educational context. The works in this area explore the application of gamified *social networks* and t*echnology-enhanced learning* in the contexts of *STEM* courses [274]–[278] and *lifelong learning* [279], [280].
- Cluster 5, in purple, groups 37 keywords. The most frequent ones are *education, serious game,* and *software engineering*. A further analysis of the keywords and works in this cluster suggests that it groups works that use the terms such as *serious games*, *digital games*,

computer games and *pervasive games*, as synonyms of gamification. The experiences described in these works are in the *education* domain and mostly focused in learning *software engineering* activities [281]–[284], particularly *programming* [285]–[287], and *project management* [288]–[290]. There is also a group of works aiming at using gamification in different processes and activities of professional software development [108], [291]–[294] and software engineering research [295], and describing software engineering methods to build gamified software [148]. The relations between the results of using *serious games* and gamified learning in this context are also explored in this cluster [112], [296], [297].

The results of this analysis show there are five gamification research streams: a) the interest in exploring gamification to increase the user experience, within the context of Human-Computer Interaction; b) the analysis of the relations between personality and game elements; c) the exploration of the effects of gamification using different pedagogical methods; d) the use of gamification to promote users participation in different activities; and e) the analysis of how gamification complements and differs from games and serious games. These streams have been mostly explored in the health, the first one of the listed above, and the educational domains, the four remaining ones.

J. RQ10: HOW HAS THE RESEARCH FOCUS EVOLVED OVER TIME?

To analyze the conceptual evolution of the field, we divided the dataset into three consecutive time periods of three years each: 2011-2013, 2014-106, and 2017-2019. In each period, the publication keywords were used to create the co-word bibliographic networks. After applying a clustering algorithm on each network, the resulting clusters reveal the main themes of research of that period [50].

To visualize the different themes of research found, each theme is finally represented on a strategic/thematic map according to the values of the two following measures [78]:

- Centrality: Measures the degree and strength of the links of a cluster with other clusters in the network. The higher the centrality of a cluster, the more essential is considered to be its associated theme for the research community.
- Density: Measures the strength of the links among the words in the same cluster. The higher the density, the more coherent and stable is its associated theme.

When the clusters are plotted horizontally, by increasing order of centrality, and vertically, by increasing order of density, a strategic map is obtained. In addition, by dividing this graph into four quadrants, it is possible to classify each cluster into one of the following categories [50], [78]:

- Motor themes. Located in the upper-right quadrant, these are considered well-developed themes, which are both highly interconnected and highly cohesive given their high centrality and density values.
- Basic and transversal themes. Can be found in the lower-right quadrant. These themes are considered important given their many links to other themes, but they are still not vey developed since the strength of their internal links is not very high yet.
- Highly developed and isolated themes. Located in the upper-left quadrant, these themes are also well-developed themes but their lower level of interconnection with other themes reveal they are rather peripheral, such as highly specialized themes.
- Emerging or declining themes. Can be found in the lower-left quadrant and represent themes which are both peripheral and not highly developed. A theme in this quadrant may represent either an emerging or a declining theme. Its evolution needs to be analyzed along time to reveal the nature of its contribution.

Figs. 18, 19 and 20 show the thematic maps referred to each three-year period resulting from the analysis conducted with the bibliometrix R package. Each map represents the themes of research in that period by a node labeled by its two most-frequent keywords. The size of the node is proportional to the number of works developed in that theme.

In the first period (Fig. 18), five main themes emerged. In the lower-right quadrant, *gamification* appears as a general theme closely linked to the improvement of *motivation* and *engagement* in educational and e-learning settings. In this quadrant, although with a much lower frequency of works the theme *game* appears. An analysis of the works in this theme shows that it is integrated by the works exploring the applications of game principles and the differences between the use of gamification and games, mostly in terms of their use in educational settings. On the upper left quadrant, the theme *augmented reality*, used to describe the gamification experiences that integrate this technology, appears with a high density but low centrality indicating that it is a highly explored theme in this period, but as a very specialized and isolated one.

Finally, two similar themes *social media* and *social networking* occupy the lower-left and upper-right quadrants. After an analysis of the works described by both keywords in this period, we can conclude that the authors seemed to have used both terms as synonyms. The works in the theme social networking are, in fact, works describing the use of social media as a significant element within a gamification experience. The presence and position of both terms in the strategic diagram suggests the preferred use of the term social networking over the term social media in this period. Additionally, the high density and centrality of such term, places it as the motor theme in this sub-period, as the many gamification experiences based on the use of social media/networking published in this period confirm.

TABLE 10 shows the five most cited documents published and the most cited references in this period. The most-cited documents published in this period belong all to the general theme *gamification*. Three of them discuss the educational applications of gamification [96], [116], [124], and

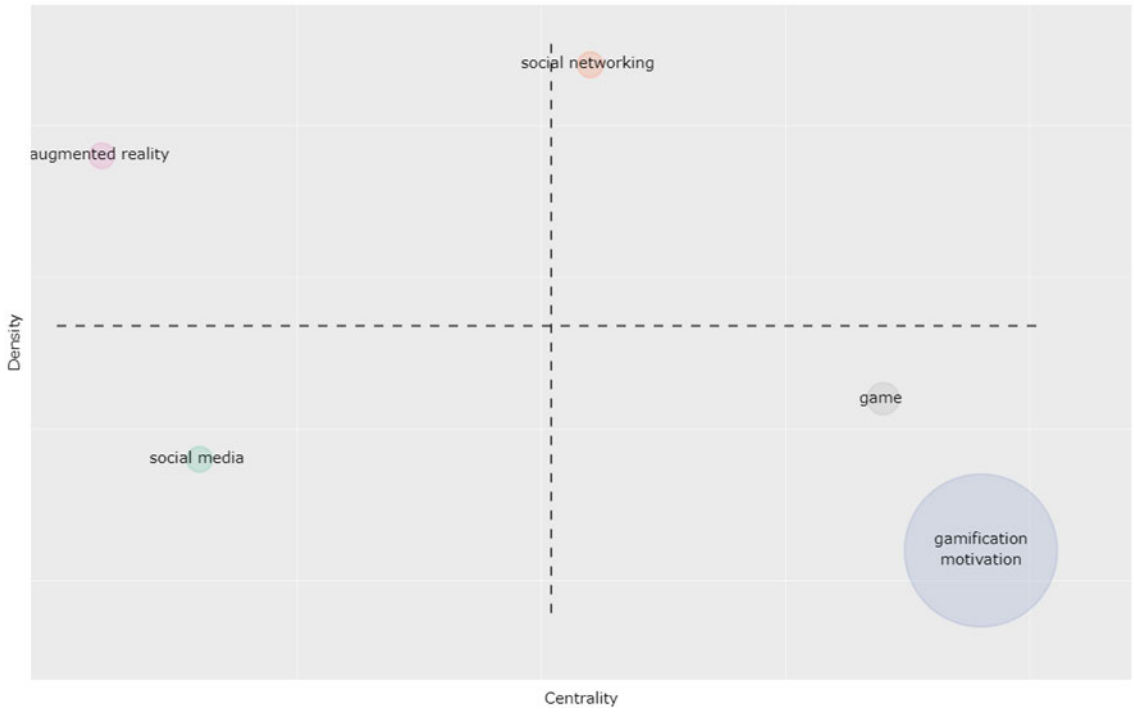

FIGURE 18. Thematic map of the period 2011-2013.

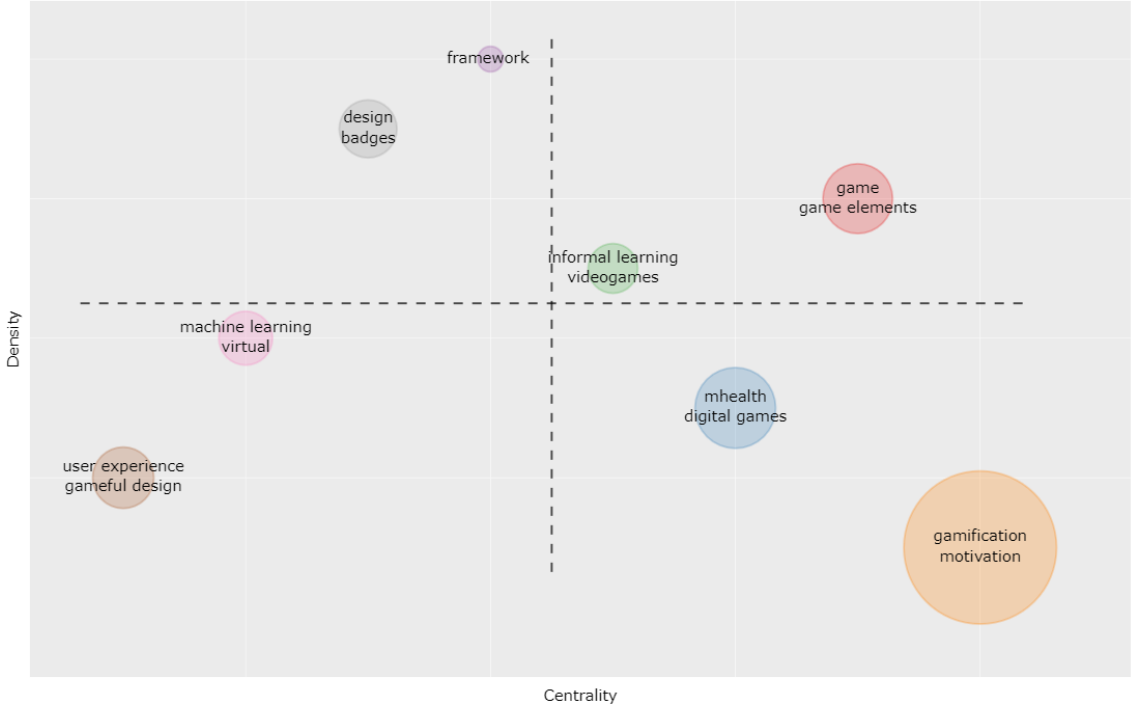

FIGURE 19. Thematic map of the period 2014-2016.

the other two explore the uses of gamification in the mobile health [136] and trading services [137].

The references that are most cited in the knowledge building process in this period are two books describing how to apply game-based principles to solve problems in different contexts [158] and in consumer-oriented websites [162], respectively, and three journal articles, two providing a definition for the term *gamification* [1], [165] and another one describing the educational use of gamification [298].

TABLE 10. Most cited publications and references in the period 2011-2013.

	Most cited publications
1	Dominguez et al. (2013): *Gamifying learning experiences: Practical implications and outcomes*. Computers & Education, vol. 63. DOI: 10.1016/j.compedu.2012.12.020.
2	Cafazzo et al. (2012): *Design of an mHealth app for the self-management of adolescent type 1 diabetes: A pilot study*. Journal of Medical Internet Research, vol. 14. DOI: 10.2196/jmir.2058. TC: 282
3	Simoes et al. (2013): *A social gamification framework for a K-6 learning platform*. Computers in Human Behavior, vol. 19. DOI: 10.1016/j.chb.2012.06.007.
4	Hamari (2013): *Transforming homo economicus into homo ludens: A field experiment on gamification in a utilitarian peer-to-peer trading service*. Electronic Commerce Research and Applications, vol. 12. DOI: 10.1016/j.elerap.2013.01.004.
5	Muntean (2011): *Raising engagement in e-learning through gamification*. 6th International Conference on Virtual Learning, ICVL 2011.
	Most cited references
1	Zicherman and Cunningham (2011): *Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps*. O'Reilly Media.
2	Deterding et al. (2011): *From Game Design Elements to Gamefulness: Defining "Gamification"*. Proceedings of MindTrek 2011.
3	McConigal (2011): Reality is Broken: Why Games Make Us Better and How They Can Change the World. Penguin LCC US.
4	Deterding et al. (2011): *Gamification: Toward a Definition*. Proceedings of the 2011 ACM CHI Conference on Human Factors in Computing Systems.
5	Kapp and Rice (2012): *The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education*. International Journal of Gaming and Computer-Mediated Simulations, vol. 4.

In the second period (Fig. 19), gamification research pivoted on eight themes of research. The applications of *gamification* to boost *motivation* and *engagement*, mostly within the educational context, remain as the most important theme of research given its high centrality, which maintains from the first period. The density of this theme remains low, as in the first period, revealing that the theme is not yet consolidated, partly because of the growing diversity of the theme in the second period. In fact, the number of keywords used to describe the gamification theme grows from the initial nine keywords used in the first period to the 50 keywords used in this second period. This growth reveals the increasing diversity of the studies on gamification that are conducted in this second period. The most-frequent keywords remain the same as in the first period revealing that the educational applications of gamification remain as the most frequent ones also in the second period. However, apart from the many new keywords that appear in this period also related to the educational field, new keywords appear to reflect the interest in aspects of gamification design imported from the field of games, such as *game design* and *game mechanics*, and the HCI field, such as *user-centered design*. Additionally, new keywords reflect the application of gamification in other contexts rather than the educational one such as *crowdsourcing*, *sustainability*, *health*, *management*, and *software engineering*.

The analysis of the works and keywords in this period also reveal that the themes of the first period *social media/networking* and *augmented reality* have also become part of the main theme *gamification*, since they are treated as enabling elements for its implementation, particularly in the educational domain.

Curiously, the term *social media* is the preferred keyword used in the works in the *gamification* theme, whereas *social networking* is the preferred keyword in the theme *mhealth*, which appears in this period as a new basic and important theme of research about the application of gamification in the mobile health context. The analysis of the nine keywords and the works published in this theme suggest these works are typically linked to the gamification of mobile health and health digital games to motivate users to either workout, register data about the evolution of particular diseases, mainly obesity and diabetes, and to improve the professional and formal education in healthcare.

In the lower-left quadrant, we can find two themes of research. Firstly, the theme *machine learning* can be considered as an emerging topic. It encompasses different types of works related to *machine learning* and *data mining* approaches and gamification. Under this theme, the application of machine learning algorithms within gamified exam platforms and the gamification of data science courses are investigated. Out of the educational scope, gamification is used to encourage the participation in the crowdsourced development of specialized knowledge-based systems by means of data mining methods, and to implement adaptive gamified systems, mostly in the domain of sustainability. This theme can be also considered as the seed of the incipient application of machine learning and data mining methods to analyze the results and add adaptiveness to gamified systems. The keywords *human factors* and *interaction* in this theme identify the elements that are being analyzed in the design of the adaptive gamified systems together with *visualization*, which emphasizes the need of graphical representations of the results of gamification data analysis.

The interest on interpreting the results of gamified experiences is complemented by the research efforts towards gamification design and its impact on the participants in gamified experiences. In the strategy diagram of this period, several themes regarding this general topic can be observed. An analysis of the keywords and works described by the themes *user experience/gameful design* and game/*game elements* suggests that different groups of keywords are being used to describe closely related themes of research.

Works coming from the Human-Computer Interaction research community (HCI) have a preference for the keyword *user experience* to describe the experience of a user with a gamified system. They are influenced by the seminal work of Deterding [165], in which the aspects involving the design of gamification experiences are described under the term *gameful design*. The works in this theme address gamification as a particular topic of human- computer interaction and as so, measure the impact of *gameful designs* in terms of *user experience*. On the other hand, works related or influenced by the game design community have a preference for terms such as *game* and *game elements* to describe works that either compare the results of using games and gamification

or focus on the analysis of the impact of different types of game elements within gamification experiences. This impact is measured and analyzed under the light of proposals from the field of psychology and the theory of behavior. In the strategy diagram, the theme *game/game elements* reaches higher values of density and centrality and is one of the motor themes of the period. Conversely, the theme *user experience/gameful design* reaches lower levels of centrality and density indicating it is a lesser developed theme.

Together with the *game/game elements* theme, the diagram shows a second motor theme described by the keywords *informal learning/videogames*. Although the educational use of gamification is mostly explored in formal educational settings and under the basic theme gamification, the works in this topic emerge in this period to describe experiences of using gamification to support learning within non-formal educational contexts, such as how to participate in social networks, language learning for refugees, healthy habits, teamwork and music.

The upper-left quadrant is occupied by two themes with a high density revealing they are highly developed themes, but have not yet reached a high degree of importance. Both themes can be associated with gamification design. The first theme, *framework*, which presents the highest level of density, explores different frameworks to design and implement gamification in different educational as well as non-educational contexts. The second theme, *design/badges* focusses on the use and impact of badges as the rewarding element of a gamification design and different proposals of digital badges taxonomies mostly assessed in communication contexts.

TABLE 11 shows the five most cited documents published and the most cited references in this period. Again, the most-cited documents published in this period belong to the general theme *gamification*. Three of these five publications are reviews of the literature aiming at summarizing the effects of gamification from the empirical studies already conduced. The list is topped by the most cited publication ever, which consists on the systematic literature review of empirical studies on gamification conducted by Hamari *et al.* [87]. Similar aims are shared by the systematic survey conducted by Searborn and Fels [113] and the mapping study developed by Dicheva *et al.* [92], though this last one is focused on the domain of education. The remaining works describe the conclusions of two gamification experiences. The first one collects the results of a two-year longitudinal gamification study conducted in the educational domain [93]. Analyzing the data collected via an online survey of the users of a physical exercise platform to find if and how demographical differences influence on the perceived benefits of gamification is the aim of another of second publication [95].

Four of the most cited references of the first period remain among the most cited in this second period [158], [162], [165], [298]. It is important to notice that of the two publications that were cited to describe the term *gamification* in the first period, the work published by Deterding *et al.* in the MindTrek 2011 conference [165] results the preferred one over the paper published by Deterding *et al.* in the ACM CHI 2011 conference [1], which is not in the list of the five most cited references of the period. Its place is occupied by a new publication, a book by Werbach and Hunter introducing the elements and design process of gamification with a special emphasis on commercial and professional applications of gamification [163].

TABLE 11. Most cited publications and references in the period 2014-2016.

	Most cited publications
1	Hamari et al. (2014): *Does gamification work? - A literature review of empirical studies on gamification*. Proceedings of the Annual Hawaii International Conference on System Sciences DOI: 10.1109/HICSS.2014.377.
2	Seaborn and Fels (2015): *Gamification in theory and action: A survey*. International Journal of Human-Computer Studies, vol. 74. DOI: 10.1016/j.ijhcs.2014.09.006.
3	Hanus (2015): *Assessing the Effects of Gamification in the Classroom: A Longitudinal Study on Intrinsic Motivation, Social Comparison, Satisfaction, Effort, and Academic Performance* Computers and Education, vol. 180. DOI: 10.1016/j.compedu.2014.08.019
4	Dicheva et al. (2015): *Gamification in education: A systematic mapping study*. Electronic Educational Technology and Society, vol. 18.
5	Koivisto and Hamari (2014): *Demographic differences in perceived benefits from gamification*. Computers in Human Behavior, vol. 35. DOI: 10.1016/j.chb.2014.03.007.
	Most cited references
1	Deterding et al. (2011): *From Game Design Elements to Gamefulness: Defining "Gamification"*. Proceedings of MindTrek 2011.
2	Zicherman and Cunningham (2011): *Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps*. O'Reilly Media.
3	Kapp and Rice (2012): *The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education*. International Journal of Gaming and Computer-Mediated Simulations, vol. 4.
4	Werbach and Hunter (2012): *For the Win: How Game Thinking Can Revolutionize Your Business*. Wharton School Press.
5	McConigal (2011): *Reality is Broken: Why Games Make Us Better and How They Can Change the World*. Penguin LCC US.

Fig. 20 shows the strategy map for the last three-year period analyzed (2016-2019). It reveals a significant decrease in the number of themes with only three. The theme *gamification/motivation* remains as a highly developed and important theme. With an increased centrality over the previous periods, the *gamification* theme is a coherent and important theme, which is described by 95 keywords. The most frequent keywords remain the same as in the previous period revealing the constant interest on the educational applications of gamification.

New keywords appear in this period anticipating the interest in providing a formal theory for gamification grounded on the *self-determination theory*, the formal measurement of its impact in education measured with the help of learning *analytics* and the design of *personalized* experiences. Themes of the previous period such as *design*, *game elements*, and *badges* have been absorbed by the general theme of *gamification*, which is evolving from a basic to a motor theme.

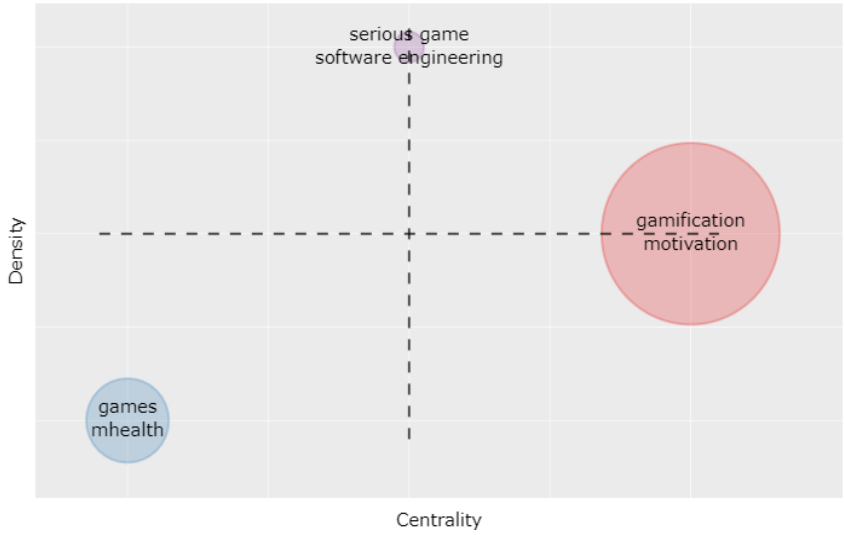

FIGURE 20. Thematic map of the period 2017-2019.

It is remarkable the significant growth of the new theme called *serious game/software engineering*. Although research on serious games and gamification applied in education have been present in the general gamification theme since the initial period, it is in the second period where the application of gamification within the context of software engineering and, in particular, in its management processes started to be explored. But it is in the third period when a significant growth of this theme occurs. In fact, the theme reaches the highest value of centrality and a medium density in the diagram. The theme is described by eight keywords that represent the use of serious games and gamification mostly in the education of software engineers, especially for the training of management, development and testing processes, and software sustainability.

Finally, the theme that had experienced a significant growth during the second period, *mhealth*, transitions to the lower-left quadrant signaling a decreasing interest on this theme. Although the low centrality and density of the theme suggest a decreasing interest, the number of keywords used to describe it grows from 9 in the second period to 24 in the third one. A further analysis of these keywords reveals that this theme absorbed in this period the themes *user experience* and *social media*, which in previous periods were identified as independent, although closely related, themes.

TABLE 12 shows the five most-cited documents as well as the most cited references by the documents published in this period. Once again, the most cited documents of this period belong to the general theme of *gamification*. Three of the publications describe empirical experiments conducted to find the effects of: a) different game elements on the fulfillment of basic psychological needs [140], b) digital badges on the users activity [138], and c) points, leaderboards and levels on the intrinsic motivation and performance of users of a tagging platform [143]. There is also a systematic literature review exploring the different gamification strategies in the e-health domain [7]. The top-5 most cited list is closed by a proposal by Huotari and Hamari with a definition of gamification for the service marketing domain [5] as an improved alternative to the much broader definition provided by Deterding *et al.* [165].

Only the publication by McConigal [158] abandons the list of top five most cited references in this period, although the other ones have some changes in their position. The most-cited publication by Hamari *et al.* [87], joins this top list and becomes the second most cited reference in this period.

IV. LIMITATIONS OF THIS STUDY

In the previous sections, we presented the process and findings of a bibliometric study aimed at describing how gamification as a scientific discipline is structured and how it has evolved over time. In this section, we describe the limitations of our study.

First, the accuracy and validity of bibliometric studies depend on the quality of the dataset and its source. Our final dataset was obtained after conducting different pilot searches in the Web of Science (WoS) database. There are other databases such as Scopus or Google Scholar that could have also been used for this study. We decided to build our dataset from WoS since it is the most internationally recognized product, applies transparent and rigorous inclusion and exclusion criteria, is publisher-independent and is a multidisciplinary global citation database [59], [79]. Selecting a single database for the study entails some limitations such as not having included in our dataset high-quality relevant works not indexed by WoS. Even though the number of missing relevant papers is not expected to be high, missing them could compromise the generalization of our findings. This limitation can be removed by replicating this study with datasets built from searches on such databases, as it is in our agenda of future works.

Second, the building process of the dataset is also another crucial step. In this study, we conducted several pilot searches in order to design the search strategy that retrieves the relevant

TABLE 12. Most cited publications and references in the period 2017-2019.

	Most cited publications
1	Sailer et al. (2017): *How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction*. Computers in Human Behavior, vol. 69. DOI: 10.1016/j.chb.2016.12.033
2	Hamari (2017): *Do badges increase user activity? A field experiment on the effects of gamification*. Computers in Human Behavior, vol. 71. DOI: 10.1016/j.chb.2015.03.036
3	Mekler et al. (2017): *Towards understanding the effects of individual gamification elements on intrinsic motivation and performance.* Computers in Human Behavior, vol. 71. DOI: 10.1016/j.chb.2015.08.048
4	Sardi et al. (2017): *A systematic review of gamification in e-Health.* Journal of Biomedical Informatics, vol. 71. DOI: 10.1016/j.jbi.2017.05.011
5	Huotari and Hamari (2017): *A definition for gamification: anchoring gamification in the service marketing literature*. Electronic Markets, vol. 27. DOI: 10.1007/s12525-015-0212-z
	Most cited references
1	Deterding et al. (2011): *From Game Design Elements to Gamefulness: Defining "Gamification"*. Proceedings of MindTrek 2011.
2	Hamari et al. (2014): *Does gamification work? - A literature review of empirical studies on gamification*. Proceedings of the Annual Hawaii International Conference on System Sciences DOI: 10.1109/HICSS.2014.377
3	Kapp and Rice (2012): *The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education*. International Journal of Gaming and Computer-Mediated Simulations, vol. 4.
4	Werbach and Hunter (2012): *For the Win: How Game Thinking Can Revolutionize Your Business*. Wharton School Press.
5	Zicherman and Cunningham (2011): *Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps*. O'Reilly Media.

works for the aims of the study. We finally decided to limit the searches to works written in English that contain the term ''gamification'' and its variants in the title, abstract and author's keywords. To assure the papers retrieved were relevant, the works were manually analyzed. As described in Section 2, we removed a small number of papers because they clearly not related to gamification research, were missing some key information, were duplicated or had been published outside of the time period of this study.

Finally, another limitation affecting the dataset comes from the accuracy of the data retrieved and the fact that WoS is continuously being updated. This means that the results offered by the same search strategy conducted on different dates may be slightly different. We have experienced that our search strategy was offering different results affecting not only the number of citations received by a paper, but also the number of papers retrieved, when conducted on different dates. Although the difference in the results obtained is not excessively high, we need to warn about this. In case the reader uses our same search strategy, it is possible that the results obtained are not exactly the same ones included in this study, which results from conducting the search on October 22, 2020. We do not consider this is a limitation affecting the repeatability of this study since it is an intrinsic feature of how WoS operates.

V. CONCLUSION AND FUTURE RESEARCH AGENDA

In this paper, we proposed the use of bibliometric methods to visualize and analyze the structure and evolution of gamification research from 2011 to 2019 based on the data collected from WoS. We conducted a performance analysis by means of quantitative methods and co-citation analysis to identify the influence of authors, institutions, countries and journals and the relationships among them.

This study reveals that from a small number of publications that firstly appeared in 2011, the number of gamification works has rapidly grown until reaching its maximum values in the last year of the period analyzed. More than half of the research production takes the form of conference papers, followed by journal articles. USA, Spain and Germany are the most productive countries, whereas the most influential research has been produced in Finland, Canada and Switzerland. The University of Tampere (Finland) is the most productive and influential institution, mainly due to the fact that it staffs the most regular, productive and cited author in the field, Hamari. Computers in Human Behavior is the journal that has published the highest number of works in gamification research and also the most cited ones.

The analysis of the authors' collaborative structures revealed a small degree of collaboration among the most productive authors in the field. Although some established groups were identified, the network showed no clear evidence of consolidated pivotal authors linking those research groups.

We have also used science mapping methods to visualize and describe how the conceptual structure of gamification research has been built over time. Our analyses confirm that gamification has been mostly used to improve the motivation, engagement and performance of the participants in gamified experiences, frequently, in combination with other technologies, mostly social media, virtual and augmented reality, and mobile applications. It has been found that gamification has been implemented in many different domains, but the educational one is the one that has attracted the highest level of research interest. This can be seen in the high number of education-related publications in the research front as well as in the intellectual base of the field. The analysis of the thematic evolution of the discipline is consistent with this conclusion and shows that this high interest in the educational applications of gamification has been sustainably growing in quantity and diversity along the years. Most of these applications report positive findings in terms of student's motivation and engagement, although the findings are not conclusive regarding a positive impact on student's performance. Another frequent domain of application has been healthcare and wellness, in which gamification has been used to improve healthcare professionals' and students' training, to promote healthy habits such as physical exercising and to support the self-management of different health and mental health conditions. The preferred gamifying instrument in the healthcare domain has been the mobile application.

TABLE 13. Most cited publications of gamification research (h-classics).

	TI	AU	SO	PY	DI	TC	AVG CIT
1.	Does gamification work? - a literature review of empirical studies on gamification	Hamari J;Koivisto J;Sarsa H	2014 47th Hawaii International Conference On System Sciences (Hicss)	2014	10.1109/hicss.2014.377	844	125.14
2.	Gamifying learning experiences: practical implications and outcomes	Dominguez A;Saenz-De-Navarrete J;De-Marcos L;Fernandez-Sanz L;Pages C;Martinez-Herraiz Jj	Computers & Education	2013	10.1016/j.compedu.2012.12.020	539	68.75
3.	Gamification in theory and action: a survey	Seaborn K;Fels Di	International Journal Of Human-Computer Studies	2015	10.1016/j.ijhcs.2014.09.006	476	82.5
4.	Assessing the effects of gamification in the classroom: a longitudinal study on intrinsic motivation. social comparison. satisfaction. effort. and aca	Hanus Md;Fox J	Computers & Education	2015	10.1016/j.compedu.2014.08.019	415	72.17
5.	Gamification in education: a systematic mapping study	Dicheva D;Dichev C;Agre G;Angelova G	Educational Technology & Society	2015		341	59.17
6.	Design of an mhealth app for the self-management of adolescent type 1 diabetes: a pilot study	Cafazzo Ja;Casselman M;Hamming N;Katzman Dk;Palmert Mr	Journal Of Medical Internet Research	2012	10.2196/jmir.2058	282	32
7.	A social gamification framework for a k-6 learning platform	Simoes J;Redondo Rd;Vilas Af	Computers In Human Behavior	2013	10.1016/j.chb.2012.06.007	271	35.25
8.	Demographic differences in perceived benefits from gamification	Koivisto J;Hamari J	Computers In Human Behavior	2014	10.1016/j.chb.2014.03.007	236	34.43
9.	Transforming homo economicus into homo ludens: a field experiment on gamification in a utilitarian peer-to-peer trading service	Hamari J	Electronic Commerce Research And Applications	2013	10.1016/j.elerap.2013.01.004	230	29.25
10.	An empirical study comparing gamification and social networking on e-learning	De-Marcos L;Dominguez A;Saenz-De-Navarrete J;Pages C	Computers & Education	2014	10.1016/j.compedu.2014.01.012	215	31.57
11.	How gamification motivates: an experimental study of the effects of specific game design elements on psychological need satisfaction	Sailer M;Hense Ju;Mayr Sk;Mandl H	Computers In Human Behavior	2017	10.1016/j.chb.2016.12.033	201	54.75
12.	Do badges increase user activity? A field experiment on the effects of gamification	Hamari J	Computers In Human Behavior	2017	10.1016/j.chb.2015.03.036	152	38.75
13.	Just a fad? Gamification in health and fitness apps	Lister C;West Jh;Cannon B;Sax T;Brodegard D	Jmir Serious Games	2014	10.2196/games.3413	150	22.57
14.	Towards understanding the effects of individual gamification elements on intrinsic motivation and performance	Mekler Ed;Brithlmann F;Tuch An;Opwis K	Computers In Human Behavior	2017	10.1016/j.chb.2015.08.048	143	38
15.	Raising engagement in e-learning through gamification	Muntean Ci	Proceedings Of The 6th International Conference On Virtual Learning. Icvl	2011		143	14.9

TABLE 13. *(Continued.)* **Most cited publications of gamification research (h-classics).**

16.	Is it all a game? Understanding the principles of gamification	Robson K;Plangger K;Kietzmann Jh;Mccarthy I;Pitt L	Business Horizons	2015	10.1016/j.bushor.2015.03.006	141	24.67
17.	A mobile gamification learning system for improving the learning motivation and achievements	Su Ch;Cheng Ch	Journal Of Computer Assisted Learning	2015	10.1111/jcal.12088	139	24
18.	Why do people use gamification services?	Hamari J;Koivisto J	International Journal Of Information Management	2015	10.1016/j.ijinfomgt.2015.04.006	135	23
19.	The gamification of advertising: analysis and research directions of in-game advertising. advergames. and advertising in social network games	Terlutter R;Capella Ml	Journal Of Advertising	2013	10.1080/00913367.2013.774610	128	16.38
20.	The lens of intrinsic skill atoms: a method for gameful design	Deterding S	Human-Computer Interaction	2015	10.1080/07370024.2014.993471	123	21.17
21.	Gamification for engaging computer science students in learning activities: a case study	Ibanez Mb;Di-Serio A;Delgado-Kloos C	Ieee Transactions On Learning Technologies	2014	10.1109/tlt.2014.2329293	123	18.43
22.	Digital badges in education	Gibson D;Ostashewski N;Flintoff K;Grant S;Knight E	Education And Information Technologies	2015	10.1007/s10639-013-9291-7	120	20.5
23.	Gamification in software engineering - a systematic mapping	Pedreira O;Garcia F;Brisaboa N;Piattini M	Information And Software Technology	2015	10.1016/j.infsof.2014.08.007	120	20.67
24.	Developing a theory of gamified learning: linking serious games and gamification of learning	Landers Rn	Simulation & Gaming	2014	10.1177/1046878114563660	120	18.14
25.	"working out for likes": an empirical study on social influence in exercise gamification	Hamari J;Koivisto J	Computers In Human Behavior	2015	10.1016/j.chb.2015.04.018	117	20
26.	Gaming the quantified self	Whitson Jr	Surveillance & Society	2013		116	14.88
27.	A systematic review of gamification in e-health	Sardi L;Idri A;Fernandez-Aleman Jl	Journal Of Biomedical Informatics	2017	10.1016/j.jbi.2017.05.011	112	30
28.	A multilevel analysis of the effects of external rewards on elementary students' motivation. engagement and learning in an educational game	Filsecker M;Hickey Dt	Computers & Education	2014	10.1016/j.compedu.2014.02.008	107	16
29.	Gamification in assessment: do points affect test performance?	Attali Y;Arieli-Attali M	Computers & Education	2015	10.1016/j.compedu.2014.12.012	104	18.17
30.	A definition for gamification: anchoring gamification in the service marketing literature	Huotari K;Hamari J	Electronic Markets	2017	10.1007/s12525-015-0212-z	102	26.25
31.	A game plan: gamification design principles in mhealth applications for chronic disease management	Miller As;Cafazzo Ja;Seto E	Health Informatics Journal	2016	10.1177/1460458214537511	97	20.4
32.	Gamifying education: what is known. what is believed and what remains uncertain: a critical review	Dichev C;Dicheva D	International Journal Of Educational Technology In Higher Education	2017	10.1186/s41239-017-0042-5	92	25

TABLE 13. *(Continued.)* **Most cited publications of gamification research (h-classics).**

33.	Gamification of cognitive assessment and cognitive training: a systematic review of applications and efficacy	Lumsden J;Edwards Ea;Lawrence Ns;Coyle D;Munafo Mr	JMIR Serious Games	2016	10.2196/games.5888	90	19.6
34.	Gamification and mobile marketing effectiveness	Hofacker Cf;De Ruyter K;Lurie Nh;Manchanda P;Donaldson J	Journal Of Interactive Marketing	2016	10.1016/j.intmar.2016.03.001	90	18.2
35.	Empirical study on the effect of achievement badges in trakla2 online learning environment	Hakulinen L;Auvinen T;Korhonen A	2013 Learning And Teaching In Computing And Engineering (Latice 2013)	2013	10.1109/latice.2013.34	90	11.25
36.	Gamification for health promotion: systematic review of behaviour change techniques in smartphone apps	Edwards Ea;Lumsden J;Rivas C;Steed L;Edwards La;Thiyagarajan A;Sohanpal R;Caton H;Griffiths Cj;Munafo Mr;Taylor S;Walton Rt	BMJ Open	2016	10.1136/bmjopen-2016-012447	89	19
37.	On the effectiveness of game-like and social approaches in learning: comparing educational gaming. gamification & social networking	De-Marcos L;Garcia-Lopez E;Garcia-Cabot A	Computers & Education	2016	10.1016/j.compedu.2015.12.008	87	18.6
38.	Be a "superhost": the importance of badge systems for peer-to-peer rental accommodations	Liang S;Schuckert M;Law R;Chen Cc	Tourism Management	2017	10.1016/j.tourman.2017.01.007	83	22.75
39.	An experience report on using gamification in technical higher education	Losup A;Epema D	Proceedings Of The 45th Acm Technical Symposium On Computer Science Education (Sigcse'14)	2014	10.1145/2538862.2538899	82	12.14
40.	Leaderboards in a virtual classroom: a test of stereotype threat and social comparison explanations for women's math performance	Christy Kr;Fox J	Computers & Education	2014	10.1016/j.compedu.2014.05.005	79	12
41.	An empirical test of the theory of gamified learning: the effect of leaderboards on time-on-task and academic performance	Landers Rn;Landers Ak	Simulation & Gaming	2014	10.1177/1046878114563662	77	11.71
42.	The rise of motivational information systems: a review of gamification research	Koivisto J;Hamari J	International Journal Of Information Management	2019	10.1016/j.ijinfomgt.2018.10.013	76	43
43.	An investigation into gamification as a customer engagement experience environment	Harwood T;Garry T	Journal Of Services Marketing	2015	10.1108/jsm-01-2015-0045	76	12.67
44.	Mental health on the go: effects of a gamified attention-bias modification mobile application in trait-anxious adults	Dennis Ta;O'toole Lj	Clinical Psychological Science	2014	10.1177/2167702614522228	74	10.71
45.	Deconstructing gamification: evaluating the effectiveness of continuous	Zuckerman O;Gal-Oz A	Personal And Ubiquitous Computing	2014	10.1007/s00779-014-0783-2	70	10.57

TABLE 13. *(Continued.)* **Most cited publications of gamification research (h-classics).**

	measurement. virtual rewards. and social comparison for promoting physical act						
46.	The gamification user types hexad scale	Tondello Gf;Wehbe Rr;Diamond L;Busch M;Marczewski A;Nacke Le	Chi Play 2016: Proceedings Of The 2016 Annual Symposium On Computer-Human Interaction In Play	2016	10.1145/2967934.2968082	68	14.8
47.	Measuring flow in gamification: dispositional flow scale-2	Hamari J;Koivisto J	Computers In Human Behavior	2014	10.1016/j.chb.2014.07.048	68	10
48.	Gamification and education: a literature review	Caponetto I;Earp J;Ott M	Proceedings Of The 8th European Conference On Games Based Learning (Ecgbl 2014). Vols 1 And 2	2014		68	10
49.	Persuasive technology for health and wellness: state-of-the-art and emerging trends	Orji R;Moffatt K	Health Informatics Journal	2018	10.1177/1460458216650979	67	23
50.	Gamification and student motivation	Buckley P;Doyle E	Interactive Learning Environments	2016	10.1080/10494820.2014.964263	67	14.4
51.	Psychological perspectives on motivation through gamification	Sailer M;Hense J;Mandl H;Klevers M	Interaction Design And Architectures	2013		67	8.38
52.	Game on: engaging customers and employees through gamification	Robson K;Plangger K;Kietzmann Jh;Mccarthy I;Pitt L	Business Horizons	2016	10.1016/j.bushor.2015.08.002	65	13.4
53.	Gamification as a tool for enhancing graduate medical education	Nevin Cr;Westfall Ao;Rodriguez Jm;Dempsey Dm;Cherrington A;Roy B;Patel M;Willig Jh	Postgraduate Medical Journal	2014	10.1136/postgradmedj-2013-132486	64	9.43
54.	Designing moocs for the support of multiple learning styles	Grunewald F;Meinel C;Totschnig M;Willems C	Scaling Up Learning For Sustained Impact	2013		64	8
55.	Motivating participation in social computing applications: a user modeling perspective	Vassileva J	User Modeling And User-Adapted Interaction	2012	10.1007/s11257-011-9109-5	64	7.11
56.	Gamicad: a gamified tutorial system for first time autocad users	Li W;Grossman T;Fitzmaurice G	Uist'12: Proceedings Of The 25th Annual Acm Symposium On User Interface Software And Technology	2012		64	7.56
57.	Shallow gamification: testing psychological effects of framing an activity as a game	Lieberoth A	Games And Culture	2015	10.1177/1555412014559978	63	10.83
58.	Effectiveness of gamification in the engagement of students	Seixas Ld;Gomes As;De Melo Ij	Computers In Human Behavior	2016	10.1016/j.chb.2015.11.021	62	13
59.	Myths and realities of respondent engagement in online surveys	Downes-Le Guin T;Baker R;Mechling J;Ruyle E	International Journal Of Market Research	2012	10.2501/IJMR-54-5-613-633	62	7.11
60.	Serious games and the gamification of tourism	Xu Ff;Buhalis D;Weber J	Tourism Management	2017	10.1016/j.tourman.2016.11.020	61	16.25
61.	Engaging Asian students through game mechanics: findings from two experiment studies	Hew Kf;Huang B;Chu Kws;Chiu Dkw	Computers & Education	2016	10.1016/j.compedu.2015.10.010	61	13.2

The results of the thematic evolution analysis help also to identify potential areas of interest that can be proposed for future research. One of these areas is the need to develop and consolidate a common *ground theory for gamification*. This topic has become an important part of the *gamification* theme in the last three-year period in which it has been positioned as a motor theme. Typically, its evolution needs the collaboration of multidisciplinary teams integrated by researchers from the Psychology, Education and Computing areas of knowledge. Among their aims could be to: a) explore and provide a better understanding of the relations between different game elements and their effects on factors such as motivation, engagement, and performance, b) develop, test and empirically validate current and new theories for the explanation, consolidation and evolution of the discipline.

A solid ground validated theory for gamification is a key factor towards the second future area of research, which is focused on *gamification design*. Topics related to gamification design such as *gameful design*, *game elements*, *design*, and *frameworks* have also become part of the *gamification* motor theme in the last three-year period. Our analysis and the conclusions of much of the works included in our study highlight the need of increasing the knowledge towards effective gamification design. Among the topics that can be explored are: a) the experimentation with new game elements, such as *narrative*, further from the well-known PBL (points, badges and leaderboards) triad, b) the definition of design processes that take into account the particularities of the domain in which gamification will be applied, and c) the definition of objective metrics to track, monitor and empirically assess the results of gamification experiences.

The two former areas of future research are essential for paving the way for the third area of future research, which aims to develop *personalized and adaptive data-driven gamification*. By having a solid theoretical base and design process that supports the gathering of empirical data about the experiences, we can think of creating gamification experiences that are particularized for each user. To achieve this, it could be important to promote the initial works, which appeared in the second period of our analysis (2015-2017) as emerging topics, starting to explore the applications of machine learning and data mining techniques to better address the design of gamified experiences that take into consideration the different personalities of their participants. Precisely, a very recent work reviews the literature of tailored gamification highlighting the importance of this topic, and proposes a particular research agenda [299]. Additionally, a data-driven design process for adaptive gamification could also benefit of the latest advances of process automation.

Finally, the advances in theory and methods need to be validated by conducting *empirical research* that can help us offer verifiable evidence of the positive and negative effects of gamification. This has been a claim of the most influential publications of the community and, along the years, we have witnessed how the number of publications describing empirical studies has been and still is growing.

There are other areas of research that can be potentially interesting and that our study proves have not been sufficiently explored. One of them is the *implementation process of gamification*. Very often, the details of how gamification was implemented are not sufficiently described further than the development of an ad-hoc plugin for an existing system or a new mobile application. The complexity and the costs of implementing gamification should also be explored so that organizations can make a better informed decision-making towards its potential adoption.

Finally, only 18 works in our dataset explored the *ethical use of gamification*. Some of the criticism gamification has received lies precisely on the moral legitimacy of its practices and the ethical use of user's performance, behavior and personality data. The ethical issues of gamification were described in a literature survey conducted by Kim and Werbach [300]. With an increasing trend of publications in the last three-year period, we can foresee this is a topic that is getting an increasing interest but has not been sufficiently explored yet.

APPENDIX

See Table 13.

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