A Systematic Literature Review of Game-based Learning and Safety Management

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Abstract. With the rapid advancement of computer and multimedia technologies, game-based learning has the potential to increase the effectiveness of learning. One of the applications of game-based learning can be safety training. In this study, a systematic literature review of both these topics has been conducted using tools like VOSviewer, MAXQDA, Harzing's Publish or Perish, AuthorMapper and Mendeley. A co-citation analysis was conducted to determine the most important articles in the literature. It was found that there are very few examples of game-based learning being used for safety training. To encourage the use of game-based learning, it is essential to develop a better understanding of the tasks, activities, skills and operations that different kinds of game can offer and examine how these might match desired learning outcomes. Virtual reality (VE) technology is another promising technology that can be used to increase the effectiveness of safety training. Finally, it was concluded that a combination of cognitive, motivational, affective, and sociocultural perspectives is necessary for both game design and game research to fully capture what games have to offer for learning.

Keywords: game-based learning, safety management, training, bibliometric analysis, Harzing, VOSviewer, MAXQDA, Mendeley, AuthorMapper.

1   Introduction

In recent years, various issues of educational games have been widely discussed because of the rapid advancement of computer and multimedia technologies (Sung & Hwang, 2013). Game-based learning techniques have the potential to increase the effectiveness of training. The study of gaming communities, from the perspective of education, is still at a nascent stage. Educators could benefit by studying games as a social community because increasingly games have become social activities, especially for the younger generation (Studies, 2004). Researchers have indicated that educational games can be an effective way of providing a more interesting learning environment for students to acquire knowledge (Sung & Hwang, 2013).

The high rates of accidents in the construction industry are due to factors such as lack of safety in design, poor construction planning, inadequate safety training, worker behavior, and lack of knowledge of site rules (SAEED, 2017). In this study, an attempt has been made to explore if any research has been conducted on the role of game-based learning in safety management. In this context, the issue of human-computer interaction (HCI) design becomes even more important. The aim should be to provide access to training material to anyone, from anywhere and at any time, through a variety of platforms and devices (Constantine Stephanidis et.al., 2012).

2 Purpose of Study

The aim of this study is to conduct a systematic literature review of articles based on game-based learning and see if game-based learning techniques can be applied to safety management in general and safety training in particular. With emerging technologies like virtual reality (VR) and other online training tools, there is an opportunity to reduce costs and increase the effectiveness of safety training. This study tries to find out if efforts in this direction have been made and the level of success achieved during these efforts. Various tools like Harzing's Publish or Perish, VOSviewer and MAXQDA have been used in this study. Mendeley was used to cite the articles and generate a bibliography (*Mendeley*, n.d.).

3 Research Methodology

3.1 Data collection

Data required to carry out analysis of the literature was collected by conducting keyword search in two different databases – Web of Science and Google scholar. The data acquired from the web of science includes authors, title, source, abstract and cited references. The information related to cited references is necessary for co-citation analysis which has been described later in this paper. The data acquired from Google scholar does not contain cited references. However, it encompasses a wider range of sources which helps get better results for cluster analysis of keywords. "Harzing's Publish or Perish" which is a software tool used to collect data from different databases was used to get metadata from the keyword search conducted in Google scholar. The maximum number of results that this tool can give is 1000. Two separate searches were carried out using the keywords "game based learning" and "safety management". The search conducted in Web of Science core collection yielded 2960 and 7600 results respectively. The search conducted through Harzing's Public or Perish in Google scholar's database for "game based learning" was stopped at 450 results. For "safety management", the search stopped at 1000 results which is the upper limit for Harzing's (*Harzing's Publish or Perish*, n.d.).

3.2 Trend analysis

Trend analysis is based on the data from the web of science. Web of Science allows the analysis of its data by providing various tools. The data from 2020 was excluded as the year has just begun. This was done to get a better sense of the trend.

Fig. 1 shows the trend analysis for game-based learning. It was observed that the first published article was dated June 2001 in the Web of Science database for this particular keyword search. There was a steady rise in the number of articles published after 2006. The number peaked in 2017. A similar trend was noticed when data from Harzing's was analyzed for trend (*Harzing's Publish or Perish*, n.d.). The number peaked in 2015. It is possible that there is a lag in the database and citation updates. It is also possible there is a decline in the number of papers in 2018. One cannot tell with certainty now. However, the upward trend through 2017 is clear.
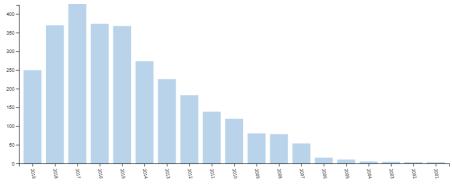

Fig. 1. Trend analysis of articles on game-based learning (*Web of Science*, n.d.)

Field: Source Titles	Record Count	% of 2,937
PROCEEDINGS OF THE EUROPEAN CONFERENCE ON GAMES BASED LEARNING	274	9.329 %
LECTURE NOTES IN COMPUTER SCIENCE	141	4.801 %
INTERNATIONAL JOURNAL OF GAME BASED LEARNING	78	2.656 %
EDULEARN PROCEEDINGS	76	2.588 %
COMPUTERS EDUCATION	73	2.486 %
INTED PROCEEDINGS	54	1.839 %
PROCEEDINGS OF THE 11TH EUROPEAN CONFERENCE ON GAMES BASED LEARNING ECGBL 2017	53	1.805 %
PROCEEDINGS OF THE 12TH EUROPEAN CONFERENCE ON GAMES BASED LEARNING ECGBL 2018	48	1.634 %
PROCEEDINGS OF THE 10TH EUROPEAN CONFERENCE ON GAMES BASED LEARNING	46	1.566 %
PROCEEDINGS OF THE 8TH EUROPEAN CONFERENCE ON GAMES BASED LEARNING ECGBL 2014 VOLS 1 AND 2	46	1.566 %

Fig. 2. Analysis of source titles for game-based learning (*Web of Science*, n.d.)

Top ten sources of titles for game-based learning have been shown in Fig. 2. This analysis was done using tools provided by Web of Science. This figure shows that most of the titles have been sourced from various editions of the proceedings of the European conference on game based learning.
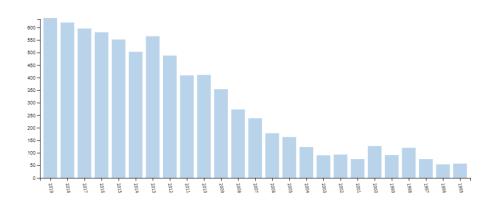

Fig. 3. Trend analysis of articles on safety management (*Web of Science*, n.d.)

Field: Source Titles	Record Count	% of 7,546
SAFETY SCIENCE	431	5.712 %
PROCESS SAFETY PROGRESS	186	2.465 %
PROGRESS IN SAFETY SCIENCE AND TECHNOLOGY SERIES	153	2.028 %
JOURNAL OF LOSS PREVENTION IN THE PROCESS INDUSTRIES	141	1.869 %
APPLIED MECHANICS AND MATERIALS	103	1.365 %
FOOD CONTROL	102	1.352 %
PROCEDIA ENGINEERING	92	1.219 %
ACCIDENT ANALYSIS AND PREVENTION	82	1.087 %
ADVANCED MATERIALS RESEARCH	81	1.073 %
JOURNAL OF CONSTRUCTION ENGINEERING AND MANAGEMENT	59	0.782 %

Fig. 4. Analysis of source titles for safety management (*Web of Science*, n.d.)

Trend analysis of articles on safety management is shown in Fig. 3. It can be seen that there has been a steady rise in the number of articles published since 2004. The higher number of articles published in 2013 indicates a temporary peak bucking the trend because the number of articles published in 2014 is less than in 2013. However, there is a steady increase in the number of articles published after 2013. Overall, the trend indicates that interest in safety management has increased in the last 25 years.

Top ten sources of titles for safety management have been shown in Fig. 4. Unlike game-based learning, the titles for safety management have been sourced from eclectic sources. The sources indicate that research was carried out in various fields like process safety, accident analysis and construction safety.

4   Results

4.1 Co-citation analysis

"Citation analysis is used to examine the degree of connectivity between pairs of papers" (Fahimnia et al., 2015). VOSviewer was used for co-citation analysis. Pairs of papers which have been cited together form clusters. To determine important papers within them, papers which have been cited the greatest number of times were selected. So, the criteria to select the most important papers was the link strength (the number of times they have been co-cited) and the number of times they have been cited individually. The latest 500 papers in terms of date of publication were considered for this analysis.
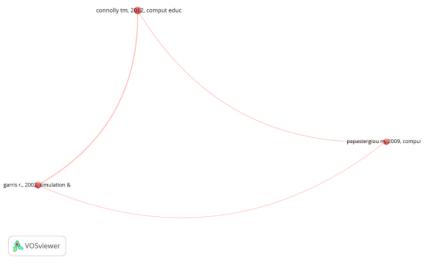
Fig. 5. Co-citation analysis for game-based learning (*VOSviewer*, n.d.).

The data file exported from the Web of Science was imported into VOSviewer. Fig. 5 shows a co-citation analysis of game-based learning. For game-based learning, the minimum number of citations of a cited reference was set at 36 to get the top three research papers which were cited the greatest number of times. The top three papers had 55, 40 and 36 citations respectively.
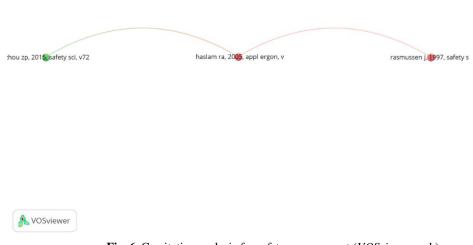
thou zp, 2016, safety sci, v72   haslam ra, 2005, appl ergon, v   rasmussen j, 1997, safety s

VOSviewer

Fig. 6. Co-citation analysis for safety management (*VOSviewer*, n.d.).

Fig. 6 shows the co-citation analysis of safety management. For safety management, the minimum number of citations of a cited reference was set at 17 to get the top three research papers which were cited the greatest number of times. Each of the three papers had 18 citations. Full references associated with the nodes in figures 5 and 6 are shown in the reference section.

4.2 Content analysis

To analyze the content within the research articles, data collected through Harzing's was used. The data was imported into VOSviewer to create a map based on all the text data. The terms were extracted from the title and abstract fields. The resultant map consists of clusters of words which appeared the greatest number of times and the strength of links indicate the number of times they appeared together. To map the most relevant words, the minimum number of occurrences of words was increased so that around 150 words could be mapped in clusters. To determine keywords, the minimum occurrences of words was further increased so that five words which occurred the greatest number of times could be chosen. These keywords can be used to conduct a lexical search in the articles obtained from co-citation analysis to determine if the articles are relevant to the study.
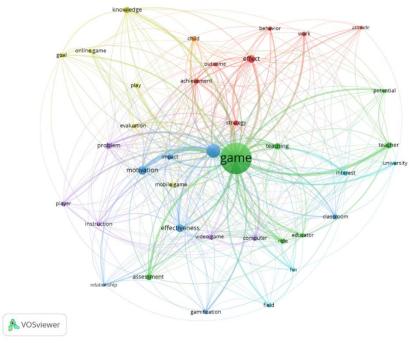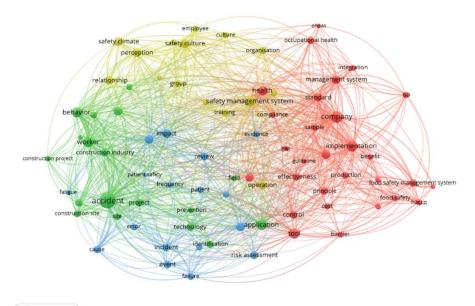
Fig. 7. Cluster analysis for game-based learning (*VOSviewer*, n.d.)

Table 1. Keyword selection for game-based learning (*VOSviewer*, n.d.)

Keyword	Occurrences
Game	913
Learning	184
Digital game	159
Environment	141
Student	140

Fig. 7 shows the cluster map generated when data related to game-based learning was analyzed. The minimum number of occurrences to map clusters was set at 10 by default. Only 78 words fit this criterion. Words which occurred less than 10 times were deemed to be irrelevant. Table 1 shows the keywords and the number of times they occurred in the data that was analyzed. The table indicates that except the word "game" which has expectedly occurred the greatest number of times, the rest of the words have occurred fairly close to 150 times.

Fig. 8. Cluster analysis for safety management (*VOSviewer*, n.d.)

Table 2. Keyword selection for safety management (*VOSviewer*, n.d.)

Keyword	Occurrences
System	1091
Safety	1002
Risk	412
Safety management	580
Accident	495

Fig. 8 shows the cluster map generated when data related to safety management was analyzed. The minimum number of occurrences to map clusters was set at 35 resulting in 157 words being mapped. Table 2 shows the keywords and the number of times they occurred in the data that was analyzed. It can be seen that in general, the number of times these words occurred is way more when compared with the number of occurrences of keywords related to game-based learning. This can be attributed to the fact that articles related to safety management have been published for much longer and hence have a greater number of publications compared to game-based learning.

4.3 Content Analysis Results from MAXQDA

To get the keywords from all the articles which are referred to in this paper, MAXQDA was used. All the key articles selected through co-citation analysis and other reference

papers were imported into MAXQDA and a word cloud was generated. This gives us the overall keywords which are important in the context of this study. The word cloud has been shown in Fig. 9.

Fig. 9. World cloud from MAXQDA (*MAXQDA*, n.d.)

5   Discussion

5.1 Game-based learning

Students' motivation towards games contrasts with their lack of interest in curricular content. To bridge this gap, games that encompass educational objectives and subject matter have the potential to make the learning of academic subjects more learner-centered, easier, more enjoyable, more interesting, and, thus, more effective (Papastergiou, 2009). It was found that simulations were by far the most frequently occurring genre in game-based learning techniques. To encourage the use of games in learning beyond simulations, it is necessary to develop a better understanding of the tasks, activities, skills and operations that different kinds of game can offer and examine how these might match desired learning outcomes (Connolly et al., 2012).

There are some issues which need to be resolved to make game-based learning techniques effective. One of them is the capacity of a particular game to hold the player's attention over a longer period of time. It has been seen that players tend to get addicted to a game until they are "played out" following which they move on to another game. This indicates that simulation games become less effective when they are used over a longer duration of time (Garris et al., 2002).

A considerable amount of work has already been done by educational researchers to make game-based learning techniques good for learning. However, this has not led

to widespread adoption of game-based learning techniques in the classroom (Denham et al., 2016).

The trend analysis for game-based learning (in section 2.2) based on the data from Web of Science showed a decreasing trend in the number of articles being published after 2017. This seemed counter-intuitive and hence to verify this trend, data was obtained by conducting a search in AuthorMapper. The keyword used was "game based learning". The search yielded 4446 results. The results from 2020 were excluded from the trend analysis. The trend analysis cannot be exported directly. The other issue was that the number of results that could be exported was limited to 2000. To get around this, the number of publications for every year were manually entered into Microsoft Excel and trend analysis was obtained which is shown in Fig. 10.
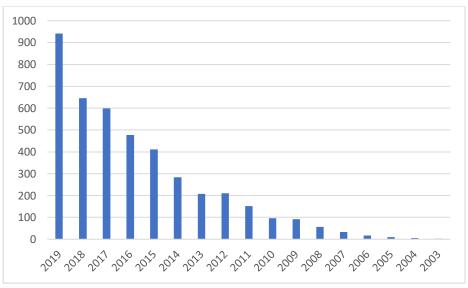

Fig. 10. Trend analysis for game-based learning from AuthorMapper (*AuthorMapper*, n.d.)

It can be seen that the trend shows an increase in the number of articles published year over year. This is contrary to the trend analysis obtained from the Web of Science. One reason for this could be that there is a time lag between the publication of the article and the date it is updated in Web of Science. However, a deeper analysis is needed to ascertain the reason for the trend shown by the data from Web of Science. This analysis is outside of the scope of this study.

5.2 Safety management
Over the years, accidents and injuries have continued to plague the construction industry notwithstanding the efforts made towards improving safety. Because of this,

the number of peer-reviewed papers published, and the range of research topics has been increasing over the years (Z. Zhou et al., 2015). Greater attention needs to be given to the design and selection of tools, equipment and materials (Haslam et al., 2005). Visualization technology has been widely used in construction management research. Some studies show that BIM-based 4D models created during the design process can help site safety planning (Y. Zhou et al., 2013).

Depending on the nature of the hazard, different risk management strategies have evolved. Occupational safety focusses on frequent, but small-scale accidents (Rasmussen Jens, 1997). The root cause of worker injuries and illnesses can be addressed through a workplace ergonomics program as part of a larger occupational safety and health program (Lehto et al., 2012). Occupational safety is concerned not only with construction safety but with workplace safety in general. Safety training is an important component of any occupational safety and health program. Hence, an effective safety training program is necessary to improve workplace safety.

6   Conclusion

Despite the optimism that games might be useful in promoting better learning outcomes, the few papers which provide evidence to support this claim present qualitative rather than quantitative analysis (Connolly et al., 2012). As researchers explore innovations in visualization and apply them in new domains, effective information visualization has the potential to improve the usability of information and to increase the generation of valuable insight (North, 2012). Although some examples of game-based learning being used for safety training like fire safety training for children were found in literature, there is scope for a lot more research in this area intersecting game-based learning with safety training. It can be concluded that a combination of cognitive, motivational, affective, and sociocultural perspectives is necessary for both game design and game research to fully capture what games have to offer for learning (Plass et al., 2015).

7   Future work

Apart from game-based learning, another interesting training technique that can be explored is virtual environment (VE) consisting of unique I/O devices, perspectives, and physiological interactions. However, there are certain factors that need to be considered before using VE as a training method. VE simulators are generally less effective for initial training. High fidelity VE training can be used to reinforce acquired knowledge and develop advanced strategic knowledge and tactical skills (Stanney & Cohn, 2012). The application of VE in safety training is something which can be explored further.

In one of the studies, a web-based Construction Safety Management Information System (CSMIS) was developed for better management of safety. CSMIS can be utilized for safety education and training. The CSMIS helped the construction

managers and workers to understand the possible risk factors better (Park et al., 2015). A virtual environment (VE) training integrated into these types of systems has the potential to increase the effectiveness of safety training.

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