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Review

Technological Aspects for Pleasant Learning: A Review of the Literature

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Abstract: The teaching–learning process, at each educational level, is often an open problem for educators and researchers related to the stated topic. Researchers combine emerging technologies to formulate learning tools in order to understand the abstract contents of the subjects; however, the problem still persists. A technological learning tool would be effective when projected into an educational model that looks at motivation, usability, engagement, and technological acceptability. Some of these aspects could be attributed through the use of augmented reality and games. The aim of this work is to analyze, in the literature, the trends of learning models based on computer technologies for an effective and enjoyable learning activity. The analysis of the literature in that context—emphasizing acceptability, categories, entertainment, educational models—shows that it is still not well explored.

Keywords: enjoyable learning; augmented reality; educational games; learning models; learning tools

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1. Introduction

The teaching–learning processes, at all educational levels, are an open problem for educators and researchers related to the subject in question because the topics of abstract concepts, content in many areas of knowledge, such as mathematics, chemistry, physics, among others [1], as well as technology and engineering subjects [2], are not correctly assimilated by all students. Learning technologies help a lot, but they also increase the difference in the learning rate between students of the same level. Educators consider several factors in this learning behavior; among these factors are those related to the effectiveness of technological learning tools.

Along with the evolution of technologies, research work emerged from different areas of external education, especially in the field of computer science, looking for effective alternatives to learning processes through the use of augmented reality (AR) and the approach of games. A common approach found in the literature is to find ways to minimize the complexity of understanding abstract content related to the students' universe [3–5]. With respect to this effort, finding an ideal scenario where all subject content is learned by the entire student universe is, perhaps, a utopia. However, and thanks to the technologies mentioned above, the learning process has evolved notably.

On the other hand, it has been observed that many learning tools based on computer applications have not been accepted. This could be due to unsatisfactory results related to parameters in technological acceptability [6], motivation [7], and usability [5], among other parameters, required by educational users. In addition, application approaches depend on considerations of age and educational level of the learners to incorporate motivational attributes, combined with augmented reality (AR) game techniques, which allow learners to maintain application use. Lack of motivation and perception of relevance in the real world are consequences of a child's low interest in science [8]. In this case, games based on learning and narratives can be the right tool to generate an intrinsic motivation in learning. In a general way, we understand that this tool must captivate the users (students and learning agents) as a technological acceptance. This means that it must be related to some educational model, using learning techniques that are engaging, motivating, intriguing, and enjoyable.

The aim of this work is to analyze the trends of the technological aspects for an enjoyable learning, addressed in the literature, according to the effective learning technological tool. For this case, the contribution of this work is focused on analyzing, clarifying, and responding to the issues we formulated in Section 2. Educational technologies are presented in Section 3; existing work on enjoyable learning tools is discussed in Section 4; proposed topics are discussed in Section 5; and finally, conclusions are presented in Section 6.

2. Method

There are numerous literature review articles on AR in education [9], providing assistance in science, technology, engineering, and math learning [10,11]; AR games related to learning and social interaction [12]; educational games [13,14] and digital games in interesting activities [15,16]; AR-Mobile in learning abstract concepts [17]; AR as an interactive system for math learning [18]; AR in sport education and training [19]; and using games and AR in education [20]. However, it is not common for literature reviews to integrate AR, games, learning models, and pedagogical ways for fun learning. Therefore, the aim of this review is to investigate the characteristics that occur in learning methods based on computer technologies, use of AR paradigms and games, and learning motivation in students of different levels. It is worth mentioning the relevant aspects involved in this study, for which the following questions are resolved:

Q1: Are used acceptable parameters for effective learning applications?
Q2: How are the teaching–learning technology tools classified?
Q3: What elements are considered to make a learning technology tool entertaining, interesting, and intriguing?
Q4: How does AR contribute to improved learning?
Q5: What educational models are used in AR-based assistive learning technology tools?

For that, relevant articles from 2015 were analyzed. Documents were obtained from IEEE Xplore, ACM Digital Library, Science Direct, Springer, and other scientific sources. Articles were searched using the following keywords and their variants: "augmented reality in education", "augmented reality and learning", "enjoyable learning", "games in education", "learning methods and technologies", "augmented reality and motivation". Some sources before 2015 were also used to obtain references of concepts and approaches, especially in relation to the origin of some important technological trends mentioned in this study.

3. Information Technology and Education

The insertion of information technology in education aims to promote effective improvements in the learning process. For this we consider that a technological tool for teaching–learning is appreciated from the perspective of the learners, instructors, and educational promoters. Depending on the type of tool, its qualities should captivate users interested in learning through its use. Therefore, we see that it is necessary to specify the elements that could define these attributes and the types of technological tools commonly used.

3.1. Elements for a Pleasant Technological Learning Tool

The elements considered in the design of a teaching–learning technological tool define attributes that cause positive attitudes in the learner user and the teacher for their acceptance of use. These attributes are related to the effectiveness of learning, pleasant interaction, expected motivation, and construction of knowledge through experiences, among others [16]. These elements are generally integrated in learning methods, motivational psychology, usability principles, learning games, and physical–virtual combination approaches, among others.

3.1.1. Learning Methods

Active learning methodologies encourage students to develop their knowledge by performing dynamic activities such as teaching, practicing, and discussing specific topics [21]. One of the techniques of active methodologies is project-based learning (PBL) [22], in which students acquire knowledge and skills by exploring problem-based challenges. This means the method integrates knowledge and doing, and focuses education on the student who learns from the experience [23]. PBL is associated with Piaget-inspired constructivist theory, in which knowledge is constructed by the student through experiences and global perception. Constructivism encourages students to learn science and develop critical thinking skills by solving real situations, and this is motivating for better learning [24]. These methods are incorporated to technological tools, based on the Internet and interaction devices, giving good results in the development of fundamental, critical, and investigative skills of students [25], particularly in the learning of science, technology, engineering, and mathematics [26,27].

3.1.2. Motivational Psychology

In positive motivational psychology, the theory of self-determination (SDT) studies motivation and human personality. Motivational SDT considers intrinsic and extrinsic sources. Intrinsic motivation leads to pleasant and interesting behavior, while extrinsic motivation is based on external compensations or impositions. SDT bases its principles on the fact that humans have a natural tendency to be intrinsically motivated, including external regulations, for example, self-regulation for personal psychological growth, social integration, and well-being [28]. The SDT hypothesis is that people have three innate psychological needs: competence, autonomy, and relationship. Competence is related to the desire to be sufficiently effective when performing an activity. Autonomy refers to the desire to regulate one's own behavior. Relationship refers to the desire to have a close relationship and affectivity with others. The reviewed works consider that the use of AR and games induce motivational aspects for learning [19,20].

3.1.3. Usability in Learning Tools

A technological learning tool must captivate the user and possess the following attributes: ease of use, attractiveness, promote a pleasant and efficient interaction, and, above all, be acceptable for adoption. Researchers in human computer interaction (HCI) are clear on how to deal with the concept of usability, which is a parameter that offers performance measurements, error rates, or user satisfaction in human and system interaction. Usability, for example, when several users interact with the technology, is measured in terms of factors such as the quality of conversations, richness of gestures, and smoothness of movement. In [5] usability was considered in relation to the user as individual constraints, experiences, perceived cognitive load, technical design aspects, and orchestration load. Usability takes priority in the development of learning tools with augmented reality (AR) technology [9,29]; since technology implies an intense user interaction, usability also implies cognitive dimensions and good user experiences related to affective variables. Cognitive load, as approached by [30] in AR educational games, can be divided into mental effort and mental load. Mental effort (or foreign extrinsic cognitive load) refers to the external resources needed to perform a task; it implies that the design of learning approaches should minimize mental effort to leave more memory operating capacity. Mental workload (or intrinsic cognitive workload) is caused by the learning material and by the interaction between tasks as well.

3.1.4. Learning Games

Learning through games has been effective in various situations [31], for different purposes and for different ages. In particular, the learning processes in children have shown that games have a great potential to capture attention [8]. Games are intrinsic motivators for children to actively participate in the learning process. Learning games have demonstrated to be appropriate in helping students develop an understanding of scientific concepts and processes [32]. A player is trapped for an unlimited amount of time looking for strategies to win and experience the excitement of play. Precisely, these actions are subject to the fundamental psychological needs of SDT, among which are the following: competence, autonomy, and relationship, considered as the basis for gamification [28]. Therefore, games provide a sense of well-being. When a game is projected with educational purposes, it is necessary to address the concept of gamification that, according to [31,33], is related to the design of game elements, strongly related to ludus, games with purposes, and serves to create meanings, sense of actions in human beings, classifications and competence [20,34].

3.1.5. Augmented Reality

The AR system is characterized by the combination of virtual and real objects, perfectly aligned, in a real scenario, so that a user can interact with them in real time [9]. Such connection between physical and digital domains allows the human being to build complete visions of cases and phenomena that happen as if everything were real. The interactions are carried out through desktop computers with cameras and, more recently, through cell phones [35]. An AR system uses input and output devices with spatial position and orientation that can be tracked on a computer platform, based on a framework of manipulation of AR input/output software and application behavior. In education, students can analyze the abstract concepts of science at the level of objects and their properties for effective discernment and, therefore, increase knowledge retention through experimentation [36], following, for example, the constructivist approach. Students can use AR mobile applications (MAR) in or out of the classroom. The trend of research in recent years is the preference for the use of MAR in education at various levels (61%) [37]. About 24% of AR educational tool users are on the desktop computer [35]. The portability and variety of resources favor the preference for the use of AR. For example, the AR game Pokémon Go is used as a MAR with geolocation [38] that motivates the cognitive aspects (concentration) of children, and its extension can be oriented to learning [37].

3.2. AR-Based Educational Tools

Technology-based education promotes learning improvements in the classroom, in the laboratory, and as a supplement. Teachers and students use the tools in the classroom to develop subject matter classes that require more attention for comprehension. With lab experiences, learners verify the theories addressed in the classroom and conduct simulated practice for better understanding. The supplement encourages self-directed learning for any interested person [30]. A fourth category of the tool is aimed at people with disabilities. In [39], good effects on the science of education using AR-based learning tools are shown in relation to conceptual change, PBL attributes, sustainability, and special ability. In terms of uses, authors in [12] show that 42% of AR-based tools are used in the classroom, and 9% are used outside the classroom as a supplement.

3.2.1. Classroom

Research has shown that the use of information technology in the classroom enriches the teaching–learning process, increasing the performance of students in contrast to the use of this tool [36]. The theoretical concepts of the conferences can be illustrated with explanations in 3D, manipulating the operations of the tool [40]. For that, a combination of AR and tangible user interfaces (TUIs) is an effective complement to learning. To create new learning experiences, as mentioned [5], the use of TUI facilitates direct object manipulation and the ability to make a smooth transition between real life and virtual reality. Internal and external constraints must be met for learning solutions to work well in the classroom. To do this, ease of use and usability factors must be evaluated. The complexity of classrooms, particularly in laboratory tests, can affect the expected results; therefore, there must be a pedagogical way to control the environment, based on the postulate of the load of orchestration in the classroom [5], which is actually the minimization of the effort needed for the teacher and other actors involved in the classroom to perform effective learning activities.

3.2.2. Laboratory

The experimental verification of theories can be done in a real laboratory environment combining virtual and real elements, in an AR-based paradigm. This combination facilitates the interaction with scientific concepts, such as the behavior at the molecular level of gas dynamics [41], and visually unobservable phenomena in real cases [2], such as at the microparticle level [42]; it significantly improves the development of laboratory skills and develops positive attitudes in physics laboratory work for university students [9]. To some extent, the results of students' learning and laboratory skills have been ignored [39]. The MEteor mixed reality game system, interactive due to its body inclusion, allows an accurate understanding of astronomy physics for teenagers [2], discarding misconceptions learned in theory. According to [43], regarding lectures and learning science, technology, and engineering, which generally require laboratory exercises for experimentation and concept understanding, the use of technology as virtual and augmented reality offers advantages compared to real laboratories.

3.2.3. Complementary

AR-based learning technology cannot be used strictly in classrooms and laboratories, it can also be used, perhaps even more effectively, as a complement to traditional learning methods [44] with desktop or portable devices, promoting positive attitudes in learners [45]. Students can complement or deepen some subjects of studied knowledge, as any other academic, and the use of these tools generally is focused on human knowledge. Technicians can practice activities related to their profession or out of curiosity, as demonstrated [41] by technical assistance in sophisticated mechanical repair machines, where technicians must experiment repeatedly to learn, such as discerning abstract calculus concepts [18]. Academic scholars recognize that AR applications potentially motivate activities outside the classroom.

3.2.4. Disabled

Learning technologies in this category are generally targeted to children within a treatment for a specific disability to allow for easy education. Work in this category is generally based on play with motivational, psychological, and pedagogical attributes. There are works considered as good, such as ALERV, which help children with reading and writing problems, proposed by [46]. Reference [47] works with a game called ABCDyslexic, aimed at children with dyslexia, and mentioned by [48], it helps hearing impaired children through an interactive puppet show. An application derived from [49] for preschool autistic children identifies emotions through play. Reference [50] uses movement and object detection in the environment to train deaf and blind children [51] and presents an interactive MAR application for learning geometry, which improves learning motivation and frustration tolerance of disabled children. Among other approaches for that purpose, the combination of play and AR has been found to be quite productive.

4. Augmented Reality and Games in Education

The use of AR approaches and play techniques are generally preferred by researchers in the motivational educational context [7]. AR, which provides visual and interactive experiences combined with relevant information, allows the understanding of complex phenomena [52], while play techniques add the motivational aspect to the learning process [8]. The appropriate combination of AR and games, in the psycho-pedagogical context, within an educational model, promises to offer the student an interesting technological learning tool [35].

4.1. Educational Models with Technologies

The educational model is a set of organized and systematized activities to approach and solve a scientific problem in a cycle of initiation–execution–closure. They are known as teaching–learning sequences (TLS) for the classrooms, particularly focused on areas of abstract content such as science. Among them, the "demand for learning" and "educational reconstruction" stand out [53]. The first model is based on individual considerations and socio-cultural views of learning. The lectures discuss scientific ideas in class, focusing on students' daily thinking. It is the paradigm of the teacher–student and scientific relationship every day [54]. The model of educational reconstruction focuses on the construction of scientific knowledge for student understanding, summarized as a process of abstraction and deduction.

The four-stage TLS model (exploration, introduction of variables, systematization, and application) combined with AR technology, proposed in [3], improves the understanding of "reactivity in organic chemistry". In these phases, several activities are carried out with two types of operators: detailed level screens of their chemical compositions and experimental operators for the real-time manipulation of three-dimensional molecular elements. Usability principles, related to user experience, cognitive load, collaborative effort, and limitations of the classroom environment, are also considered in the model. We appreciate that, in this model, the TLS focuses on how to transfer content in the given context, and the tools allow for a constructivist approach to achieve the learning objectives proposed in each topic.

There is also good work on technologies in educational models that use the concept of instructional design. That concept, according to [55], is the process of transferring learning principles into educational practice, considering material, activities, sources of information, and evaluation. In [5], for example, instructional design focuses on the "development of learning activities" and "learning technologies", especially considering learning outcomes, the specificity of the contents to be learned, the peculiarity of the learners, and the principles of educational psychology, which are intrinsic elements in the learning process.

In that context, extrinsic elements, such as time, level of discipline, instructor workload, and class heterogeneity, addressed by [3,56], must also be taken into account. The practical aspects, as well as the interactive experiences of AR, make instructional design more effective [36]. This would be complemented by the postulate of "orchestration" [3] for good classroom logistics and learning relationships. There are continuous activities of intrinsic and extrinsic scenarios related to learning, which teachers must adequately integrate with digital and non-digital educational resources for effective work with students. This integration will be efficient if the educator feels that there are improvements in the habit of education.

4.2. Interactive Learning Model

Computer technology facilitates the interactive learning of the theories of science, making even microscopic elements and phenomena visible, for better understanding and abstraction. In this sense, science and technology are in agreement with the constructivist approaches, implemented following some instruction model. The constructivist theory is a dynamic and interactive conception of human learning, where the students redefine, reorganize, elaborate, and change the initial concepts through experiences in the environment [57]. In 1980, the Biological Sciences Curriculum Study (SBCS) developed the 5E model, as an improved version of the previous sequential model, inspired by the constructivist theory of learning [58]. This model, composed by five states (E1–E5), has been used by some works of interactive learning, as [51,52] with good results. Each state of that model can implement different methods and techniques of teaching [59]. The 5E is a sequential model of interactive instruction applied in an inquiry-based learning process [45]. This model fosters understanding of scientific concepts, research skills, analytical thinking, and reasoning skills. It encourages exploration and reflection related to other concepts [60,61]. The five states are Engagement (E1), Exploration (E2), Explanation (E3), Elaboration (E4), and Evaluation (E5). In each phase, an activity is carried out to complement the previous one. For example, in [58] teachers approach a new concept and relate it to previous and current knowledge, which is included in the E1 phase; in E2 students complete their knowledge through exploration experiences; in E3 activities are focused on aspects of participatory experience to show their skills and understanding; in E4 students are challenged to broaden their conceptual understanding to expand and deepen their knowledge and skills exposed in the previous phases; and finally, in E5 students are evaluated according to the objectives of instruction.

There are studies of the traditional 5E model, or combined with technological approaches, to facilitate the learning of science and technology. For example, in laboratory activities based on the 5E model, analyzed in [62], chemistry students began E1 with a "brainstorming technique" related to previously acquired known concepts. In the following states, they conducted experiments, interpreted the micro- and macroscopic levels of chemical solutions, and looked for explanations of the solutions. In [63], with good results, the 5E model was complemented with interactive multimedia to promote the learning achievement of undergraduate students in SQL. Due to the advantages of the 5E model for science education, an investigation among science teachers in schools in Turkey [61] concludes that states E3, E2, E4, and E5, in that sequence, are more conducive to the use of technologies. E2 state allows enabling cognitive constructions and interactive experiments, while E3 is more effective with visual elements. E4 should be used to relate to everyday life. E5 can be used to monitor multiple skills. An interactive model using AR within the context of the 5E interactive cycle for learning chemistry is implemented in [60]. The use of AR in this model is inspired by the good results of the works. The efficiency of the proposed model is verified with a group of students to learn the phosphorus molecule. In state E1, an interactive AR was used to engage the student, different from the brainstorming used in [62]. The learning outcome with this model was better than using, for the same process, only the conventional 5E model without AR or only conventional AR without 5E.

The analyzed works show that the use of interactive models based on 5E, combined with technological approaches in their states, as indicated [61], favors the improvement in the learning of science and technology concepts. The AR in a 5E model state, for example in [60], allowed better learning. It follows that other states could also be implemented with AR and narratives to motivate students to promote research. Table 1 illustrates a summary of the benefits observed by some sources analyzed using the 5E model and technologies.

Table 1. 5E model and technology.

Model and Technology	Results
5E + mobile	Develop scientific inquiry skills, learning motivation [64]; improves educational achievement [65]; improves reasoning ability, facilitates research, improves student participation [45].
5E + website	In mobile [66]: prolonged engagement in the mobile learning, enhances students' scientific knowledge, understanding, and motivation. In computer [61]: engage attention of students, make concepts more meaningful.
5E + conceptual play	In [67]: develop scientific knowledge and understand scientific ideas.
5E mobile + AR	In [60]: learning motivation, significantly improves educational achievement, construct mental images of the microcosmic world.

4.3. Augmented Reality in Learning

The use of AR in learning improves the development of students' positive skills and attitudes [16,18,35,66]. By simulating chemical processes using AR, for example, students can conduct research experiences by interacting with 3D models of microparticles [68]. Students better understand scientific concepts, for example, the analysis of chemical gas phenomena, verifying in the AR laboratory that they can visualize phenomena at the molecular level, which in real cases are not observable [69]. Similar benefits occur in the studies of phenomena and behaviors in nature. Particularly for basic natural science, students could observe and manipulate the time and situations of the evolving virtual insects on plant leaves for an effective understanding [70]. A similar form is possible to analyze the biological elements in 3D simulation for better understanding [36].

In mathematics, an AR-based tool, involving both technical and academic skills, can enable the student to develop his or her abilities for spatial and temporal perception of mathematical concepts and models. This can be oriented to the analysis and synthesis of calculation concepts, with 2D and 3D visualization of their geometries [27,32,71], with collaborative approaches (fighting against information exclusion) as a complement to the concepts addressed in the classes, interpretation of the results consistent with the theories as established by [40]. Learning basic mathematics with everyday life [72]—among which are mathematic teaching methods related to the theory of the Piagetian stage—is also an achievable alternative with AR, as addressed in [73], to weigh the physical, cognitive, and contextual dimensions. In this approach, mathematical concepts are assimilated by physical manipulators (such as coins, fruits, among others) and virtual manipulators (interactive software applications) that represent mathematical learning concepts. This form of interaction increases knowledge retention because abstract educational concepts are related to physical spaces and actions. Priority is given to aspects of intuitive interaction and coding of physical actions, which is part of computer-based interaction. In addition, in this line, computer science students improved the understanding of abstract and technical concepts using AR mobile tools combined with video material [18].

The use of AR in the classroom allows students to actively participate [41]. Classes are more effective and enjoyable if these tools are designed with pedagogical and orchestration techniques in the classroom [5]. However, some learning tools based on AR showed some observations in relation, in general, with the aspects of usability of interactive systems. In [74] they showed that AR tools generate a learning cost because the use of the natural interface reduces the external cognitive load [23,63], which is the mental workload generated by cognitive activities indirectly related to the learning objective. It also suggests, particularly for children, that AR experiences should work in a context that is appropriate for each user. This allows to take advantage of contextually relevant learning methods that can be accessed at any time from any place through mobile devices.

4.4. Games and AR for Pleasant Learning

The use of play techniques in education makes the learning process fun and enjoyable for students of all ages [20,75]. Students are motivated and participate enthusiastically in classes. For example, motivation, participation, and better understanding were observed in "introductory students to the industrial engineering program" when they were presented with complex situations in the professional field during the first year of classes through educational games, as demonstrated in the study conducted by [76]. The game techniques also generate motivation in computer-assisted language learning [77], which when combined with MAR technology are interesting tools in language studies to be used in or out of the classroom [78]. Some use serious games in learning, such as [79], combining with video games to teach parametric design and environment simulation principles for architecture students, with emphasis on quantitative performance and qualitative assessment, in an attractive and collaborative way.

Children are more attracted to games. This attraction is exploited by game-based tools that induce knowledge, such as those presented by [80] in the fun learning of numbers by experiencing stories through MAR. Another MAR Game system, based on multimedia elements, is presented in [34] to help primary school students understand science reading. The effectiveness and motivation of learning-related concepts is eminent when the visual objects are converted into 3D models on mobile devices. Thus, games combined with AR techniques are effective in inducing knowledge in children. It is also observed that the AR game Pokémon Go promotes the development of attention, concentration, and socialization in children and adults [37].

In general, the attributes of the games make users of game-based applications improve their visual attitudes and attention span [78], while enjoying their experimental qualities, psychological satisfaction, and possibilities for autonomous play [81]. The games in the AR learning tool cause positive effects such as pleasure and interest, with a greater incidence in effective learning improvements, and they promote social interactions among the students [12]. In addition, AR games facilitate a natural and independent way of learning manipulation, particularly favorable for self-directed students [39], despite generating some cognitive load. This is shown in [30], in comparison with the task-based method used by students in sequential mode to learn English vocabularies. In this case, the cognitive load caused by AR games can be minimized with usability principles. Language learning, focused on [78], is more natural and enjoyable with MAR games based on local objects known as trees and works of art, which are combined with virtual objects and texts [82]. In chemistry [83], presents the AR game "mystery of the table" for the learning complement in the form of stories, which allows students to enjoy and learn by manipulating virtual chemical elements. The interactivity and cooperative attitudes of the users in the interpretation of the abstract concepts of mathematics, based on the 3D geometric representations provided by AR applications, allows a fun learning experience and improvement in performance [18].

In this sense, the works of the educational systems based on AR games are mainly focused on pleasant experiences with the visualization of objects and phenomena in 3D using AR paradigms for a better understanding of the concepts studied; additionally, this takes advantage of the location and orientation that modern mobiles have. An example, among others, is the AR games mobile framework for educational support (MAGIS) for the development of new educational games based on AR [76,84]. This framework uses the Unity game engine as a base and is composed of the AR game logic subsystem, the AR subsystem, the navigation subsystem, and the analytical subsystem. Using this framework, virtual city tour games are created to learn history and eventually interact with historical characters that offer help, in this case, as a mobile AR adventure game with GPS as the player's location sensor for representation purposes. In [19], the benefits of RA in education and sports training are analyzed. Their location-based MAR games approach provides feedback, in cooperation with other participants, that can be useful for training scenario designs. You get additional information, additional feedback for simulated practice, introduce new rules, and create new sports. Table 2 shows the good results achieved by the different sources studied involving AR, games, and AR games.

Table 2. Technologies for learning and enjoyable learning.

Elements	Sources	Results
AR	[18]	Effective learning experience in abstract courses.
	[36,68]	Meaningful learning and increased effectiveness for low-achieving students.
	[34]	Improving the teaching–learning process in a fun and interactive way.
	[85]	Improves performance in learning abstract content.
	[86]	Improves attitude and learning outcome through interaction.
AR-Games	[8]	Intrinsic motivation in learning.
	[19]	Students significantly increased their conceptual understanding.
	[18,20]	Motivation to learn and work collaboratively.
Games	[76]	Motivation to participate and better understand the content.
	[32]	Improved learning and problem solving.

5. Topics Analysis According to the Questions Asked

Throughout the review of the literature, reference is made to different educational levels in which the designed tools are applied, but our interest is focused on the analysis of tools that are applied from secondary level to higher education and that aim to improve content assimilation.

The topics presented in Sections 3 and 4 are directly related to the questions posed in Section 2. These problems are shown with more evidence in this section.

5.1. Q1: Are Used Acceptable Parameters for Effective Learning Applications?

We understand that the effectiveness of a teaching–learning application is directly related to the acceptability attributes that this tool offers to students. To demonstrate this acceptability, applications using techniques based on game strategies with constructivist approaches were analyzed. Some works incorporate strategies focused on motivation and participation. Others work on the basis of usability criteria, cognitive aspects related to age and educational level, social influence, and attitude and intention. In addition, we observe that some works are based on scenarios and capacities offered by formal and informal education in social networks. In most of the works analyzed, the term pleasant is used to describe non-tedious actions. Table 3 synthesizes the parameters mentioned directly or indirectly in different related works for effective learning.

Table 3. Parameters used in various research works.

Sources	Parameter	Purposes
[87,88]	Perception easiness, perceived usefulness, perceived enjoyment, collaborative, social factor	Social factor influencing attitude and behavioral intention using mobile devices in education.
[8,34,38,71,89,90]	Gameplay, emotion, attention, motivation, competence, autonomy, gamification	Student attention capture, science understanding with AR and games in learning projects.
[19,91]	Interactivity, feedback	Mobile devices for student participation in the class.
[18]	Interactivity by physical and virtual handlers	Importance of physical, cognitive, and teaching contextual dimensions.
[27]	Intuitive interaction and tangible interfaces	Effective development of class in the room and less learning effort.
[9,18,36,37,41]	Motivation, constructivism, reflective, retention, investigative, cognitive, realism	Interaction of students visualizing virtual contents plays actions in real time.
[27,29,49,51,92]	Gameplay, motivation, psychology, pedagogy	Education easiness for children with handicaps.
[44,93]	Motivational, perceived utility	Mobile devices use in education.
[9,29,39]	Usability, collaborative	Interaction between systems and students.
[30]	Cognitive	Mental effort and mental load in games with AR.
[25]	Skills, reflective, research	Digital technology incorporated in PBL.
[94]	Study levels, pedagogy, psychology, collaboration	Gradual application of educational technology on each education levels.

Figure 1 illustrates the comparative synthesis of the parameter frequencies used in the papers reviewed. It is observed that most of the papers refer to motivation parameters, followed by playability, cognition, pedagogy, psychology, and research. On the one hand, the interfaces, skills, and educational levels at which the tools should be applied are neglected. Therefore, the works analyzed vary in the parameters of acceptance as an effective learning tool.

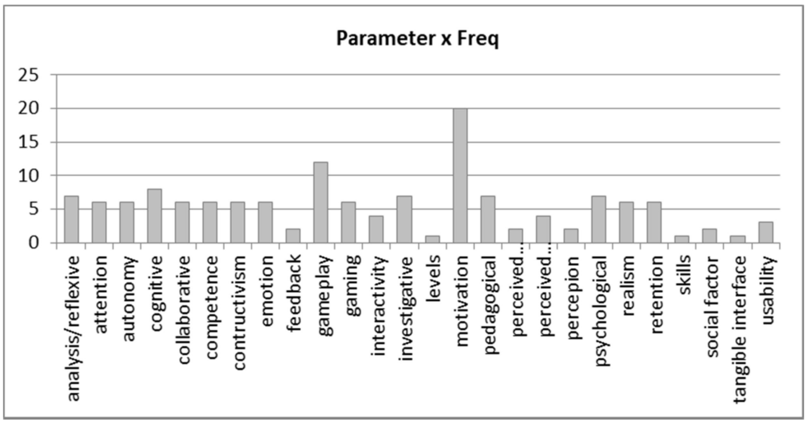

Figure 1. Parameters used in works and their frequencies.

5.2. Q2: How Are the Teaching–Learning Technology Tools Classified?

This topic is synthesized in reference to the work of [39]; four categories of pleasant learning technology tools involving AR were found, as detailed in Section 3.2, for classroom, laboratory, supplemental, and handicapped. In [12] it is reported that most tools are oriented to the classroom and, to a lesser extent, to supplement. In the classroom, the technological tools enrich the teaching and learning guided by the teacher [36], as a 3D geometry class in tertiary education [40], with an intuitive interaction with objects and an adequate load of disposition in the classes [18]. In the laboratory, the virtual elements (object and effect) are combined with real elements according to other operations [41] with dynamic result experiments obtained in [39]. AR and VR technologies offer advantages over real laboratories [43], e.g., for physics laboratories [9,90], immersive interaction in astronomy [2], observation of gas dynamics in chemistry laboratory [69], and operations at microparticle level [68]. The complement to the traditional method [44] is similar to self-directed learning [30], and generally it is used outside the classroom [38] and promotes positive attitudes [45]. Technical assistance [41], understanding of abstract concepts in calculus [18], and understanding of ecology can be found among the first. There are several computer technologies with greater emphasis on children for users with deficient learning considering motivational approaches through games [42,49,92], intelligence [50], and MAR for mathematics [51], among others.

5.3. Q3: What Elements Are Considered to Make a Learning Technology Tool Entertaining, Interesting, and Intriguing?

The elements that generate pleasant, interesting, and intriguing sensations in human-application interaction are generally related to the elements of the games. Learning games have the potential to capture attention and concentration, due to the attribute of competence, for the understanding of the subject. Therefore, games also allow students to stay longer in that process to achieve the proposed objectives, as well as share the activity with others and feel good. These elements of the game, accompanied by the fulfillment of the learning objective, can be inserted in the learning tools through gamification techniques, serious games, or induced games. On the other hand, AR, by linking physical elements with virtual elements, provides students with constructivist experiences of the concepts studied. This activity is considered the experimental part of learning, showing with it an interesting and intriguing way of experimentation in real time. Table 4 shows elements used in references that make fun, available, and investigative work more widely used. The motivational approach is the second one dealt with by the researchers. It could be said that constructivism, interactivity, pedagogy, and simulation represent the third focus of interest, while cognitive, collaborative, intriguing, intuitive, location, reality, and virtual problems are the fourth topic of interest in the current works. Few focus on attention, spontaneity, extrinsic elements, feedback, gradualism, incentives, temporality, and usability.

Table 4. Tool elements for enjoyable, interesting, and intriguing learning.

Elements	References
Attention	[8,17]
Availability	[20,35,38,70,95,96]
Cognition	[30,35,37]
Collaboration	[18–20]
Competition	[90]
Constructivism	[11,27,43,97]
Extrinsic	[36]
Feedback	[19,20]
Funny	[38,60,70,71,95]
Gradualism	[60,96]
Incentives	[17,35]
Interaction	[9,18,45,97]
Interactive	[2,29,68,69]
Intrigue	[38,92,97]
Intuition	[9,69]
Research	[11,20,27,45,60,69,97]
Location	[35,38,95]
Motivation	[8,32,35,36,70,90]
Narrative	[8]
Pedagogy	[8,17,35,60,71]
Reality	[9,69,71]
Social factor	[35,37,38]
Spontaneity	[18]
Simulation	[9,32,68,69,96]
Temporality	[90]
Usability	[9,29]
Understanding	[2,32,43]
Virtual	[9,68,69]

5.4. Q4: How Does AR Contribute to Improved Learning?

According to the literature reviewed, AR has attributes that contribute to improved learning by aiding in science concepts and judgment processes, also correcting acquired misconceptions; it improves skill development and laboratory work positive attitudes [9]. The connection of physical and digital domains allows the construction of cases and phenomena with complete visions that happen as if everything were real; also, it elevates the commitment and the interest of the student [35]. Complex phenomena and abstract concepts of science are analyzed at the level of objects and their properties for an effective understanding and to increase knowledge retention through experimentation [36]. Non-visible phenomena are visible at molecular levels [69], and interaction with non-observable 3D elements in real instances are possible and allow to perform a series of experiments for a better understanding [42,68] that promotes research trends and strengthens the motivation to learn and improve practices in education [7,22,65]. MAR is available in any environment [78], for any age [96] and subject [22,74], and in natural sciences by using the evolutionary cycle in time [70]. It facilitates the student–teacher interaction, as an exposure flow, in the class [19,20]. It motivates children in the cognitive aspect (attention and concentration) and socialization [37]. It develops spatial capacity, practical abilities and conceptual understanding [39], intuitive interaction, relating abstract themes with daily and personalized matters [73].

5.5. Q5: What Educational Models Are Used in AR-Based Assistive Learning Technology Tools?

An effective AR-based technology tool and games with enjoyable learning characteristics must necessarily be implemented under an educational model. In the literature reviewed, several TLS for the interpretation of abstract content emerged, with the researcher at the center. It was observed that the works focused on the relationship of learning sequences in which analysis, research, and evaluation of the constructivist approach prevail in a cycle of initiation–execution–closure. The instructional design focused by [5], combining technology and principles of educational psychology, emphasizes intrinsic and extrinsic motivations, also used by [36]. The interactive educational model 5E is used in several works, implementing AR in some of its stages to allow an enjoyable, exploratory, and investigative learning interaction [54,93]. In the 5E stage, technologies such as AR can be used, as suggested [61]. The exploration and development stages use AR [62] for chemical solutions, and the same is used to understand SQL in computing [63]. With varied approaches, AR is used in 5E to enhance learning and is presented in research by [51,58,94].

6. Conclusions

With the use of AR technologies and games, and under the terms of an educational model scheme, an efficient learning tool can be implemented in different scenarios, such as the classroom, the laboratory, the educational complements, and for users with difficulties to capture such processes. The proposed model is a pleasant way of learning for any subject and, in particular, for sciences with abstract concepts that can be addressed to children or for any age, and for any educational level. Efforts were observed in the scientific and technological world; among them, learning tools must meet acceptability criteria for their adoption in educational activities. These are not yet adequately standardized in the educational technology fields because specialists in education, learning, and psychology have proposed elements to be considered for efficient and inclusive learning; it diverges somewhat when it comes to the development of technology for education. As can be observed in the comparison tables constructed in this document, fun, availability, and research domains can be found during the implementation of the model, followed by motivation, constructivism, interaction, and simulation; aspects such as attention, participation, and narrative are neglected. What is required for acceptability are elements related to comfort, followed by cognitive, research, pedagogical, and psychological problems. During the study it was also observed that few RA-based educational tools are implemented in an educational model, e.g., 5E or others, and even fewer with the principles of enjoyment or fun in such a way that they encourage motivation, attraction, research, reflection, and temporality.

Finally, the present research serves as the basis for the development of future works that aim to design an enjoyable learning model that incorporates AR technologies and games, to facilitate the understanding of abstract concepts related to chemistry, but that can be adapted to other disciplines that involve this type of concept.

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