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Game-Based Learning Approach in Science Education: A Meta-Analysis

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ABSTRACT: In the generation of technological advancement, students tend to have difficulty learning science education since it encompasses numerous fields, making it challenging for students to assimilate knowledge about the topic. An approach called game-based learning exhibits positive results in students' academic performance where teachers integrate a learning approach for students to engage and motivate them throughout the learning process. Since there is a lack of empirical evidence, this metaanalysis study conducted a systematic literature review that seeks to know the methods, theoretical foundations, and educational outcomes of game-based learning in science education. This study includes a document analysis of 26 empirical literature studies from 2016 to 2021. Significant findings include that (1) most articles employed quasi-experimental research design, (2) most empirical studies utilized strategy games as the game genre, (3) most learning theories associated with science game-based learning are rooted in constructivism, and (4) most commonly observed science game-based learning outcomes focus on knowledge attainment among reviewed empirical literature. Significant findings imply that game-based learning is effective and can become productive for students in science learning.

KEYWORDS: game-based learning, science education, games, meta-analysis

INTRODUCTION

Rapid development and an increase in technological advancement will affect students' learning and create new forms of engagement for students to meet the needs of students education. Science students are corporate to study many branches, making it difficult to digest and transmit different thoughts and concepts in real-life situations. Moreover, students can lower their motivation and interest in learning because they find the subject boring and perceive it as not enjoyable (Jufrida, Kurniawan, Astalini, Darmaji, Kurniawan and Maya 2019). Therefore, if students are not motivated and lose their interest in learning, it will be difficult for them to engage and learn. In connection, the game-based learning approach is gaining popularity in education as a support mechanism. This approach shows potential in increasing students' performance in the classroom, along with reaching a balance between gameplay and instruction while allowing students to apply their learning in a natural environment (Perera, Hewagamage and Weerasinghe 2017). On the other hand, game-based education can provide learning opportunities for student-centered instructional approaches and permit creative teaching approaches employing technology and other instruments (Shu and Liu 2019).

In science education, a game-based learning approach becomes promising, especially in introducing and discussing complex concepts and topics (Al-Tarawneh 2016). However, Zeng, Zhou, Hong, Li and Xu (2020) noted that, although game-based learning has gained much attention in the educational world in recent years; nevertheless, its usefulness of game-based learning is not yet solidly established. In congruence, there is still a lack of scientific evidence to support its authenticity (Hainey, Connolly, Boyle, Wilson and Razak 2016). Thus, a meta-analysis of the empirical literature on game-based learning is promising to comprehensively examine the potential effectiveness of the game-based learning approach in science educational settings from a more contemporary perspective. Game-based learning is an approach that achieves educational goals and the learning process by constructing student-centered, entertaining and compelling activities through the game (Pesare, Roselli, Corriero and Rossano 2016). Learning designers can employ these traits on multiple methods because it allows unique game designs that could aid in learning. It means that following the stages of a specific learning approach or process can also create an educational game. The method used can also determine the effectiveness and efficiency of learning (Pratama and Setyaningrum 2018). Learning is an approach guided by the objectives of the created educational games. In addition, Giannakas, Kambouraakis, Papasalouros and Gritzalis (2018) emphasized the need to support educational activities by developing effective instructional learning strategies and the significance and fundamentals of incorporating learning strategies or methods into gaming circumstances or goals.

Game-based learning can encourage students to learn beyond the limits of given resources and allow them to develop into self-directed learners. Game-based learning is in line with Experiential learning theory. Dimitra, Konstantinos, Christina and Katerina (2020) stated that game-based learning is often experience-based and depends upon experiential, exploratory learning, and problem-based approaches. According to Kolb (1984 as cited in Krath, Schürmann and Von Korflesch 2021), experiential learning theory is the process of learning in which the knowledge and concepts are obtained through direct and environmental experiences instead acquiring through a manifestation of the teacher's instructions. It is a process in which knowledge is created that will transform into an experience. Game-based learning provides opportunities to learn by doing in a setting where students are actively engaged and can continue their activities independently (Bakan and Bakan 2018). This approach of using games as a learning tool was used in numerous literature review studies to guide and evaluate students' learning outcomes in the aspect of game-based learning (Krath, Schürmann and Von Korflesch 2021). In addition, previous studies explain that digital game-based learning will foster students' good academic outcomes and motivation. It will improve their learning performances because the higher the excitement it creates for students, the higher their learning will receive and retain (Hsieh, Lin and Hou 2016; Alenjadria, et al., 2023). Moreover, a study conducted by Braghirolli, Ribeiro, Weise and Pizzolato (2016) found that game-based learning successfully improves the student's understanding of the course material and their involvement in the learning process.

Various literature reviews were conducted to analyze game-based learning to provide direction to educators and researchers. Most of these studies have investigated game-based learning from different features focusing on the trends of game-based learning as they relate to learning outcomes (Hainey et al 2016). However, several reviews have specified the positive effects that game-based learning brings to learning outcomes; only a few highlight the potential and limitations that game-based learning brings (Dimitra et al 2020). Although these previous works discover that game-based learning is an excellent strategy to engage learners and promote learning outcomes. Further research is required to understand how these can impact learning and point out specific factors and aspects of game-based learning that influence learners (Shu et al 2019).

Objectives of the Study

This study examined the recent scholarly articles concerning using a game-based approach in the context of science education. Specifically, this study sought to know the following:

1. What are the methods used in Game-based learning?

1.1. Research Design

1.2. Game Genre

2. What are the theoretical foundations of game-based learning in science education?
3. What are the educational outcomes of the literature being studied?

Furthermore, the results of this study may provide science teachers insight into motivating students in terms of a game-based learning approach and can gain value of usefulness when it comes to attaining specific objectives in teaching. This study can also help science students develop an interest in learning science concepts and increase motivation to improve scientific knowledge. Moreover, the institution can also gain and further develop a new approach to teaching and learning science.

METHOD

Materials

In conducting this study, the researchers established specific criteria to assist in selecting articles to be reviewed, to choose and include those related to this research subject, and to reject those that did not fulfill the required parameters (Kalogiannakis, Papadakis and Zourmpakis 2021). Hence, the inclusion criteria used for this literature review study are the following – 1) that the articles can be found on google scholar; 2) that the articles were published between 2016-2021; 3) that the articles are focused on gamebased learning, specifically in the science field of education; 4) that the articles must have an English version and must have the full text available in pdf; 5) that the articles must be empirical research studies (research that is based on observation and measurement of phenomena); 6) that the articles must have an implementation of at least one specific game used on learners in teaching science-related content, and 7) that the articles contain empirical findings regarding students' learning processes or outcomes when a learning activity is completed.

Furthermore, the researchers used Google Scholar as the specific electronic database and academic search engine to search for relevant articles to be reviewed. Gusenbauer (2019) states that Google Scholar is the most comprehensive academic search engine, with 389 million records. Also, Xiao and Watson (2019) stated that Google Scholar is an impressive open-access database that stores journal articles and "gray literature," like conference proceedings, theses, and reports. According to several studies, Google Scholar surpasses WoS (Web of Science) and Scopus in terms of publication coverage (Waltman 2016). The researchers only used Google Scholar to search scholarly articles because, aside from being a compelling open-access database, it is also easily accessible and convenient. There is no difficulty in registering an account to view research papers because they are free to access. Furthermore, another wellknown academic database cannot be accessed easily without creating an account and buying the full-text article.

Moreover, the keywords for the literature search should be drawn from the study's research problem (Xiao and Watson 2017). Hence, the search strings (combination of keywords) used for typing and searching relevant articles about game-based learning in science education were already listed which are the following – *1) Game-based learning in science, 2) Game-based learning in Physics, 3) Game-based learning in Biology, 4) Game-based learning in Chemistry, 5) Game-based learning in Earth science, and 6) Instructional Games in Science.* According to Cronin, Ryan and Coughlan (2008), as cited by Kalogiannakis, Papadakis and Zourmpakis (2021), it is vital to consider alternative terms having equivalent meanings to maximize the number of articles included in a literature review. As provided, the synonymous keywords about science education were used together with the keyword '*game-based learning.'* Such synonymous keywords associated with science education are – *Science*, *Physics*, *Biology*, *Chemistry*, and *Earth science*. In addition, another combination of keywords (*Instructional games in science*) was used as well.

Design and Procedure

This research is a meta-analysis study. According to Pigott and Polanin (2020), meta-analysis is a set of statistical techniques used in a systematic review to synthesize the results of several studies and is employed when the leading research question deals with a numerical summary of study results. A metaanalysis is concerned with aggregating results from several studies (Gough, Oliver and Thomas 2017 as cited in Pigott and Polanin 2020). This study mainly employed a systematic literature review. According to Mohamed Shaffril, Samsuddin and Abu Samah (2021), a systematic literature review seeks to comprehensively discover and synthesize related studies in a systematic, transparent, and repeatable manner at each stage of the process. Also, Webster and Watson (2002 as cited in Erdem 2017) claimed that a systematic search should guarantee that authors gather a relatively thorough census of related literature.

Additionally, this systematic literature review study adopted a *qualitative research design.* Since this study design is descriptive, it describes the findings of the game-based learning research articles in science education. According to Kyngäs (2020), observations, interviews, journal entries, and written documents are standard components of qualitative research design. Kyngäs (2020) further discussed that the qualitative research process reduces data, groups data, forms categories or concepts, and eventually describes the examined phenomena and answers the research objective. Furthermore, the researchers employed a *document analysis* method as a qualitative research method in this study. Document study (*document analysis*) refers to the researcher's review of written documents (Busetto, Wick and Gumbinger 2020). Furthermore, document analysis is a qualitative research form that systematically analyzes documentary evidence and addresses particular research questions. Document analysis involves repeated reviewing, examining, and interpreting the data to obtain empirical knowledge and meaning about the concept under study. Document analysis is frequently utilized to triangulate findings collected from another data source. If used to triangulate, documents can corroborate or refute, elucidate, or expand on findings from other sources of data which aids in avoiding bias (Gross 2018). Hence, the researchers performed a document analysis of scholarly articles wherein the researchers reviewed only those empirical game-based learning research studies in science education.

Moreover, the process that the researchers followed in conducting the literature review was specified, which comprised the following six generic steps according to Templier and Paré (2015 as cited in Paré and Kitsiou 2017), which are the following:

1*) Formulating the research questions and objectives;*
2) Searching the existing literature;
3) Screening for inclusion;
4) Assessing the quality of primary studies;
5) Extracting data, and
6) Analyzing and synthesizing data.

Step one (1) is *Formulating the research questions and objectives*. It involves the identification of the review's main objective/s (Okoli and Schabram 2010 as cited in Paré and Kitsiou 2017) and the articulation of research questions that the researchers propose to investigate (Kitchenham and Charters 2007 as cited in Paré and Kitsiou 2017). Next is step two (2) – *Searching the existing literature*. This step involves searching and identifying works of literature and deciding the suitability of the manuscripts to be included in this literature review (Cooper 1988 as cited in Paré & Kitsiou 2017). Furthermore, Xiao and Watson (2019) stated that during the *searching of the literature* step, this stage is mainly focused on reviewing research titles. In this case, the researchers examined the article titles as the primary focus for searching and identifying potential manuscripts applicable to this study. If the title is not enough for making a decision, the researchers will examine the abstract section for further details. Since there are six (6) sets of keywords, every set of keywords was individually searched to collect relevant articles using Google Scholar extensively. Owing to the large number of articles that resulted in the database, the researchers decided to analyze the first 200 results following the recommendations of Haddaway, Collins, Coughlin and Kirk (2015 as cited in Kalogiannakis, Papadakis and Zourmpakis 2021).

After that, the subsequent phase is step three (3) – *Screening for inclusion*. This step entails evaluating the applicability of the articles identified in the previous step. After identifying a set of potential studies, the researchers screened them to determine their relevance using the established inclusion criteria indicated in the *Materials* subsection (Petticrew and Roberts 2006 as cited in

Paré and Kitsiou 2017). In addition, during the *screening for inclusion* step, the judgment frequently focused on the abstracts of the articles. The conclusion section should also be read if the abstract does not give enough information. Individual assessments should be inclusive - if doubtful, always include the research manuscripts (Brereton, Kitchenham, Budgen, Turner and Khalil 2007 as cited in Xiao and Watson 2019). Ultimately, a list of rejected manuscripts should be kept for record-keeping, repeatability and crosschecking purposes (Kitchenham and Charters 2007 as cited in Xiao & Watson 2019). In this case, the researchers screened the articles, not limited to the abstract and conclusion sections alone but examining the introduction, methodology, and results to meet the inclusion criteria and ensure the accuracy of the screening process.

Following that is step four (4) – *Assessing the quality of primary studies*. Aside from the potential scholarly articles being screened to be included in this study, the researchers may require a process of assessing the scientific quality of the chosen articles. It means to evaluate the rigor of the research designs and methods and to polish which articles are eligible to be finally included in the sample to be reviewed in this study (Petticrew and Roberts 2006 as cited in Paré and Kitsiou 2017). In addition, the *quality assessment* process involves reading the whole text to analyze each manuscript against the inclusion criteria thoroughly. The full-text review also gives a chance for the last check on inclusion and exclusion. Studies that do not meet the standard criteria should also be eliminated from the final list of manuscripts (Xiao and Watson 2019). Similar to the previous stage, a list of rejected manuscripts in this step should be kept for record-keeping, repeatability and crosschecking purposes (Kitchenham and Charters 2007 as cited in Xiao and Watson 2019).

Next is step five (5) – *Extracting data*. This step involves collecting or extracting relevant data and facts in each empirical article listed in the sample and deciding what is relevant to the topic under study (Cooper and Hedges 2009 as cited in Paré and Kitsiou 2017). Indeed, the data that should be collected is mainly determined by the study questions (Okoli and Schabram 2010 as cited in Paré and Kitsiou 2017).

The last step is step six (6) – *Analyzing and synthesizing data*. The researchers must next organize, summarize, aggregate, arrange, and compare the evidence extracted from the included research. The data extracted should be presented meaningfully, indicating a novel contribution to the existing literature (Jesson, Matheson and Lacey 2011 as cited in Paré and Kitsiou 2017). In addition, this study used thematic analysis to process the qualitative data extracted from the relevant articles. According to Maguire and Delahunt (2017), the process of detecting patterns or themes in qualitative data is called thematic analysis. Also, thematic analysis is defined by Braun and Clarke (2006 as cited in Neuendorf 2018) as a strategy for detecting and analyzing patterns of meaning in a set of data. According to Joffe (2012 as cited in Neuendorf 2018), the outcome of the thematic analysis will emphasize the most prominent "constellations" of meanings found in the texts. In this study, the goal of using thematic analysis is to identify the themes and patterns of the qualitative data which are significant and exciting and use these themes to address the given research questions. More than summarizing the qualitative data, the thematic analysis will be used to organize, interpret, and make good sense of the data (Maguire and Delahunt 2017).

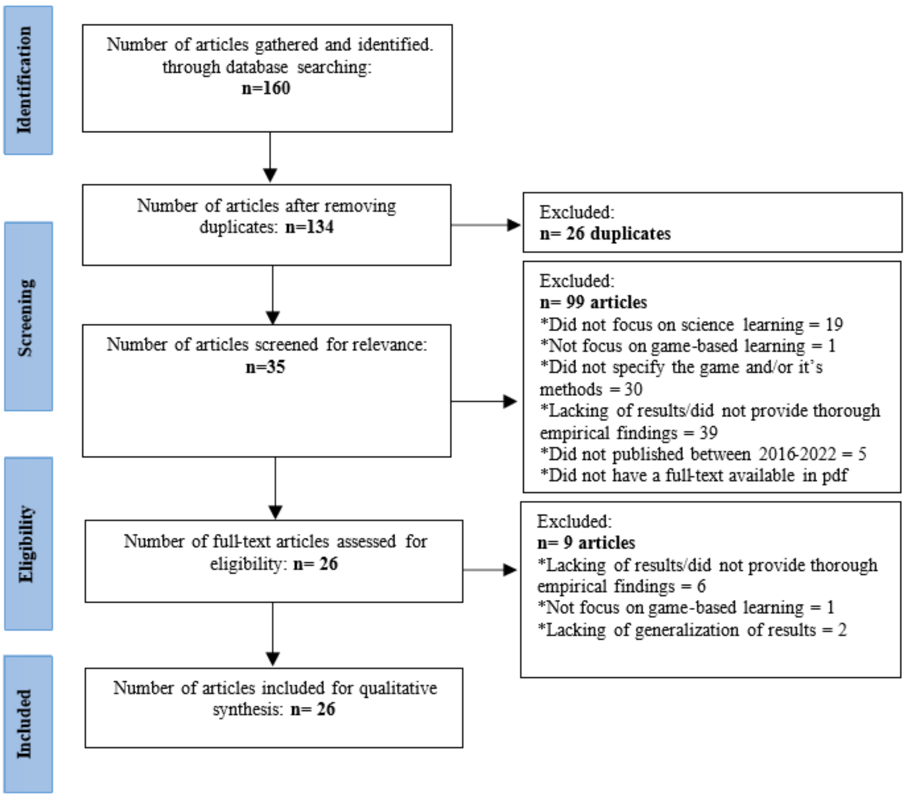

Figure 1. PRISMA flow diagram

To systematically present the conduct of the literature review, the researchers followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram as depicted in figure 1. The PRISMA flow diagram is used to describe the systematic literature review process in an organized manner (Liberati, Altman, Tetzlaff, Mulrow, Gøtzsche, Ioannidis, Clarke, Devereaux, Kleijnen and Moher 2009 as cited in Mohamed Shaffril et al 2021). Figure 1 summarizes the number of research articles obtained from the database during the initial search process, the screening process for possible inclusion studies, and the studies that eventually satisfied the inclusion requirements. Furthermore, the *PRISMA* flow diagram shows that out of 160 articles identified during database searching, 134 articles were obtained with the removal of 26 duplicates. The next phase was the screening for relevance with the use of inclusion criteria in which there are 35 articles retained out of 134 studies, with the removal of 99 articles due to the following reasons: did not focus on science learning (19); did not focus on game-based learning (1); did not specify the game and its methods (30); lacking results/did not provide detailed empirical findings (39); did not publish between 2016-2021 (5), and did not have a full-text available in pdf version (5).

The remaining 35 articles were further screened for eligibility, with nine articles being removed. Hence, the researchers arrived at a final number of 26 articles for qualitative synthesis subjected to analyzing and synthesizing data. The final 26 articles included in this study were arranged under their corresponding publication sources, as shown in the following figure. Figure 2 summarizes all twenty-six
(26) research articles found in Google Scholar arranged according to their corresponding online publication sources. On the other hand, figure 2 shows six (6) significant online academic publication sources: *Springer, IEEE Xplore, Elsevier, JSTOR, Taylor and Francis*, and *SAGE Journals*. *Springer* has six (6) articles; *IEEE Xplore* has two (2) studies, and *Elsevier*, *JSTOR*, *Taylor and Francis*, and *SAGE Journals* have one (1) article in each of them. While the remaining fourteen (14) articles are in other publication sources not indicated in figure 2 (refer to Appendix H for a further list of other articles' publication sources).

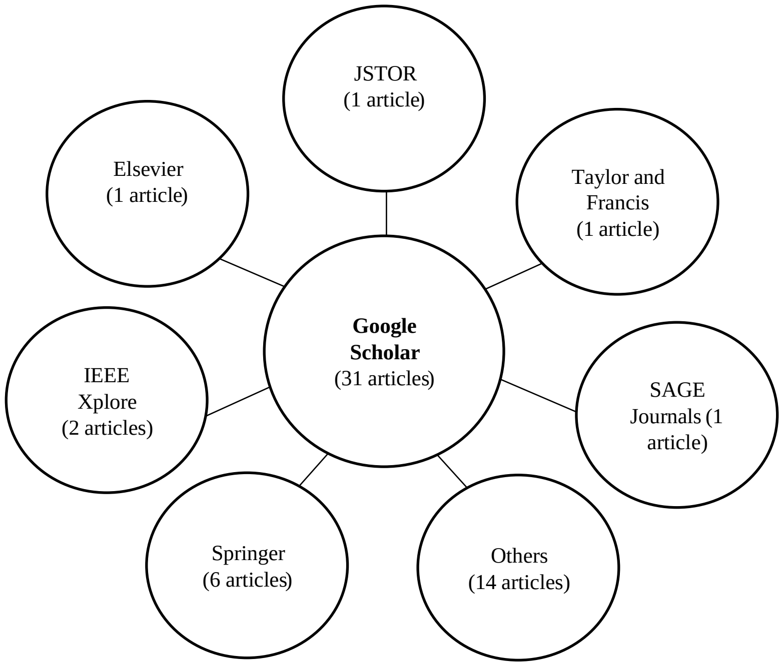

Figure 2. Designation of article's academic publication sources

RESULTS AND DISCUSSION

This section entails the study's results and discussion accompanied by the succeeding tables and figures. This section is also further divided into six sub-content headings.

Methods Used in Game-Based Learning in Science: Research Design

Figure 3 shows the research designs of game-based learning in science education as documented in the meta-analysis of 26 articles in this study. As depicted in Figure 1, the results revealed that the quasiexperimental research design reaped the highest frequency of 14 (53.8%). It was then followed by an experimental design with a frequency of 8 (30.8%). The descriptive quantitative study came last with a frequency of 4 (15.4%). Quasi-experimental is a research design aiming to replicate randomized, actual experiments with rigor and organization but lacking random assignment (Cook and Wong 2008; Kirk 2009). This research design also utilizes pre-test and post-test measures but varies whether; one-group, two-group, three-group, or more. Of fourteen (14) articles that utilized quasi-experimental research design, nine utilized one-group pre-test and post-test while five articles utilized the two-group pre-test and post-test design. Moreover, the experimental research design was the second most used research design with eight (8) articles. This research design also employs pre-test and post-test measures. According to Cook and Wong (2008), pre-test and post-test measures are most commonly used in experimental designs, particularly in educational research studies (Rogers and Revesz 2019). The pretest and post-test experimental research design also vary whether one-group, two-group, three-group, or more, similar to quasi-experimental. Of eight (8) articles, three (3) utilized a one-group pre-test post-test design, another three (3) articles utilized a two-group pre-test post-test design, and two (2) utilized a three-group pre-test post-test design.

Furthermore, descriptive quantitative has the lowest used research design with only four (4) articles. Descriptive studies can be either purely descriptive or descriptive comparative in nature (Siedlecki 2020), which in this area consists of quantitative data. Descriptive designs are most helpful when describing phenomena or events about which little is known or when recognizing new or emerging phenomena (Dulock 1993). Most articles that employ descriptive quantitative only describe the similar emerging characteristics of the students according to their responses. Overall, quasi-experimental is the most utilized research design from the reviewed articles on game-based learning in science. This result is also parallel and consistent with the study of Hussein, Ow, Cheong, Thong and Ebrahim (2019), in which sixteen out of twenty-three articles utilized a quasi-experimental design. In addition, Boyle, Hainey, Connolly, Gray, Earp, Ott, Lim, Ninaus, Ribeiro and Pereira (2016) empirical review shows that quasiexperimental design was the predominant research design in both studies for entertainment and learning games.

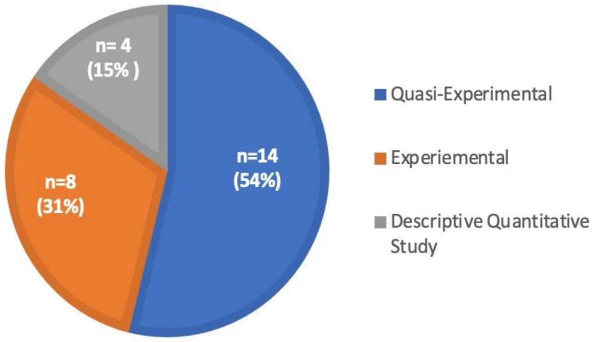

Figure 3. Most used research design in Game-based learning in Science

Methods Used in Game-Based Learning in Science: Education Game Genre

Figure 4 shows various genre used in game-based learning in science education classified to its' genre. This study utilized the multidimensional framework established by Connolly, Boyle, MacArthur, Hainey and Boyle (2012) for classifying games along with the following variables: 1) Digital or non-digital, 2) game purpose, 3) game genre, 4) subject discipline of the game and 5) game platform/delivery. However, the study only focused on the game genre. The game genre was further classified following the taxonomy of eight entertainment games established by Herz (1997 p. 24-31), which are: 1) Action Games, 2) Adventure Games, 3) Fighting Games, 4) Puzzle Games, 5) Role-Playing Games or RPG, 6) Simulations, 7) Sports Games, and 8) Strategy Games. After classifying games based on their genre, the study's result only categorized five (5) genres of games: Strategy, Role-playing game, Adventure, Simulation, and Sports games. The study reveals that the most popular game-based learning approaches used in science education emerged under strategy games, with a frequency of 16 (61%). Role-playing games or RPGs followed it with a frequency of 6 (23%). Adventure games appeared next with a frequency of 2 (8%). Then, simulation and sports games came last with a similar frequency of only 1 (3%).

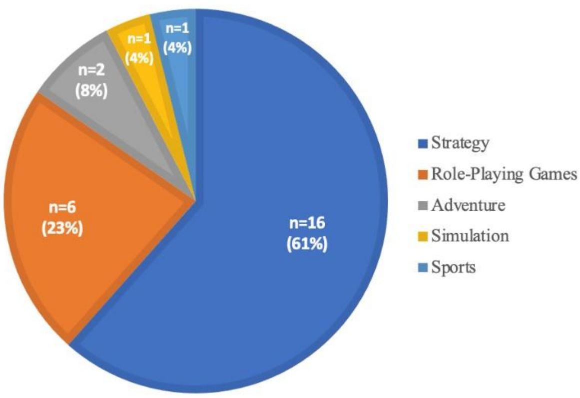

Figure 4. Game genre used in game-based learning in science education

Theoretical Foundations of Game-Based Learning in Science

Based on numerous studies and tests, learning theories have arisen to improve the effectiveness of the learning process. Learning is a model or system comprising various generalizations and principles that explain how individuals learn based on an extensive study result (Bakan and Bakan 2018). Based on the study's findings, Figure 5 revealed three major theoretical foundations anchored on the use of gamebased learning in science education which follows from most to minimal frequency: *Constructivism*, *Affective and Motivational Theories*, and *Cognitivism*. Out of twenty-six articles reviewed mentioning theories, results revealed that *constructivism* garnered the highest frequency of fifteen (58%). It was followed by *affective and motivational theories* with a frequency of eight (30.8%) and *cognitivism*, with a frequency of three (11.5%), respectively. The study's result is consistent with other literature review findings (Qian and Clark 2016; Cheng, Chen, Chu and Chen 2015; Guan, Sun, Hwang, Xue and Wang 2022). The literature review of 29 articles by Qian and Clark (2016) aiming to investigate the use of GBL in 21st-century skills enhancement reveals that constructivism is the most prevalent learning theory being used as bases for research design. Also, the literature review of Cheng et al (2015) from 2002 to 2013 regarding educational games in science learning shows that constructivism and Vygotsky's concepts were the most commonly cited theoretical foundations underlying the usage of educational games in relevant papers. Lastly, the recent literature review of 35 studies by Guan et al (2022) focusing on integrating games in primary school reveals similar theoretical bases drawing upon constructivism theories.

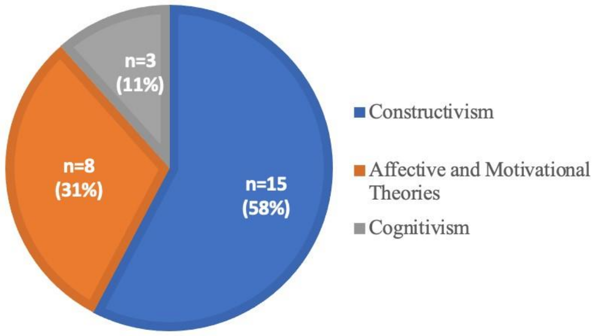

Figure 5. Theoretical foundations of Game-based learning in Science

Educational Outcomes of Game-Based Learning in Science Education

This meta-analysis study also discusses the educational outcomes of game-based learning in science education. The proposed classification framework by Connolly, Boyle, MacArthur, Hainey and Boyle (2012 as cited in Hussein, Ow, Cheong, Thong and Ebrahim 2019) was used to guide this study. Their framework classified the learning outcomes of computer and serious games into four main dimensions: *1) knowledge attainment, 2) skills attainment, 3) affective, motivational, and physiological outcomes*, and *4) behavior change outcomes*. However, the inadequate number of articles encouraged Hussein et al (2019) to repurpose Connolly et al (2012) framework. Likewise, since none of the included game-based learning articles in this current study explored physiological outcomes in the third dimension, only the *affective and motivational outcomes* were retained. Also, no behavioral change outcome was yielded in the study; hence the fourth dimension was removed. Thus, the final dimensions or foci of learning outcomes employed in this study are *1) knowledge attainment, 2) skills attainment* and *3) effective & motivational outcomes*. Figure 6 shows the educational outcomes documented and analyzed in this study. Figure 6 reveals that out of twenty-six (26) sample articles, the most frequently occurring educational outcome in science game-based learning is knowledge attainment, with a frequency of eighteen (69%). Affective and motivational outcomes followed it with a frequency of five (19%). Skills attainment came last with a frequency of three (12%). The study's results are highly consistent with Connoly et al (2012) and Hainey et al (2016) findings. A literature review study by Connoly et al (2012) regarding the impact of computer games on student learning showed that the most observed outcomes were knowledge acquisition and affective and motivational results. Also, a similar literature study by Hainey et al (2016) exposed that the most studied effects of learning games were knowledge acquisition, followed by affective and motivational outcomes.

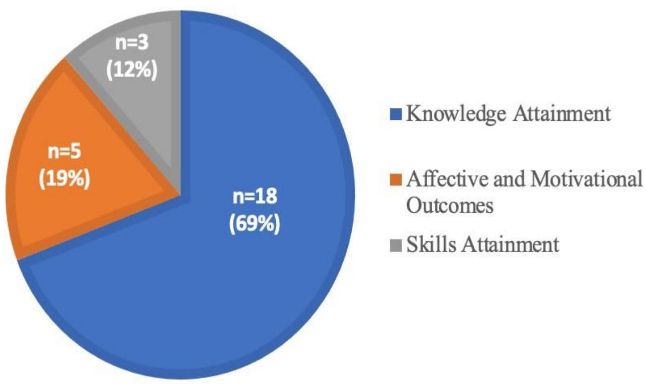

Figure 6. Educational Outcomes of Game-based learning in Science

SUMMARY AND IMPLICATIONS

The most significant idea about the current meta-analysis study of relevant empirical articles from 2016 to 2021 focusing on game-based learning in science education was the various kinds of research that primarily provide positive effects and outcomes on students, whether digital or non-digital games. The salient findings documented and analyzed in this systematic literature review study are enumerated as follows – (1) most articles employed a quasi-experimental research design; (2) most of the studies utilized strategy games as the game genre; (3) most learning theories associated to science game-based learning is rooted to constructivism; and lastly, (4) most commonly observed science game-based learning outcomes focus on knowledge attainment. The salient findings of the study imply that constructivism is more efficient concerning game-based learning as it helps students construct knowledge based on their personal experiences and interactions that lead them to become independent and active learners. In addition, most empirical studies imply that the educational outcome of game-based learning has aided students in acquiring knowledge in different aspects of science. Significant findings suggest vigorous empirical effectiveness of game-based learning and can become productive for students in science learning. Also, it may provide science educators insights into the utilization of game-based in teaching science from various areas. However, more research that utilizes randomized group assigning is required to give more conclusive proof of this effectiveness. Since most of the documented studies utilized quasi-experimental design, which lacks randomized assignment.

Considering the summary and implications of game-based learning in science education as obtained from the meta-analysis conducted, the following avenues are enumerated, which are suggested for future research endeavors. First, further research using randomized assigning of groups should be performed when comparing game-based learning in science and traditional learning. This is essential since this will determine the effectiveness of game-based and will help to support the transition of science teaching and learning into game-based. Next, further investigation of game-based learning in science using qualitative method considering that this method will be more effective in terms of determining the behavioral change outcomes of students. Also, a mix of quantitative and qualitative methods is suggested to determine the measurement and degree of student learning using game-based with the support of qualitative data. Additionally, since the current study is concerned with reviewing the general aspect of game-based learning in science, further research about digital and non-digital games in two different studies is suggested to identify further and distinguish the definite and specific outcomes of these games to students. Subsequently, other research associates games in order to acquire a specific skill since only a few of the reviewed studies are concerned with acquiring cognitive learning skills such as problemsolving and higher-order thinking skills. Lastly, further meta-analysis research using not only Google Scholar but also multiple academic search engines is suggested in order to expand the collection and obtain a more significant number of relevant articles to be included in the study.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

FUNDING STATEMENT

This research did not receive any financial support.

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