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Serious Games and Gamification: Science Education. A systematic literature review.

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***Abstract*—Keeping in mind the increasing trend and need for serious games in science education, we have done a systematic literature review. These papers show the trends and patterns of research carried out in this field from the year 2011 to 2020. Specifically, we investigated country-wise concentration and most common evaluation methods. Literature is reviewed from IEEExplore, Springer, and Scopus. Moreover, we discussed the role of Augmented Reality(AR) games in teaching physics. Lastly, we have discussed the positive and negative aspects of serious games in science education in particular, and the trend of using serious games in the past decade in education in general.**

***Index Terms*—serious games, science education, games in education, augmented reality.**

I. Introduction

Video gaming is one of the biggest industries in the world right and generated approximately $ 114 billion in 2020 [1]. Thanks to advancement in graphics quality and the network speed, the gaming industry spurred from early 2000 and since then, the revenue is on the rise. Additionally, big franchises organized online gaming events, and the number of participants are on the rise. A graphical depiction of global revenues of the video game industry from 1971 to 2018 without considering the inflation is shown in Fig 2. The time and effort put in by gamers are considerably high. In the modern world where technology improves every aspect of every industry, including gaming and education, it is important to see how science education has improved under its shadow and how it links to gaming. Science education is about teaching science to school children and other non-scientists, and the gaming industry has played a major role in its spread by producing serious games.

Serious gaming is the use of games to fill needs other than just entertainment [2]. Serious games are also called applied games and this concept of gaming is used by industries like defense [3], health care [4], emergency management [5], [6], education [7], exploration [8], city planning [9], engineering [10], and politics [11]. In addition to this, computer vision and deep learning based techniques can be exploited in gaming context to analyze performances of sports players through tracking [12], [13] in an virtual environment [14], detection [15], [16], analysing anomalous behaviour [17], [18], simulating individual [19], [20] and crowd behaviour [21]–[25] for public infrastructure design [26], [27], and a variety of other multi media applications [28], [29].

Fig. 1. The relationships between games, video games, serious games and serious educational games [30]

In one part of this review, we discuss how education science uses serious gaming to help children with an improved learning experience with the help of some real-world examples including games like around and around, as well as other games from science kids and science seekers.

There is no doubt that the vast prosperity of the gaming industry is because of the interesting combination of the concept of play and technology. A huge percentage of video games players find it to be an extremely pleasurable experience. Not just that, they are willing to invest a serious amount of time and effort in playing them [31].

A. Serious Games in Science Education

Teaching science through the use of computer games and simulations goes all the way back to the 1970s and early 1980s, where the ability of games and simulations has been widely explored as a new teaching method [33]. In the early 1990s, the first communication and information technology games to investigate scientific and technological aspects were created [34]. Figure 1 shows the relationship between games, video games, serious games, and serious educational games. At the start of millennium, value of commercial video games

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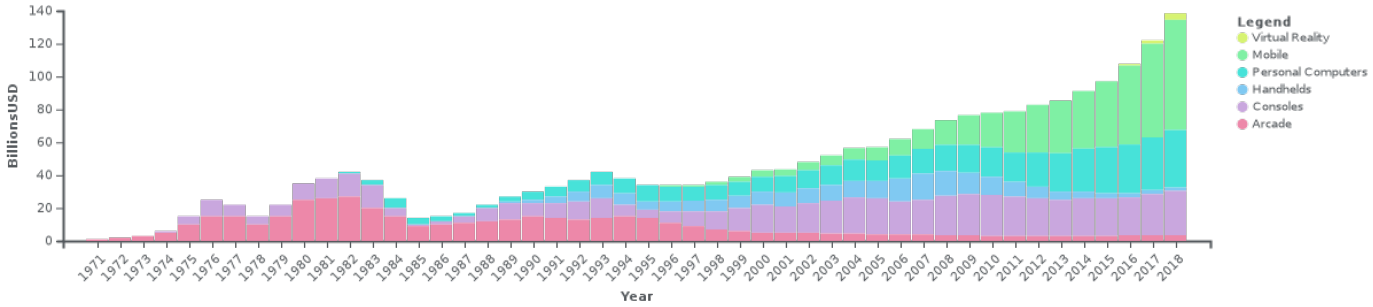

Fig. 2. Global revenues of the video game industry from 1971 to 2018, not adjusted for inflation [32]

in science education has risen, as has been the case with the development of serious games with scientific subjects such as chemistry, physics, and biology [35]. A study was carried out in 2014 at the ILD Lab at Aalborg University, Denmark categorized the science games in their research projects into five different categories as follows.

1) Training Games
2) Inquiry Games
3) Professional Simulation/epistemic games
4) Embodied system games
5) Research collaboration games

Table I shows the example of serious games in each of the above mentioned category.

B. Simulation based Augmented Reality games in Physics

In 2016, the GPS-based Augmented Reality (AR) game "Poke mon Go" captured the attention of the whole world from young to old. In just over two weeks, it secured a fan club and active users of size over 20 million [37]. It became the top game-winning Twitter and Facebook over daily active users and on time spent per day, respectively. People started going outside and socialize to find virtual monsters and gain points. That was probably a good signal for the future of AR games. Augmented reality can show an image, information, buttons as an addition to reality by which helping to analyze interact or understand what people see on the screen of glasses or smartphone. Interactivity and smooth integration to the real-world make Augmented reality one of the most promising technologies of our current world. we would also like to discuss how beneficial AR can be in simulation-based games related to Physics considering characteristics of science subject. We reviewed two experiments like the impact of usability on motivation in AR serious games [38] and physics-simulated serious games [39]. Analysis and results are based on the evaluation of elementary, middle, and high school teachers and students.

C. Research questions

Moreover, in this study, we thoroughly examine the previous studies and serious games developed for the advancement of science education from 2011 to onwards. To this end, the following four main research questions are addressed:

1) Which journals and conferences are more focused on this field?
2) What is the year distribution of articles?
3) What is the country-wise distribution?
4) How the intervention of serious games in science education is evaluated? e.g. administering a questionnaire to students/teachers, interviews, on-site observations, observations from recordings, etc.

II. Background

This paper reviews the work done on serious games to improvise science education. Historically, the definition of serious gaming is only restricted to "a game designed for learning and education" but since then the definition has grown and achieved a broader perspective. In the contemporary world, education science along with serious gaming covers a huge ground. Almost every other subject is covered via serious gaming. This includes some basic subjects for example sociology, psychology, anthropology, biology, political science, economics, and public policy. Other areas covered by serious gaming include engineering, architecture, mathematics, and information science. However, this paper restricts to talk about science education, and how it has improved through serious gaming over the years.

The level of interest in creating modern and creative learning resources has grown steadily in previous years, as the use of video games for instructional purposes has slowly gained ever more focus from educators and scholars, and the positive effect of video games on learning has appeared increasingly encouraging [30], [40]–[42]. This is particularly true for science education, given that the use of video games to improve science studying has progressively become very widespread since the Serious Gaming Movement was launched in 2002 [43]–[46]. Experts also believe that serious games can be an important and versatile resource for science teaching because of their special ability to mix serious subjects with entertainment [47].

A. Empirical studies on Serious games in science education

Research conducted in 2014 reported the review of empirical research on serious gaming from 2002 to 2013. The researchers identified the keywords they used to find the work they studied to conduct their research. They used the SSCI and

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TABLE I
CATEGORISATION OF SCIENCE GAMES IN RESEARCH PROJECTS AT THE ILD LAB AT AALBORG UNIVERSITY. THE GAMES LISTED IN PARENTHESES WERE NOT COVERED BY OUR RESEARCH. [36]

Science game Category	Game learning goals and activities	Game research examples
1. Training games	Designed to train skills through repetition of an individual exercise, e.g. training basic math skills or the composition of chemical compounds	MateMaTris, (other game examples outside our research: DragonBox)
2. Inquiry games	Focus on scientific inquiry; can involve data collection processes, verifying hypotheses and generating theories or building scientific arguments	Homicide (Quest Atlantis)
3. Professional simulation/epestemic games	Gamers role play scientific or technical professions and conduct authentic practices, e.g. as forensic detectives or urban planers	Game-based innovation Homicide (Urban Planer)
4. Embodied system games	Focus on experience and manipulation of scientific phenomena; centre on, e.g. atomic models or electromagnetic forces	Quantum Moves (Supercharged, NewtonWorld)
5. Research collaboration games	Participation in real high-level scientific research and technical development, e.g. in scientific discovery games designed to help real-life scientists solve authentic scientific challenges	Game-based changing of unsafe urban spaces Quantum Moves

SCI database to find the relevant work published in journals. They continued by iteratively going through these articles and involving in a discussion. These education researchers focused on three dimensions; the pedagogical approach in the game, the research method used, and the game itself. There was a detailed explanation of how every dimension is used and applied in the game, for example explaining what the pedagogical concerns of the game are, the research concerns, and how the game works. The results of the game dimension showed the most popular journals for games, followed by the most reviewed category of games which in this case was ‘adventure and role-playing games.

The results were further categorized by whether the games were single-player or multiplayer. It was also shown that out of 53 games reviewed, 45 were for science education, while the remaining eight were for non-science. Apart from this, the gaming dimension concluded the results in 7 more categories. Further in the paper, the results of the pedagogy dimension were shown, it was categorized according to most taught science domains in the games. Other categories of results were theoretical foundations, Instructional strategies, and pedagogical role. The learning environment was the most important pedagogical role used in the years mentioned. Finally, the results of the research dimension for the mentioned journals were categorized according to the most targeted audience by the games, which in this case was pre-school students. Research methods and research foci were the other two categories where charts were led by quantitative research and cognitive outcomes respectively. It is concluded that the term serious game has evolved as the number of studies covering it increases and so does the number of games. Serious gaming is becoming an important phenomenon for science education teaching [48].

B. Enhancement of serious games in science education over time

Another article published by ENVRIplus in May 2016 talks about how serious gaming is an improved, and user-friendly way of attracting students towards education and learning. ENVRIplus is a research center working on multiple domains, one of these domains include serious gaming. They talked about how the game they are developing will specifically focus on science education. They were going to train student scientists to research different infrastructures for the project. This was also a competition between students as to who contributes the most to the project, so this project was practicing a way of serious game, to conduct research on serious gaming. The game is now playable on the Envriplus website [49].

C. Use of serious games in science education for children

In addition to that, some other games are available for children to learn science education. One game that has helped children to learn about plants is ”how to grow a plant” [50] shown in Figure 3. In this game, children learn how much sunlight and water does a plant need to grow. They have to balance it out so that the right amount of water and sunshine is provided. In this game, they try to grow a perfect plant in different conditions. Another game that helps children learn about science education is melting points [51] shown in Figure 4. In this game, children learn about melting points and boiling points of different objects. They can heat things and cool them

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Fig. 3. How to grow a plant Game [50]

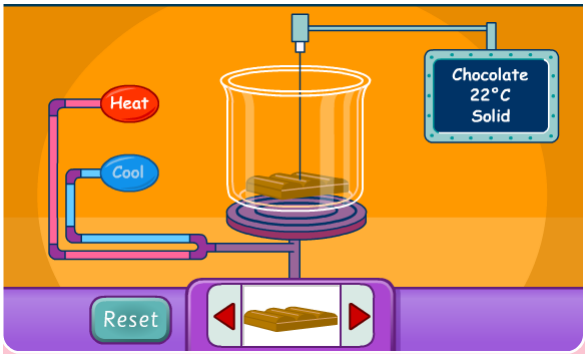

Fig. 4. Melting Points Game [51]

as there are different buttons for cooling and heating. They learn at what point do things like chocolate, aluminum, candle wax, butter, and ice candy melt. All of this stuff is helping them learn more science stuff. As you can see in figure 3 and figure 4 that the games have a very simple user interface as the purpose is to help children enjoy and not complicate the games as well and by playing the game they are also increasing their knowledge.

Learning through games is becoming the modern way now as a research 'Learning Science Through Computer Games and Simulations' covers on how the learning methods in the US are outdated for science. It is stated that we live in a time where technical knowledge along with scientific competence is vital for the future, the students in the country are dealing with uneven quality of education. In most cases, students just spend their time listening to lectures and memorizing facts which eventually makes them lose interest. On the other hand, in some cases, experts are calling for a different approach to science education. They demand a more practical approach which demands students to be part of investigations to gain scientific knowledge. It further expresses how computer games and simulations can improve the learning experience by offering interactions with scientific representations. This phenomenon can offer motivational challenges to students as well as help create new material for specific needs and interests. A two-day workshop was held to further explore and examine the possible relations between gaming and science learning followed by a discussion session among the committee to discuss and find a consensus about future possibilities in the field's research agenda. As a result, the research questions were identified, and the conclusions found were stated. It was decided that the committee believes games and simulations to be a worthy investment for the future, as they are expected to deliver a learning experience that will allow user interaction. Most investigations of simulations have concentrated on reasonable comprehension, giving promising proof that simulations can propel this science learning objective. There is moderate proof that simulations increase students' enthusiasm for science and science learning, and less proof about whether they bolster other science learning objectives. Proof for the adequacy of games for supporting science learning is developing however is as of now uncertain. Until this point in time, the examination base is restricted [49].

As serious games are increasing it is seen that all other fields other science education is also trying to improve teaching education through games. A research paper completed in 2018 'Serious game in science education: How we can develop mathematical education' talks about how serious gaming has improved science education and now they look forward to bringing a similar impact to mathematical education. They developed a computer game to help improve the players' logical thinking and declared that they were now ready to test the game in primary schools [52]. Just like them their game there a lot of games that help children learn about math now as a game canoe puppies, shown in figure 5, helps children solve simple math problems as when they solve a question their team paddles away to win the race in water which can be seen from figure 5. Other fields are also improving as a paper tells how significant and rapid development in science, engineering, and technology such as production and proliferation of mobile and electronic devices, robotics, digital communication, and information systems have enabled instant now, and exchange of various forms of data, work, and capital. These developments and activities have forever transformed the nature and organization of life, including human, non-human, and more-than-human life [53].

Furthermore, it is believed that the use of such games will strengthen student inspiration [54], encourage knowledge acquisition [55], boost task involvement [56], and nurture specific skills such as problem-solving and cooperation [57] by properly envisioning abstract ideas and fundamental precepts of particular topics in the gaming environment.

Researchers have used some popular video games as models to explain that non-learning entertainment-oriented games can be effective for learning activities given the right circumstances [58] [59].

D. Augmented Reality in Serious Games

AR is a new IT feature that can present virtual objects or digital information in the real world. AR can also be considered as a bridge between the real world and the virtual digital one [60]. Reality-virtuality continuum [61] (see Fig.

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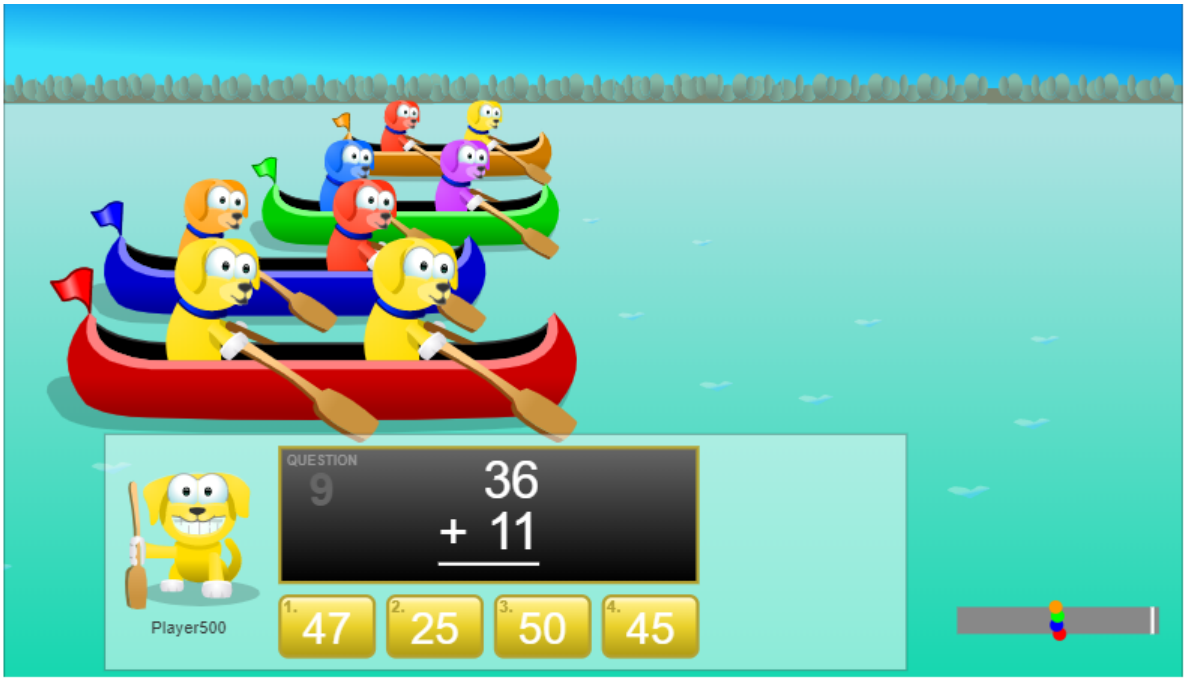

Fig. 5. Canoe puppies [51]

Fig. 6. Reality-virtuality continuum [62]

6) is most clear description the relationship between the real world and the virtual one.

Physics – is the science about nature which studies how nature works, what rules are obeyed, and what may happen in different natural processes. Simulation games – a sub-category of games which is basically a simulation of real-world activities.

We found three real-world related papers to review usability, motivation, learning effects of "AR in simulation-based games in Physics". In the last part of this paper, we will discuss the benefits of two simulation games like "Force and Motion", "State Change of Water" to analyze how successful are simulation games and do they worth being implemented in AR and one AR game "AR-SEE" [38] as an example of real application in the field of AR games in Physics.

Force and Motion is a PC game that teaches students to learn some laws of nature like gravity, friction, magnetic forces. On Figure7 which is from [39] you can see how game is implemented. The game was developed in Unity in which just typing script is enough to describe objects and positions.

The second game was "State Change of Water"(Figure 8) – a mobile game to control the flow of water to save as much

Fig. 7. "Force and Motion." (a) The game lobbies. (b) Stage selection. (c) The fist stage for quiz. (d) The second stage for learning the frictional and gravitational forces. (e) The third stage for learning the magnetic forces. [38]

water as until the final place is reached.

The third game we found; we were expecting to match what we want from AR games in Physics. Augmented Reality Solar Energy Education(AR-SEE)– the game was intended to teach solar energy education which is part of physics and its use. In Figure 9 you can see no AR Desktop version and in Figure 10, you can see AR added mobile version.

Vicente F. and others compared and proved that the learning

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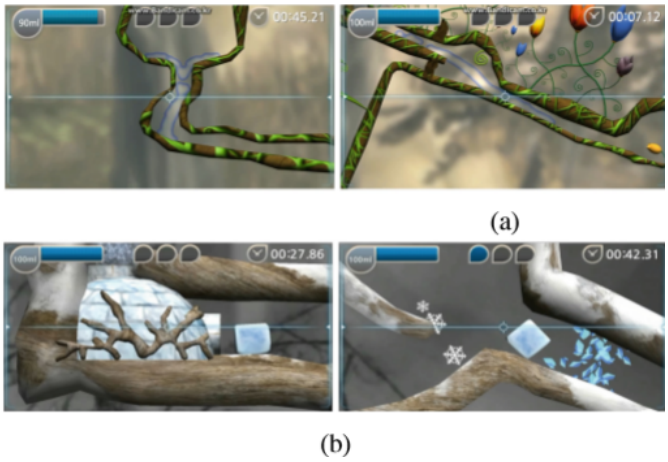

Fig. 8. "State Change of Water." (a) Water. (b) Ice. [38]

Fig. 9. "Solar Energy Education game on desktop app without AR." [38]

Fig. 10. "Augmented Reality Solar Energy Education(AR-SEE) game on mobile app." [38]

effects and motivation of the AR version are higher than the Desktop version of the game [38].

It is also widely believed that simulation-based AR games in Physics can improve the motivation and learning effects of learners since Physics is the science of nature and we need to imagine a lot of processes in nature in order to understand how nature works. it is also believed AR is a good enhancement for simulation-based games in Physics [63].

III. Method

The study aims to conduct a systematic literature review of the research conducted on science education in reference to serious gaming. To see if the use of serious gaming has grown over the years, also if the learning experience of science education is improved. To do so, first, we laid out the research questions, search keywords, and inclusion and exclusion criteria for our research. The papers selected for review in this study were from the years 2011 to onwards. Only published research papers and articles were considered for this review. (Springer database is searched for the timespan of 2016 to onwards).

All the content was looked up using IEEE explore, Springer, and Scopus libraries. The following keywords were used for the search of science education content; *('science education' OR 'education science') AND ('serious games' OR 'gamification')* in Title or Abstract. We tried searching the same keywords in the *indexing terms* of the paper, but we received lots of irrelevant papers. So we decided to narrow it down to just Title and Abstract.

A. Inclusion & Exclusion Criteria

The title, abstract, and conclusion were reviewed. It was confirmed from the abstracts that the papers use serious gaming or science education as their primary discussion. Papers were excluded based on the following criteria:

- Studies related to Serious games but not focused on Science education.
- Studies related to science education but without using serious games.
- Studies are not offered in English.
- Studies are not available in full-text.
- Preview only content.
- Literature review studies.

B. Results Overview

The results concerning libraries are as follows. We reviewed a total of ninety-two papers and found forty-two relevant.

Database	Obtained from initial search	Relevant	Year
IEEE explore	26	14	2011 - 2020
Scopus	26	11	2011 - 2020
Springer	40	17	2016 - 2020
Total	92	42	-

Figure 11 shows the complete research approach from start to finish. We started by defining the research questions, after that we defined our research strategy. At that stage, we selected

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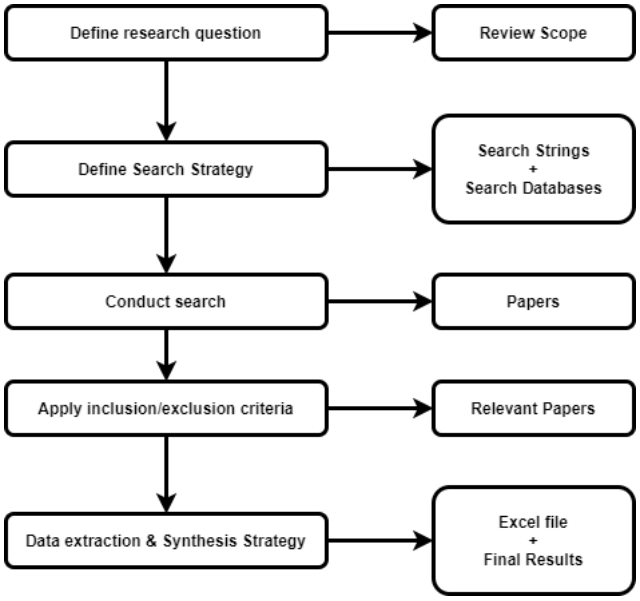

Fig. 11. Complete method for systematic mapping

the databases as well the defined the search strings. After getting results from three databases using our search string, we did an initial analysis of the papers. In the next step, we applied the inclusion \exclusion criteria. After getting relevant papers we analyzed them and created an excel sheet based on the results.

C. Research methods in related studies

We identified what research methods are used in papers generally and how their results were found. How many conducted researches were quantitative, how many qualitative, and how many were based on a systematic literature review? What was the number of participants in the research, and how the tasks were classified? The methods were defined in three different dimensions. These dimensions were gaming, teaching, and research. In the gaming dimension, the roles and categories of the games were examined. The different types of games used are role-playing games, puzzle games, strategy games, simulation games, action games, and fighting games. The games were also categorized according to their designs to see how many games were multiplayer or how many were single player. They were further categorized to see which skill or learning outcome was expected of each game.

Then comes the teaching dimension which focuses on examining the teaching concerns. The results for this dimension were categorized according to subjects taught in the games. In this case, the selected subjects were physics, chemistry, biology, and earth science. Further categories were made according to the theoretical foundation of games, the categories involved were constructivism, cognitive theories, Vygotsky's theories, situated learning theory, activity theory, and activism. This dimension also had the games categorized according to the instructional strategy used. collaborative learning, inquiry-based learning, problem-solving, learning by designing, prediction-observation-explanation (POE), and self-explanation were the categories used for this strategy.

Finally, the methods of the research dimension were explained and how the results were categorized according to this dimension. Firstly, the participants were categorized according to their academic levels, these levels were preschool, elementary school, junior high school, senior high school, and university or college. Secondly, the categories were made according to the research methods used. Quantitative research where only quantitative research methods were used, qualitative research where only qualitative research methods were used, and mixed research where both quantitative and qualitative research methods were used.

IV. Results

In this section, we will discuss the results extracted from the literature mapping and will answer each of the research questions written in the Introduction such as the major contributing journals, year distribution of the articles, country-wise distribution, and main evaluation methods. In addition to that, we will briefly discuss the results from relevant studies as well as from the study related to AR or simulation-based games in teaching physics. Furthermore, we will talk about the positive and negative aspects of the use of serious games in science education. Last but not the least, we will briefly write about the public or learners' attitudes towards the use of serious games in education.

A. Numbers of studies published and major contributing journals

Figure 12 shows the number of studies about the use of serious games in science education published from 2011 to date. It can be seen that Springer has the leading number of studies published, which is seventeen. Whereas, IEEE and Scopus have fourteen and eleven respectively. (Results of Springer database is from the year 2016 to onward).

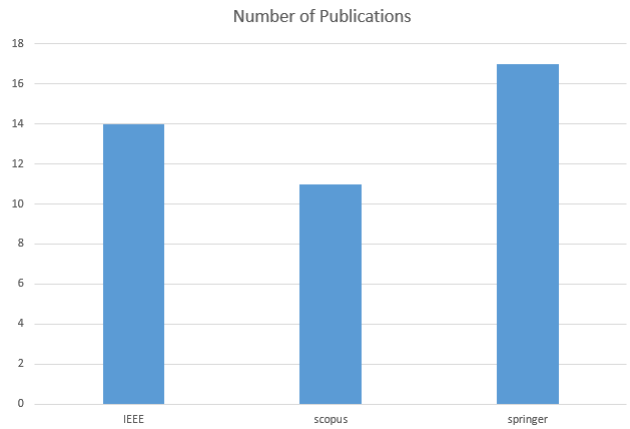

Fig. 12. Number of Publications with respect to Journal. With springer having the leading number of seventeen publications.

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B. Year distribution of the articles

Figure 13 shows the number of studies with respect to years. As per the results, the year 2016 stood out to be the most active year when it comes to research regarding the use of serious games in science education with a total number of twenty-one. In the year 2012, 2013, and 2018, four studies were carried out each year.

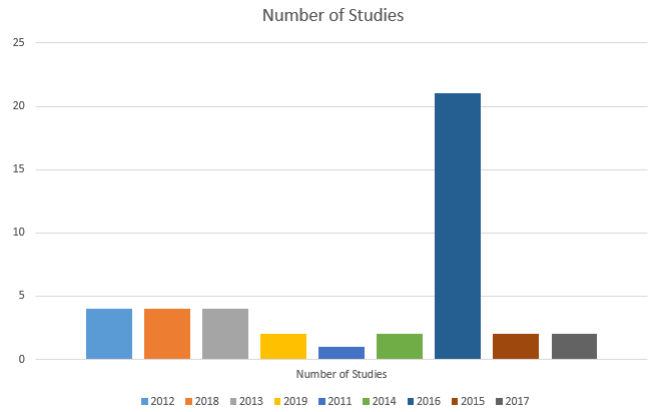

Fig. 13. Number of Studies with respect to year. Twenty one publications in the year 2016.

C. Country wise distribution

The results of the country-wise distribution of studies are shown in figure 14. Studies and research work is carried out in a total of twenty-three countries around the world. The leading number of studies, ten, are carried out in the United States. Whereas the second largest number of studies are carried out in the Netherlands. It can also be seen that a major portion of studies is done in the developed countries such as the United States and a lot of European countries, and a very small number of researches are being done in developing countries. As per the results, there is not even single research that has been done on serious games in science education in south-eastern countries like Pakistan, India, and Bangladesh.

D. Evaluation Methods

Figure 15 shows the number of studies using different evaluation methods such *Observation*, *Questionnaire* and *Interviews*. It can be seen that the leading method of evaluation in these studies was *Observation* used in twenty two studies. Eleven studies used *Interviews* as a method of evaluation. Last but not the least, nine studies used *Questionnaire* as a method of evaluation.

E. Summary of results in the relevant studies

The results found were recorded according to every dimension and each category. It was found out that adventure and simulation games have played a major role in contributing to science learning in the form of serious games whereas fighting and action games need to do better. It was also discovered that almost 65% of the games were single-player, while others were multiplayer. In the teaching dimension, it was found that physics and biology are the most taught subjects through serious games whereas not a single game was found for chemistry. Coming down to instructional strategies more games were found out about teaching problem-solving skills and collaborative learning whereas very few games are there to teach self-explanation. For the research dimension, the results we will first discuss are according to academic levels. It was discovered that most of the games are for elementary students and junior high school students. Then comes the senior high school and college for most games made and finally the pre-school. Further categorization was according to research methods. Most of the researches conducted was quantitative, then on the second it was a mixed-research method, and third was the qualitative research method with the least number of researches.

It was also found out that science education is the most used topic for serious games, research was conducted that showed there are hardly any math games for learning. Science education games were reviewed to find out the methods and approaches used for game development and how they can be improvised to create a math game. If there is research conducted of this sort, we can say that science education has come a long way in collaboration with serious games that it is now inspiring researchers of other fields to learn and improve from it. Dating back to 2002 when there was hardly any research done for science education in serious gaming to 2018 when it is inspiring other fields to get involved with serious games for an advanced form of learning, we can say that it has come a long way over a period of these 2 decades.

The evolution of science education and its teaching methods over the years has caused many improvements in the field of learning science. People find it easy to grasp science knowledge, and by learning to use it through practical methods, they find it easy to benefit from these methods learned when applying them to real-life situations. Now that the learning of science education is more practical, it is now more effective in people's lives.

F. Results for Simulation based serious games in Physics

"Force and Motion" and "State Change of Water" were evaluated using things proposed by Jung et al [64]. In Table II you can find elements of evaluation by teachers and in Table III you can find scores given by schoolteachers. The number of teachers involved is accordingly 7 teachers in "The Rift of Dwarves," 6 in "The Gold Mine of the Owl King," 8 in "The Orange Mountain Range," and 4 in "State Change of Water." Firstly in the category of teaching-learning strategy, "The Rift of Dwarves," "The Gold Mine of the Owl King," and "The Orange Mountain Range" got scores higher than "State Change of Water". The scenarios of all games were commented as good by teachers, but they mentioned bad music, a low point gaining system, challenging levels. The screen organization was evaluated below 2.5. Most probably this was due to the bad quality of graphics. But this needs to be understood as the most common weakness of prototypes. The technology was averagely 2.97 which was expected since

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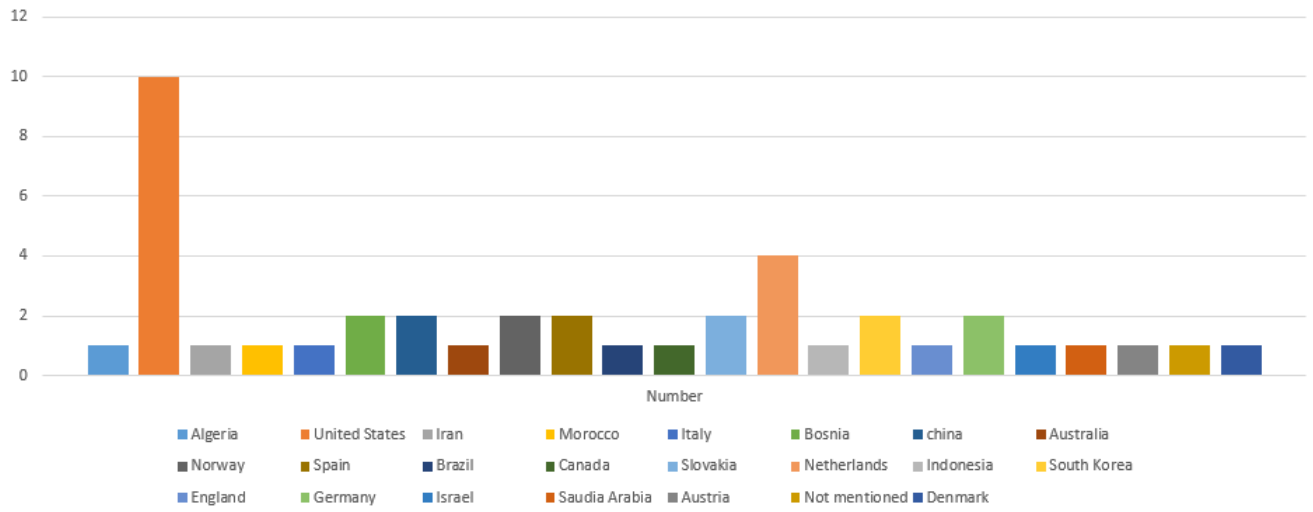

Fig. 14. Country wise distribution. Research was carried out in twenty three countries around the world with United States having the leading number of ten. In most of the countries only one research/study was done.

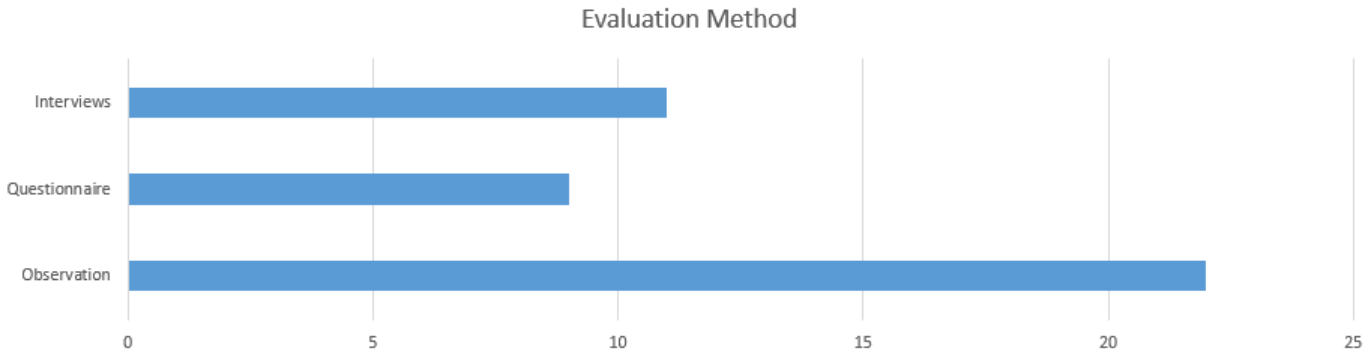

Fig. 15. Evaluation method(s): questionnaire, interviews, observation

frictional/magnetic forces and particle-based fluid simulations are excellent tools, which are almost impossible to meet on existing games. The economics-morality element got a high score. Mostly because it was available for free and easily downloadable. But also from a survey elementary school teachers mentioned that animations much are more appropriate for them and work needs to be done.

Generally, according to [39], teachers evaluated game to be low in teaching-learning content and rewarding system and needs improvement about animations since it is for elementary school students, but the technology was evaluated positively.

AR-SEE game and its desktop version were tested by 36 graduate and undergraduate computer science students, starting from 20 until 30 years old. Tests were conducted in three categories: Usability, Learning Effects, and Motivation. it was used the Kruskal-Wallis test, Wilcoxon Signed-Rank test, Spearman Rank correlation test. The results persuaded researchers that despite decreased usability, AR serious games can enhance motivation to learn.

Evaluation elements	Meaning
Teaching-learning contents	Validity of purpose, validity of contents, practicality of contents, reliability of contents, systemicity of contents, appropriacy of quantity
Teaching-learning strategy	Motivation, learner control, feedback, consideration of learner level, \system to help learning
Screen organization	Appropriacy of design, freshness of design, convenience of design
Technology	Systemicity of management, security
Economics morality	Copyright protection, human rights protection, personal information protection, economics

TABLE II
ELEMENTS OF EVALUATION [39]

G. Positive aspects about the Use of Serious Games in Science Education

There are a large number of conclusions in serious game-assisted education, which are mostly supportive, coupled with a few bad outcomes. Serious gaming infused learning will make it easier for learners to understand science comprehensively because of increased science efficiency and the continued maintenance of science information. Game immersion

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2*Games		Average scores					2*Average
		Teaching learning contents	Teaching learning strategy	Screen organization	Technology	Economic-morality	
3*Force and Motion	The Rift of Dwarves	2.31	3.00	2.33	3.00	2.65	2.89
	The Gold Mine of the Owl King	1.62	2.60	2.33	3.50	2.26	2.44
	The Orange Mountain Range	1.62	2.40	2.00	3.00	2.15	2.44
Earth and Moon		2.78	1.85	2.60	2.33	3.25	2.41
State Change of Water		2.56	2.15	2.40	3.00	3.00	2.47
Average		2.18	2.40	2.33	2.97	2.66	

TABLE III
RESULTS OF EVALUATION OF "FORCE AND MOTION" AND "STATE CHANGE OF WATER" [39]

has also been favorably associated with the success of science literacy [65]. Furthermore, in both serious gaming and non-game-assisted learning methods, no major discrepancies in undesired factors (e.g. grievances or disruptions influencing the gameplay environment of other players) have been reported between teachers and learners [66]. Serious games are effective in improving cognitive ability and power, as well as fun mood, in generalized learning. They have been observed to help learners develop cognitive abilities and increasing the positive effect of learning [67]. Serious game also helped pedagogy to offer open learning for various learners who could step beyond the boundaries of conventional learning [68]. Game-based learning has also been shown to be effective in socio-cultural learning in contexts of cognitive and uplifting effects. Given the fact that the vast majority of studies favorably assessed the impact of serious games on learning, human interactions and social communication, negative outcomes could not be overlooked [69].

H. Negative aspects about the Use of Serious Games in Science Education

Some studies also found a few negative results, especially in terms of the correlations between mental workload and learning effect. According to a research, the nature of serious games negatively influenced the relationship between mental workload and learning effect [70]. In the case that a difficult game makes the intellectual workload heavy, the playing result seems to be adversely affected and vice versa. This is also no surprise that, in the serious game "Peacemaker" (Impact Games 2007), there were no major gaps in in-depth learning between learners [71]. This form of serious game may have exacerbated the cognitive workload and thus reduced learning performance, as the mental workload, such as the increase in heart rate, has dramatically suggested learning outcomes at a certain level of difficulty [72].

I. Attitudes towards the Use of Serious Games in education in general

The development of perceptions towards serious game design using sophisticated computer technology has been recognised as a crucial factor in the use and adoption of information technology [73]. Understanding the attitude of learners towards serious game-assisted learning is important for scholars to develop effective teaching outlines to satisfy the various needs of learners and for practitioners to create sound, realistic games to promote learning performance. Different attitudes reflect the specific needs of learners and professionals, on which developers and teachers of serious games can base their theoretical and realistic structure [74]. Serious games can enable learners to maintain positive attitudes towards academic tasks with good self-regulation if they are immersed in a gaming situation. Optimistic attitudes allow learners to gain success than pessimistic attitudes. It is therefore fair to assume that serious gaming leads to far more constructive behaviors than conventional schooling. Serious games mounted on iphones, iPods or other handheld devices may be used for mobile gaming. Unlike conventional classroom-based learning, virtual learning is not limited to set classrooms. Learners continue to be drawn by their versatility and ease. Students typically have positive attitudes towards this enticing learning strategy, which quickly sparks their curiosity and inspiration [75]. In order to promote positive attitudes towards serious game-assisted learning, close attention should be given to the way serious games are created [74].

V. CONCLUSION

Previously, the word serious game has generally been used to refer directly to a game that was originally designed for training and education, as opposed to a commercial game made for amusement [76]. The definition of serious game has improved over the years as there was an increasing number of researches being done and the number of studies that employ commercial games to facilitate the occurrence of learning has increased [77].

We can conclude that a decent amount of research is being carried out, and there is a steady increase, but at the same time, this vast field has a huge room for further development and improvement. But still, it is in a very early phase. The improvement needs to pace up, because compared to technological advancements the world makes every year, serious games development is lacking behind. Especially in the developing countries, more focus and attention is required

to develop and use serious games in the institutions providing science education.

Moreover, science education must be covered entirely as some science subjects are far behind others in this regard. In the years to come the work is expected to speed up and serious gaming is expected to cover both scientific and nonscientific subjects and improve the learning experience for every field. Helping science education and serious gaming to reach this level of efficiency will be challenging as well as crucial in the coming years.

Furthermore, results of evaluation by teachers on "Force and Motion" and "State Change of Water" are considered positive, as technology improved motivation and learning effects among elementary schools' student. At the same time, it also has some limitations. Teachers somehow agreed on advantages of serious games using simulations in physics. Simulations are core of any AR game, so we got an evidence to prove that from the experiment above for AR games in Physics. In the second test using AR-SEE and its desktop version after results of tests of usability, learning effects and motivation AR games showed less usability but very high interest to learn about passive solar energy by university students proving the benefits of AR. On Table III it is clear that Technology made positive change for user motivation to learn Physics. During review of papers and evaluation numbers, we felt more confident about advantages of simulation based AR games in Physics, but a lot of things need improvement on usability of AR.

VI. Trends & Future Work

A systematic literature review was done at the Beijing Language and Culture University in 2019 to find out the trends of publications related to the use of serious games in education (not science education). As shown in Figure 16, the year 2009 began to witness publications about serious game assisted education. With the passage of time, the number of publications steadily rises until its peak in 2017. The year 2018 also predicts a large number of publications since the data were obtained in September 2018. Far more publications may be waiting to be published and indexed in "Web of Science". The reasons for the increasing number of publications should be explored, among which influencing factors in serious games assisted education should be first discussed [74].

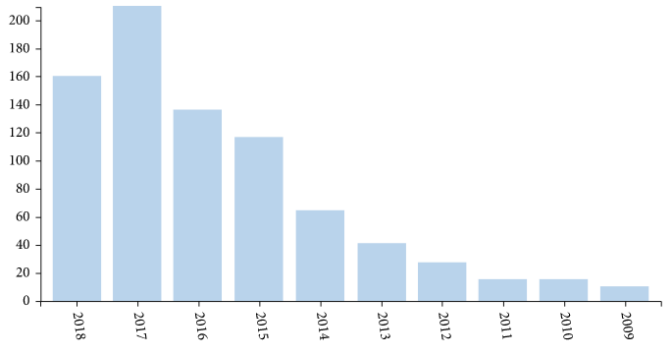

Fig. 16. A histogram of related publications ranging from 2009 to 2018

A. Future work in AR based serious games

Despite the fact that all the evaluations are done qualitatively, we still cannot absolutely answer many questions, such as what if there was human bias? What if Simulation-based AR games are not good enough for other fields of Physics like Optics or Colour? What if surveyors were felt interested in AR because they never tried it before? What if users' motivation is not stable? meaning after continuous playing they do not really engage in the game. Evaluations probably need to be done in a longer time range. There is a question of "how generalized are the results?". To answer that question more detailed questions need to be answered and if existing products would be personalized to people, maybe other evaluation methods and a different audience is required.

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