Research on educational games in STEM area 2010-2020: a bibliometric analysis of literature

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Abstract. Research on educational games in STEM area have proliferated over the past decade. Various topics on educational games in STEM settings have emerged, showing the complex, dynamic and multi-disciplinary nature of the field. In this context, there is a need for an extensive, thematic overview of related studies for a better understanding of this STEM domain. Using co-word analysis and text analysis methods, this study presents a bibliometric analysis of 260 articles on educational games in STEM area published in academic journals and conference proceedings from 2010 to 2020. The results identify some research themes in the field, which are further categorized into computational thinking, game design, simulation and projects. By incorporating the analysis results with relevant reviews, this study offers a comprehensive picture and a holistic view of educational games in STEM area, and suggests directions for further work.

1. Introduction
Studies concerning STEM Learning have been developed using various methods and media, one of which is an educational game [1], [2]. The use of games in STEM conversations that require factual knowledge such as facts, jargon, and terminology and conceptual knowledge needed to conceptualize the problem domain by providing content that is very suitable to be applied in various education levels [3]–[5]. This game can accommodate STEM learning so that it motivates individuals and increases student interaction by learning by doing [6]. The use of educational games is also related to student decision making, design, strategy, cooperation and problem solving. In addition, this game can develop cognitive skills that are very useful in learning intended for STEM learning [7]–[9].

Various definitions of educational games had become a debate among experts [10]. However, experts agree to determine that educational games are object-based learning games by using interactive content that is used using other devices and making communication with a server [11], [12]. In addition, many authors in the literature reveal that educational games are the use of games in learning that balances pedagogical requirements with an elusive fun-factor in various scientific studies [2], [13], [14]. Based on these definitions, educational games are increasingly being developed to improve the quality of learning in the STEM area [15]–[17].

Educational games have become one of the rapidly developing fields in STEM learning [2], [18]. Research on educational games has tripled over the past decade [1]. Most of these games involve digital
versions, but the table top is currently experiencing a revival of popularity since 2015 and is often referred to as the "Year of the Board Game" [19], [20]. Both are equally effective as learning tools with each type of media offering certain advantages. In particular, many board games now have digital partners and allow players to choose the experience they want [21], [22]. Educational games can be easily used for STEM topics in high school [5]. Innovative learning media such as STEM games can play a key role in engaging students with STEM [23].

Various studies related to the use of games in learning include [24], [25] who argue that the game "World of Goo" will help players to understand the topic of static balance. Providing treatment to students with Arduino and open-source exposure can improve the ability of physical concepts beyond the problems of traditional books and traditional demonstration laboratories [26]. STEM learning using Arduino Android games can investigate the concept of electricity and its application in students [27]. Various studies related to literature studies on educational games have been carried out by experts [8]. One of the bibliometric analysis regarding the use of games from 2007-2017 in learning is research conducted by Serdar Cifci et al., Many keywords used during scanning (eg computer games, video games, serious games, simulation games, game-based learning, MMOG, etc.) [28]. From 1431 publications obtained, the analysis shows that the use of games in educational technology is very popular and can be linked to various disciplines [29].

Also, Connolly, Boyle, MacArthur, Hainey, and Boyle's research in 2012 conducted a bibliometric analysis of 7392 publications which then selected 129 articles to be included in the study [30]. This study was carried out using keyword games (Digital / non-digital, Game genre, Platform/shipping, etc.). The purpose of this study is to examine the use and impact of playing games in learning. The results of his research show that game-based learning and serious game attract the attention of researchers significantly [30]. Other bibliometric studies also examine the effectiveness of educational games in learning in schools [31]. Besides, many literature review studies using both bibliometric analysis and analysis conducted with other methods have been conducted relating to educational games or game-based learning or serious games [32]. However, there are not many studies that link to STEM learning. This research takes novelty by analyzing the existence of gaps from previous studies using bibliometric analysis.

The bibliometric method is based on examining bibliometric data in scientific publications such as quotations with mathematical and statistical methods [33]. Bibliometric analysis is a method used to summarize studies in the literature by measuring certain indicators [34]. Science mapping is a generic process of domain analysis and visualization [35]. Numerical statistics are related to improvements in publications over the years along with a list of the most contributing people (authors, institutions, countries, etc.), the collaboration between authors/institutions, percentage references per publication can be made through the bibliometric method [36], [37]. The basic assumption of the bibliometric analysis method is that the citation is an indicator of the impact of the publication cited [38]. When compared with experimental-based research methods, this analysis has advantages over the amount of data obtained and a more objective analysis so that new research patterns and themes are obtained [39].

The reason for choosing this is the ability to store detailed data and the ability to present this data to researchers in an easily accessible way [40]. This study seeks to address the relationship between themes, the possibility of further research, the novelty of the research, and the gap between research by considering publications that have been published in indexed journals between 2010 and 2020. Considering the aforementioned rationale, this paper could provide an extensive bibliometric analysis of the literature in relation to educational games in STEM. This analysis can see topics and types of research documents that are the subject of the most publications so that research topics regarding educational games in STEM can be further investigated. This study adopted a bibliometric approach to analyze 260 relevant articles published in google scholar 2010-2020, with the aim of finding the main research themes and structures of field knowledge.
2. Methods
This study is a systematic quantitative of literatures. We uses bibliometric analysis using Publish or Perish to examine the literature on Educational Games in the STEM area. This study was conducted by searching online on 30 June 2020 with the keyword educational game in STEM using the criteria of the title and keywords in the topic area. The analysis consists of two stages: keyword analysis and the title of the article to study groups and themes for research using google scholar sources. All articles obtained in the database relating to educational games in STEM Education total 858 articles which were then sorted by title to 260 articles. Sample articles that have been downloaded in the *ris format are processed using VOS viewer software to facilitate visualization and see trends in this study [41], [42]. This method is largely inspired by [28], [40], [42].

VOS viewer is a software tool for building and visualizing bibliometric networks developed by the Center for Science and Technology Studies, Leiden University [43]. We can study the distribution of publications by year and type of publication, time of publication and type trends, productive countries and universities, research areas which is productively investigated [44]. Also, the VOS viewer can be used to analyze all types of bibliometric network data, for example, the citation relationship between publications or journals, the collaborative relationship between researchers, and the joint emergence relationship between scientific publications [45], [46]. With these considerations, the data analysis related to educational games in STEM in this study was conducted using the VOS viewer. Data obtained from the public of perish then visualized using this application by using the "create a map based on text data" option based on the title and abstract fields and full counting.

3. Result and Discussion
The minimum number of occurrences of terms used in the VOS viewer is 10. After being analyzed there are 45 items with 6 clusters. The division in each cluster is as follows: The first cluster there are 14 items, cluster 2 has 10 items, cluster 3 has 8 items, cluster 4 has 7 items, cluster 5 has 4 items and cluster 6 has 2 items. These clusters show the relationship between one topic and another topic marked in different colour. Cluster 1 is red, cluster 2 is green, blue, yellow, purple, and light blue. There are 645 links.

The VOS viewer can show bibliometric mapping in different visualizations, including network, overlay, and density visualization [41], [47]. The results of the data analysis that have been carried out are then tabulated and become some graphs. Picture 1 presents the number of educational game articles in the STEM area published each year from 2000 to 2020. This graph shows that the number of articles on educational games continues to increase with the highest number of publications in 2017. This shows that this field of research is growing and attracts research interest more since 2010.

![Figure 1. Distribution of the research according to year of publication](image-url)

If we search by type of publication document obtained from public data perish, then it can be seen which type of document released the most research on educational games in STEM education. From 260 publications, there are six types of documents available, namely article, conference paper, book, review, book chapter, and conference review. Figure 2. Present the number of publications based on the type of document issued.
Figure 2. Distribution of the research according to type of document

This bar chart shows that the highest number of publications is in article type. This shows that this research is interesting to be published in reputable articles and has a great opportunity to be researched and published by this type of article. After being analyzed using the VOS viewer visualization and mapping can be seen regarding the interrelations between themes (Figure 3), the distribution of publications in each year (Figure 4), and density visualization (Figure 5).

Figure 3. Visualization topic area using VOS Viewer using network visualization

Figure 4. Visualization topic area using VOS Viewer using overlay visualization
The results obtained based on the keywords in the title and abstract show clusters of different research themes in the field of the educational game in STEM area studies. The themes shown in Figure 3 show the relationship between these themes. 76 terms are obtained overall, but when you want to show the most themes with educational games in the STEM area can be seen in Figure 6 below.
Figure 6. Shows that the most closely related research themes are six terms which can then become six research themes in the field, which are educational games in STEM for computational thinking, game design in STEM, using simulation in educational games for STEM, using the project for developing educational games in STEM, using STEM concepts in educational games. Figure 4 shows that the trend of research publications every year can be a reference for further research because this research is still interesting to study especially in 2020 with a total of 11 new publications. This can be an opportunity to continue to develop this research sequentially by paying attention to the novelty in accordance with the interrelationship of the themes in Figure 3, which is visualized with the VOS viewer. In addition, from Figure 5 we can see the depth of research in the game, STEM and education can still be examined more deeply.

From the overall data obtained and the analysis that has been done, we can look for new research related to the theme of educational games in the STEM area. Researchers can contribute by linking themes that are still rarely studied, countries that publish, different methods, or types of documents for publication. From this study, we can provide data support for further research that wants to use educational games in STEM with a bibliometric analysis that can enrich research by combining different parameters in a study.

4. Conclusion
Based on the results and discussion above, it can be concluded that the development of research on the educational game in the STEM area from 2010 to 2020 fluctuates. Most publications on this theme are 2017 with 50 articles. As for document types, 112 article documents have been published. Seen from the types/types of documents that are widely studied are in the form of articles followed by books and reviews. This study obtained data from various research themes and their relationships with each other. This article visualizes various literature through bibliometric analysis to identify the main themes in each study or scope. According to the results obtained from this study, VOS viewer revealed 6 clusters in characterizing the current six meaningful research themes in the domain.

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