Article

The Impact of Augmented Reality (AR) on the Academic Performance of High School Students

Antonio Amores-Valencia [1] , Daniel Burgos [1,2,*] and John W. Branch-Bedoya [2]

1 Research Institute for Innovation & Technology in Education (UNIR iTED), Universidad Internacional de La Rioja, 26006 Logroño, Spain
2 Facultad de Minas, Universidad Nacional de Colombia, Medellín 170003, Colombia
* Correspondence: daniel.burgos@unir.net

Abstract: New technologies currently play a fundamental role in the educational context. As a result, augmented reality (AR) has recently gained a presence in educational centres. However, this educational technology has not been explored in depth at the secondary education level. Therefore, this research aims to analyse the impact of augmented reality on the academic performance of secondary education students, considering gender and the students' attitudes toward this technology. In this mixed-method research based on convenient sampling, 321 students aged 14 to 17 years from the same secondary education school were assigned to an experimental group ($n = 159$) and a control group ($n = 162$). The control group used a traditional methodology in a slide-based learning environment, while the experimental group worked with an AR mobile application (ComputAR) designed with the same concepts. The data collection instruments used comprised a pre-test/post-test in both groups and semi-structured interviews in the experimental group. The results showed that the students who used augmented reality achieved better grades, highlighting the potential benefits of integrating this technology into the teaching process. No significant differences were observed regarding the gender of the students. In conclusion, this study provides findings that encourage the use of augmented reality in secondary schools.

Keywords: augmented reality (AR); academic performance; gender; high school

1. Introduction

The educational field presents a changing scenario where methodological renewal is predisposed and necessitates the use of different technologies [1]. The current educational context proposes a work dynamic that implements new technological tools, accentuates the change in the role of students and teachers, and forces curricula to adapt to the new needs of the 21st century [2]. For this reason, teachers must improve the pedagogical model by introducing active and contextualized methodologies that promote student motivation as well as improved academic performance [3].

Unfortunately, educational centres face unmotivated and disinterested students daily, which leads to disastrous academic results as reflected in low grades and the non-acquisition of skills and abilities [4]. One possible solution is information and communication technologies (ICT) because they promote the acquisition of knowledge in many subjects, which favours their academic expectations [5,6]. These technologies also facilitate connectivity between students and/or teachers. This is a fundamental aspect that must be considered in current education since people are continuously interconnecting with each other in their day-to-day lives, and the suppression or reduction of the use of these tools in the classroom imposes an abrupt change that can have a direct impact on academic performance [7].

On the other hand, the integration of mobile devices in the teaching and learning process elicits new methodological guidelines, where dynamism is deepened, which, together with the high processing speed and portability made possible by certain devices,

introduces what is called mobile learning (m-learning) [8]. According to [9], m-learning offers characteristics that are conducive to the dynamic environment of current education, such as direct access to the Internet, high autonomy due to its loading capacity and downloading applications, and teacher-student interaction that enhances the links between them. Moreover, this type of technology is fully integrated, as 97.1% of the users reportedly have a tablet or smartphone [10].

A great deal of research has been conducted to analyse the use of mobile technology in the classroom and the various factors that it make it possible: social networks [11], digital books [12], QR codes [13] and augmented reality [14]. These investigations have considered the adaptation of the contents, the operating systems they contain, and the functionalities that may be implemented. However, it is also vital to consider the students who participate in these innovative practices, since their attitude towards them depends on multiple factors, among which stand out the previous knowledge they have and the utility that these practices can offer. The use of ICT in the classroom has been found to produce a better predisposition towards learning and an ideal emotional state, which leads to improvements in academic performance [15]. Achieving such results is intended using ICT, and more specifically, augmented reality, which is defined as the technology that combines the real and the virtual and allows interaction in real time [16]. This educational technology can stimulate students and thereby promote improvement in academic performance [17–20]. Moreover, electronic devices such as smartphones, tablets, or laptops can be introduced, generate interaction between users, and thus produce empathic experiences [21].

Therefore, we have developed an augmented reality mobile application that presents content through graphic markers with the aim of improving the academic performance of students at the secondary education level. This application is used in the academic subject of Information and Communication Technologies, which is part of the secondary education curriculum. The contents addressed in both the control and experimental groups correspond to the didactic units of computer equipment, computer architecture, and computer hardware. These contents are used to assess students and have been taught by different teachers who are part of the computer department.

Based on the purpose of this research, this study set out to achieve the following objectives:

1. Assess whether the use of AR in the learning process influences the academic performance of students based on an improvement in grades;
2. Determine whether gender presents a significant difference in academic performance based on students' qualifications before the use of AR;
3. Measure students' perceptions regarding the use of AR as a teaching tool in the classroom.

Based on these objectives, the following hypotheses are proposed:

- Student grades improve after they use AR as a learning tool;
- Gender does not present a significant difference in academic performance based on the use of AR;
- The evaluation of the students regarding the use of AR in education and their experiences with its use are highly positive.

This research is structured as follows: Section 2 presents several investigations related to this study, specifically those that incorporate augmented reality into the academic performance of secondary education students. In Section 3, the methodology and the materials used are presented. Section 4 shows the results obtained based on the data collection instruments. In Section 5, the proposed hypotheses are discussed, and, finally, in Section 6, the pertinent conclusions are developed based on a comparison between the proposed objectives and the results obtained.

2. Literature Review

2.1. Academic Performance and Its Determining Factors

This section addresses the factors that determine the academic performance of students and their importance during the teaching and learning process [22]. In addition, the causes of low performance are reflected on, as school failure is the case for many young people [23]. First, a brief introduction will be made regarding the concept of academic performance and its various determinants, followed by an in-depth look at the different variables.

Academic performance has been defined in various ways. Authors such as [24] define academic performance as the grouping of cognitive, affective, and social skills continuously acquired by students throughout different educational stages. According to [25], academic performance comprises the goals achieved in a social or academic context. Similarly, [26,27] define it as the measure of the academic goals achieved.

The difficulty of measuring or quantifying academic performance has been a challenge for researchers over the years due to the complexity involved. Students' grades may appear to be the most obvious and tangible indicator; however, it is important to highlight that grades do not precisely reflect the students' objectives, competencies, or skills acquired in relation to the subject, the teacher, or the dynamics of the group. Nor do grades usually include all possible aspects of the teaching and learning process, such as student participation, interest shown, behaviour adopted, behaviour with the group, or involvement in the subject [28].

In relation to grades as an indicator of academic performance, the study carried out by [29] included some of these qualifications as well as a personal note on the aspects to be improved in the different activities. The conclusion of that study stated that the low performance of the students was due to a misunderstanding of the contents and the proposed tasks. Nevertheless, grades continue to be the most studied, analysed, and researched predictor in reference to academic performance [30–34].

Student academic performance is determined by multiple factors and variables [35]. In recent years, research has mainly addressed cognitive and motivational variables. The study carried out by [36] analysed study habits and their impact on school performance. Other studies conducted by [37,38] proposed school climate as an indicator of student school performance. New technologies have also played a vital role in education. For example, [39] investigated the impact that technology could have on student academic performance.

In short, many studies have analysed the repercussions and influence of different variables, whether collectively or at the group or individual level, on the academic performance of students. However, the most widely used standard for measuring academic performance is grades. Therefore, this study analyses academic performance by comparing the grades obtained by students in the two groups (experimental and control).

2.2. Augmented Reality in Education

No fixed or standard definition of augmented reality exists. However, the vast majority of authors consider it to be a combination of reality and virtuality that offers the opportunity to understand real objects far more simply and easily through audio, images, video, text, URL, 3D models, and animation since AR adds information that is unknown in the real world [40,41]. The implantation or projection of virtual images in real-world objects can be considered to improve reality as it provides a simplification of the real context by creating a better one [42]. Another aspect to highlight, however, is the possible alteration of the real world through virtual content [43,44].

Augmented reality in education allows the acquisition of skills through the visualization and virtual manipulation of information and through the creation of learning objects [45,46]. However, AR technology alone cannot be expected to improve the teaching and learning process but should be integrated into an appropriate methodology that is supported by various theoretical frameworks [43,47]. In this case, the pedagogical theories

on which AR technology is based are the situated learning theory and the constructivist learning theory.

According to [48], situated learning theory is the relationship between the student and the context, based on a practical situation. Under this theory, the learning process is based on satisfaction, context, community, and participation. Applying these factors to the use of augmented reality, student satisfaction occurs when students can apply the knowledge acquired through the interaction with the information; the context offers the opportunity to incorporate 3D content that provides innovative activities; students can become part of a community when they are able to transfer the learning acquired through augmented reality to other similar and even more complicated situations; and the active participation of students is one of the main features of this technology [49,50].

The theory of constructivist learning emphasises that the construction of learning by the student must be based on previous experiences. To accomplish this, it is necessary for students to become actively involved in tasks, which are generally real problems [51]. Constructivist learning theory forms the basis of so-called discovery learning, where students achieve skills and abilities by themselves and acquire knowledge through problem solving [52]. Augmented reality enhances learning through discovery since it enables students to interact with the environment and thus gain deeper knowledge of reality as well as engage in new learning experiences. One application is augmented reality books, which provide the opportunity to interact with virtual objects that would otherwise be impossible to manipulate in reality [53,54]. Other methodologies that are based on constructivist learning theory are problem-based learning, gamification-based learning, collaborative learning, and design-focused learning. Whatever the methodology implemented, the characteristics of the students and their educational context must be considered. Such learning must therefore be active and based on the theory of situated or constructivist learning [55].

In reference to learning based on gamification, [56] highlights the scope that augmented reality achieves since it directly affects the motivation and performance of students. Likewise, the authors highlight the use of virtual games in higher education due to the considerable advantages these games provide to university students. Other possibilities are role plays or group discussions, where the acquired knowledge can be put into practice and encourages applicable experiences in the future [57]. Finally, the gymkhanas should be highlighted, where different augmented reality resources are used, such as graphic markers or geolocation [58]. All these types of games can be expected to increase student motivation and participation since they promote the understanding of concepts in an attractive way and foster critical capacity and collaborative learning [59,60].

Regarding problem-based learning, [61] indicates the importance of using augmented reality games that produce the solution to problems since these can help students understand reality, which translates into greater student participation. Similarly, the use of augmented reality in collaborative environments is of vital importance in the acquisition of cognitive skills [62,63]. In addition, design-based learning can use augmented reality to contribute to the acquisition of knowledge with the purpose of making or generating a product, which entails the consolidation of technological skills [64].

Therefore, the integration of augmented reality in the educational field is a fact confirmed by the multiple investigations previously conducted. However, it is essential to know whether the influence of this educational technology is based on the gender of the students [65,66]. A multitude of research studies have attempted to determine the influence of gender on the acquisition of knowledge as well as on performance [67,68]. According to [69,70], male and female students obtain the same results when augmented reality is used during the teaching process, which implies that the academic performance of students does not depend on gender. This finding is of great interest since it allows teachers to incorporate augmented reality in the classroom without having personalise the content based on gender. However, as stated by [71], on certain occasions, a significant difference can be

seen between male and female students in terms of content acquisition and, consequently, their grades.

In short, the use of augmented reality in the teaching process seems to favour student learning if it is accompanied by active methodologies such as those mentioned above. These methods, when supported by the different technological means of augmented reality, provide students with the necessary skills and abilities to understand and acquire knowledge in a participatory, active, and collaborative manner [72]. These elements are put to the test in this investigation.

3. Materials and Methods

3.1. Sample and Context

This study used non-probabilistic-incidental sampling as it enables the researcher to choose the sample based on its representativeness and ease of access [73]. In addition, this type of sample is one of the most representative in educational research [74].

A total of 321 students from the 3rd and 4th years of compulsory secondary education and the 1st and 2nd years of the Baccalaureate of the Colegio Cerrado de Calderón (Málaga) participated in the study. Out of the 321 students, 162 were assigned to the control groups and 159 to the experimental groups, where only 2.80% of the students had repeated a course and whose percentages by gender correspond to 66.67% males and 33.33% females. Table 1 shows the percentages of the sample for the control and experimental groups.

Table 1. Percentages of students in the academic courses for the control and experimental groups.

Group	3rd CSE	4th CSE	1st Baccalaureate	2nd Baccalaureate
Control	27.16%	37.04%	22.22%	13.58%
Experimental	22.64%	37.11%	25.16%	15.09%

Finally, the ages of the students in this sample ranged between 14 and 17 years. A total of 29.60% were 14 years old, 33.96% were 15 years old, 21.49% were 16 years old, and only 14.95% were 17 years old.

3.2. Method and Instruments

This section defines the methodological approach used in the development of this research. A mixed methodology was carried out, which combines instruments for the analysis of quantitative variables as well as qualitative data through semi-structured interviews.

To determine whether student performance improved after using augmented reality in the classroom, a quasi-experimental study was carried out where pre- and post-tests were performed on both groups, enabling a comparison of the results. First, the same pre-test was administered to both groups to find out the initial values presented by the students in each group. Subsequently, the experimental group would work on the corresponding didactic unit using augmented reality displayed on their different mobile devices. In parallel, the control group would do the lesson without the use of this type of educational technology. However, the control group was to use laptops so that they could follow the corresponding unit. This measure was aimed at increasing the validity of the research as it ensured the inclusion of ICT in the control group and would not influence the students' academic results. Finally, the same post-test would be administered to both groups to reveal the knowledge they acquired and whether the use of augmented reality had an impact on academic performance based on their qualifications.

The academic performance analysis instrument was a multiple-choice form made up of 10 items with the purpose of collecting information from three categories of Bloom's Taxonomy:

- Apply (2 items);
- Understand (3 items);

- Remember (5 items).

The form was distributed via the Internet through the Microsoft Teams learning manager, which is intricately linked to Microsoft Forms, under the pre-test (Appendix A) and post-test modalities (Appendix B). Both questionnaires contain the same items, although in a different order.

For the qualitative analysis, we used a semi-structured interview. According to [75], interviews are considered one of the best instruments for collecting data in qualitative research. Among the several types of interviews, the semi-structured interview provides more flexibility to the interviewer as it enables the interviewer to incorporate new questions during the interview and thus delve more deeply into a question to obtain more information, clarify terms, identify ambiguities, and minimize formalisms [76].

To design the semi-structured interview for the investigation, we created a categorization for the questions that included all the dimensions. Table 2 shows the designated categories, subcategories, and codes, along with the corresponding questions.

Table 2. Interview categorization.

Categories	Subcategories	Codes	Questions
Previous knowledge	Previous knowledge about ICT Previous knowledge about AR	PK_TIC PK_RA	1
AR features	Innovation Fun	IN FU	2–3
Educational use	Educational application Easy to use	EU_EA EU_EU	5–6 4–7
Educational opportunities	Positive aspects Negative aspects	EO_PA EO_NA	8–9–10
Teaching process	Duration Methodology Resources	TP_DU TP_ME TP_RE	11

The complete interview comprised 11 questions:

1. Have you had any previous experience in the use of ICT? Did you know about augmented reality as a teaching tool for the classroom?
2. Do you think that augmented reality is an innovative technology?
3. Do you think it is a fun educational technology?
4. Do you consider that augmented reality is a technology that facilitates the performance of class activities?
5. Would you like augmented reality to be a technology that is used in the rest of the subjects?
6. With what resources you have learned about augmented reality? Do you think its use in education will be positive?
7. Do you think its use is easy?
8. Do you consider that the use of augmented reality improves your performance as a student?
9. Do you think it is a good idea to use this technology during the teaching process?
10. If other teachers used augmented reality, do you think it would help you in your learning?
11. For the next academic year, what suggestions would you make to improve the duration, methodology, and resources used?

The analysis of the data collected through the interviews would be carried out based on the frequency and percentages of the students' responses, which would be duly coded. The different interviews would be carried out when the educational experience ended with

a representation of students, specifically 16 students from the different courses, considering gender and previous experience in the use of ICT.

3.3. Materials and Procedure

In reference to the means used, after analysing and rejecting the different augmented reality software for its inability to adapt to the specific content of the didactic unit being worked on (computer equipment, computer architecture, and hardware), we decided to design a mobile application using the Unity development platforms (version 2019.4.1f1), Vuforia Engine, Android Studio (version 2021.2.1) and Virtual Studio 2019. Likewise, 3D objects were taken from open digital repositories to promote the use of OER (Open Educational Resources), and graphic markers were generated and customized for viewing (Figure 1). This mobile application, called ComputAR, was duly tested on more than 20 different devices of different brands and models to guarantee its proper functioning.
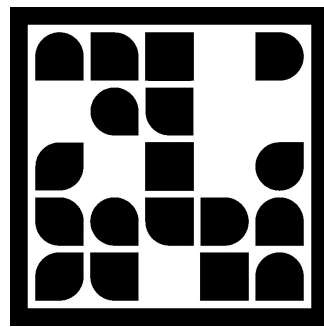

Figure 1. Graphic marker.

The ComputAR application was developed with the purpose of implementing an augmented reality application that would help teachers during the teaching process and improve academic performance. This enables work to be performed during the teacher's explanations or the completion of tasks without losing contact with the class dynamics. This quality is essential to promoting meaningful learning and encouraging participation and interaction among students. Therefore, the use of this type of application based on augmented reality allows the development of more attractive, motivating, enlightening, and dynamic explanations during the teaching process, as well as the visualization of certain contents that would otherwise be impossible because they are out of use [77].

Once the application is started, the initial screen can be viewed, where a series of virtual buttons are displayed and distributed according to the content that is intended to be developed in the educational experience. Figure 2 shows the menu offered by the initial screen.

Figure 2. ComputAR home screen.

The first section, Computer Equipment, shows buttons where different computers or machines that have been relevant throughout history can be seen. This makes it possible to observe a 3D model of the computer or machine in question, as shown in Figure 3.

Figure 3. Enigma machine (ComputAR).

The second section, Computer Architecture, reflects an image where the different internal and external parts of a desktop computer are shown, and the last section, Hardware, presents the different components of a computer (Figure 4).

Figure 4. Hardware section screen (ComputAR).

When each one is clicked, a brief explanation appears along with the option of viewing it in augmented reality (Figure 5).

Figure 5. Computer motherboard (ComputAR).

The ComputAR application and the different graphic markers used can be found in the Supplementary Materials.

For the control group, a presentation was prepared using the PowerPoint program that included the same theoretical contents as those of the ComputAR mobile application, along with images that helped to illustrate the contents.

Regarding the procedure, the study is based on ARCS instructional design model [78], which comprises four phases: analysis, design, development and pilot (implementation and evaluation).

The analysis phase focused on the review of the existing literature and the identification of data collection instruments. The subjects and participating groups were chosen, permission was requested to carry out this research, and the different applications for the visualization of augmented reality objects were analysed.

In the design phase, the contents, materials, and mobile application used in the experimental part were selected and planned, taking into account that none of the applications analysed in the previous stage conformed to the needs of the research. In addition, the available technological resources, the timing, and the instructional design of the materials were analysed and chosen. Finally, the instruments used in the data collection were designed, such as the forms, the motivational questionnaires in the instructional materials, and the semi-structured interviews.

At this point, we entered a development phase where the necessary resources and materials for the implementation were built, and the augmented reality mobile application (ComputAR) was developed. The tasks and activities that are addressed throughout the educational experience were also considered. Moreover, the instruments chosen for data collection were created, for which Cronbach's alpha was calculated to validate their reliability.

Finally, the pilot phase addressed the implementation in the classroom and the data collection during the months of October, November, and December 2022 for both the control and experimental groups. In the case of the experimental group, this project was developed over 11 sessions, while the control group needed only 10 sessions since the installation and management of the augmented reality application were not necessary. Data collection was carried out at the end of the last session for both groups. All the instruments, except for the interview, were applied using a form on the network. Regarding the evaluation, the data obtained by each of the instruments used in the investigation were analysed and interpreted with the purpose of answering the questions posed. The observed conclusions were presented along with the study's limitations and suggestions for future work.

Before showing the instructional sequencing, it is necessary to indicate that the presentation prepared for the control group served as a guide for the teachers who participated in this research. Likewise, since the two groups have the Microsoft Teams learning manager,

the different tasks and materials necessary to develop this educational experience have been incorporated into it.

Table 3 below shows the sequencing of the instructional design for the students who comprised the control group.

Table 3. Sequencing of the instructional design for the control group.

Sessions	Control Group
Session 1	Take the pre-test (maximum 10 min) Brainstorming about electronic devices Search and annotation of information in OneNote about some machines and computers (creation date, historical relevance, characteristics, image)
Session 2	Develop a timeline in Canva with the different machines and computers, highlighting the characteristics and the impact they had in their time
Session 3	Develop a timeline in Canva with the different machines and computers, highlighting the characteristics and the impact they had in their time
Session 4	Explain each of the components of a desktop computer through images
Session 5	Create a horizontal infographic in the Genially software with interactive elements, where the definitions and images of the different components are specified in their correct place
Session 6	Create a horizontal infographic in the Genially software with interactive elements, where the definitions and images of the different components are specified in their correct places
Session 7	Design a PowerPoint presentation, where each slide is a desktop computer component or accessory, including its technical specifications, price, product web address, and image
Session 8	Design a PowerPoint presentation, where each slide is a desktop computer component or accessory, including its technical specifications, price, product web address, and image
Session 9	Present the presentation made, highlighting the most interesting components of each computer for 3–5 min
Session 10	Take the post-test (maximum 10 min) Develop semi-structured interviews

The sequencing of the experimental group was identical to that of the control group, except that an extra session was necessary, since the first session was dedicated to the installation and explanation of the ComputAR augmented reality mobile application, as well as the delivery of the various graphic markers. It is important to highlight that the interaction of the students with the ComputAR application was based on reading the contents and visualizing the virtual content enabled by the superimposition of the graphic markers. Moreover, the images that were incorporated into the tasks were screenshots of the mobile devices themselves when they captured the figure in 3D, except for the final presentation, which consisted of 2D images.

The duration of the sessions was 60 min, although due to the logistics of the centre, the sessions lasted between 50 and 55 min to allow students time to travel to the corresponding classrooms.

4. Results

This section provides an analysis of the data obtained from the different instruments used in the present investigation. The results of the performance dimension, which were analysed using the different questionnaires, were transferred first, to finally present the information collected in the interviews. The analysis of all data was carried out using the Excel software, the SPSS program version 26, the GPower 3.1 application, and the Atlas.ti version 9 program.

4.1. Results of the Quasi-Experimental Pre-Test/Post-Test Study and Control Group

This section presents a series of checks that were developed for the dimension of academic performance, which was based on the students' grades. First, the assumption of normality of the data was checked for the difference between the pre- and post-tests in both groups. Second, the equality of variance of the data in the respective tests was inspected. The data were then verified to determine whether there were significant differences in the pre-test between the experimental and control groups. Next, we verified whether there were differences in the post-test once the respective learning tools had been applied, namely augmented reality and use of ICT tools in the experimental group and use of ICT tools in the control group. Finally, we examined whether there was a significant difference in gender based on the students' qualifications before the use of augmented reality as a learning tool.

4.1.1. Basic Statistical Analysis and Normality Control

In this procedure, a comparison was made of the differences registered between the pre- and post-test values based on the qualifications of the students according to the experimentation implemented. Table 4 shows the statistical results, specifically the measures of the central tendency for each group.

Table 4. Descriptive statistics of the pre-test/post-test.

Instrument	Research	Mean	Median	Typical Deviation
Pre-test	Control	4.278	4.5	1.273
	Experimental	4.270	4.5	1.260
Post-test	Control	7.654	8	1.298
	Experimental	8.626	8.5	0.965

The values of means and medians in the pre-test for each group show similar mean values and identical median values; this indicates that the students presented a highly similar level of knowledge before the educational implementation and that both groups started from the same point. The scores obtained in the post-test exceed the values obtained in the pre-test, which indicates that the students showed better academic performance in the tests carried out after the educational experience. Finally, the results achieved based on the educational experience developed reflect a higher score in the qualifications of the students who worked with augmented reality as a learning tool.

Regarding the verification of the assumption of normality of the data, the Kolmogorov–Smirnov test was used to test the hypothesis that the data sample had a normal distribution. Table 5 below shows the values obtained from this test in both groups.

Table 5. Kolmogorov–Smirnov test of normality for Pre-test/Post-test differences.

Research	Statistical	df	*p*-Value
Control	0.082	162	0.009
Experimental	0.094	159	0.001

Note: degrees of freedom (df).

The results reflect significance levels for the two groups below the significance level. Therefore, we determined that these data do not behave under the assumption of normality.

4.1.2. Application of Hypothesis Tests

Figure 6 shows the differences between the pre- and post-test stages for the different implementations carried out in the classroom: the augmented reality application and the use of other types of learning tools.
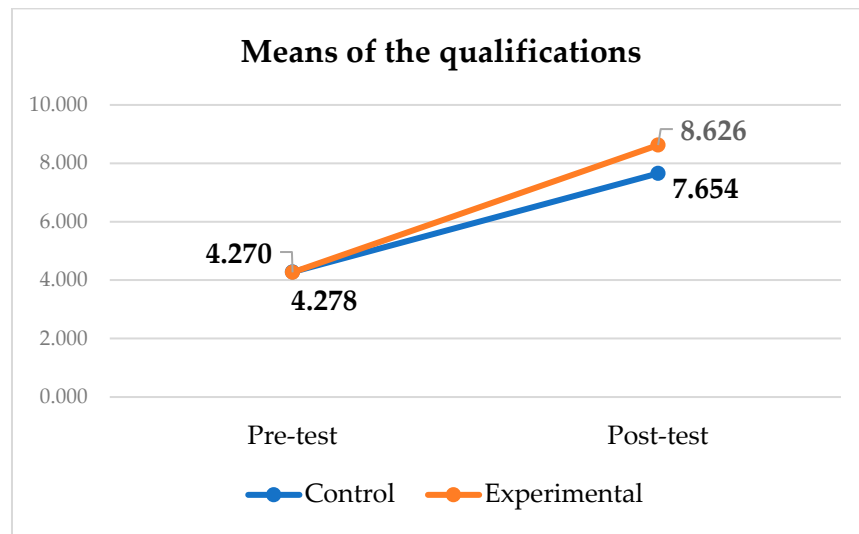
Figure 6. Rating pre-test/post-test differences according to research.

Based on the results, the applied learning tools influenced the students who participated in this research. These data needed to be confirmed by comparing a series of hypotheses based on the means of both tests for the experimental group and the control group.

The first step was to verify the assumption of equality of means between both groups. Since the data did not follow a normal distribution, non-parametric tests were used, in this case the Mann–Whitney U test, since these are two independent groups [79]. This test made it possible to test the null hypothesis that there are significant differences between the means of the control and experimental groups if the level of significance obtained is less than 0.05. Otherwise, the alternative hypothesis would be accepted, which indicates that there are no significant differences between the means of both groups.

Table 6 shows the data obtained by performing the Mann–Whitney U test based on the students' scores on the pre- and post-tests.

Table 6. Mann–Whitney U test for achievement (pre-test/post-test) in both groups.

Research	Z	U	*p*-Value
Pre-test	−0.085	12,808.5	0.932
Post-test	−6.975	7131.00	0.000

The analysis of the data in the control and experimental groups before the application of the learning tools indicates that these groups did not present significant differences before the development of the educational experience, since the value of significance was well above 0.05. However, based on the data obtained in the control and experimental groups after the application of augmented reality in the experimental group as a learning tool, it could be affirmed that these groups present significant differences. In short, the results confirm that both groups started with the same level of knowledge but that there were highly significant differences between students who used augmented reality as educational technology and those who did not.

The second step was to verify the assumption of equality of means between the pre- and post-tests. Since the data did not follow a normal distribution, non-parametric tests had to be used, in this case, Wilcoxon's W, since it is a sample measured at two different times [80]. This test made it possible to test the null hypothesis that there are significant differences between the pre- and post-tests means if the significance level obtained was less than 0.05. Otherwise, the alternative hypothesis would be accepted, which indicates that there are no significant differences between the means of said tests.

Table 7 shows the data obtained by performing the Wilcoxon W test based on the students' scores for both tests in the control and experimental groups.

Table 7. Wilcoxon W test for achievement (pre-test/post-test) for control and experimental groups.

Group	Z	*p*-Value
Control	−10.733	0.000
Experimental	−10.878	0.000

The results obtained in the pre- and post-test tests for the control and experimental groups show significant differences between the average grades of the students, since the critical level of significance is less than 0.05, specifically 0.000. Therefore, the null hypothesis was accepted, which indicates that the means are not statistically equal; that is, significant differences were observed between the mean of the pre-test and that of the post-test for the control and experimental groups. In conclusion, the data confirm that the methodology and tools used had a direct impact on the grades students achieved at the end of the learning process.

4.2. Gender: Basic Statistical Analysis and Application of Hypothesis Tests

In this section, the descriptive statistics of gender are presented based on the performance of the students in the experimental group as well as the performance of the pertinent normality controls for the application of parametric tests or not to compare hypotheses.

4.2.1. Basic Statistical Analysis and Normality Control

In this procedure, a comparison was made of the differences registered between the pre- and post-test values based on the grades of the students according to gender. Table 8 shows the results based on the statistics, specifically the measures of the central tendency for each group.

Table 8. Descriptive statistics according to the gender of the students (experimental group).

Instrument	Gender	N	Mean	Median	Typical Deviation
Pre-test	Men	106	4.410	4.5	1.2302
	Women	53	3.991	4	1.2841
Post-test	Men	106	8.575	8.75	1.0254
	Women	53	8.726	8.5	0.8295

The values of means and medians in the pre-test of the male students are higher than those of the female students, which a priori indicates that the men present a higher level of knowledge than the women. Thus, the students did not start out with the same conditions before the implementation of augmented reality. Moreover, the average grade obtained by the male students in the post-test is higher than the average grade of the female students, which reflects that the male students improved their learning of knowledge when using augmented reality. Finally, the results of the post-test show a higher score in both men and women, which indicates that the use of the ComputAR mobile application was highly positive.

The verification of the assumption of normality of the data was carried out using the Kolmogorov–Smirnov test. Table 9 below shows the values obtained from the Kolmogorov–Smirnov test for both groups.

Table 9. Kolmogorov–Smirnov test of normality for differences in qualifications (experimental group).

Instrument	Gender	Statistical	df	*p*-Value
Pre-test	Men	0.095	106	0.020
	Women	0.138	53	0.013
Post-test	Men	0.161	106	0.000
	Women	0.145	53	0.007

Note: degrees of freedom (df).

The results obtained reflect significance levels for males and females below the significance level taken at 0.05. Therefore, the hypothesis that the scores follow a normal distribution was rejected, and consequently, the alternative hypothesis indicating that the data do not behave under the assumption of normality was accepted.

4.2.2. Application of Hypothesis Tests

Figure 7 shows the differences between the pre- and post-test stages shown by men and women in the experimental group prior to statistical analysis.
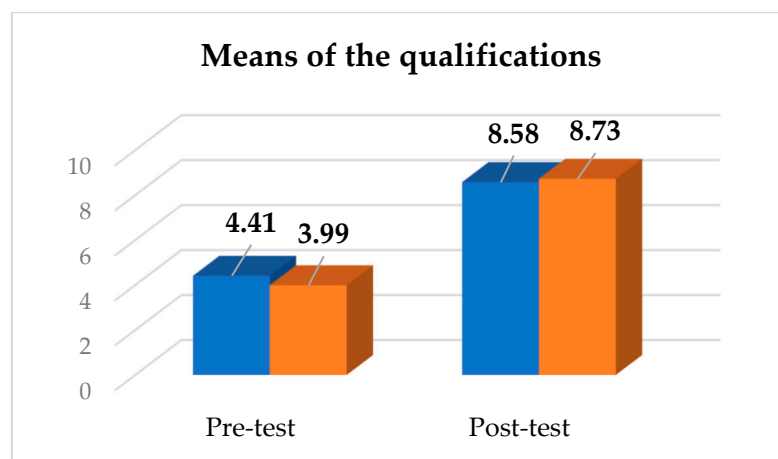
Figure 7. Differences in pre- and post-test scores according to gender (experimental group).

Based on the results, it can be affirmed that augmented reality influences the men and women who participated in this research.

Since the data did not follow a normal distribution, non-parametric tests were used, in this case the Mann–Whitney U test, since it involves two independent groups (men and women).

Although it is not necessary to know whether the male and female students presented significant differences before carrying out the learning tools, this condition was evaluated so that there would be evidence of where the students started in relation to their own knowledge. Thus, Table 10 shows the data obtained by performing the Mann–Whitney U test based on the scores of men and women in the pre-test/post-test.

Table 10. Mann–Whitney U test for achievement (pre-test/post-test), according to gender.

| Research	Z	U	*p*-Value
Pre-test	−1.859	2303.50	0.063
Post-test	−0.533	2665.00	0.594

The analysis of the data of the students before and after the application of augmented reality as a learning tool indicates that these groups did not present significant differences before the development of the educational experience, since the value of significance is greater than 0.05. In short, the results confirm that the students who are part of the experimental group started with the same level of knowledge in relation to their gender, and there were no significant differences between the students who used augmented reality as an educational technology based on their gender.

4.3. Results of the Qualitative Study of Action-Research Design through Semi-Structured Interviews

This section presents the analysis of the data collected from the semi-structured interviews, an instrument consisting of 11 questions aimed at capturing the students' perceptions regarding the use of AR as a teaching tool in the classroom. This instrument is divided into 5 general categories: previous knowledge, characteristics of augmented reality, educational use, educational opportunities, and the teaching process.

Figure 8 shows the frequency with which the interviewees have referred to the different aspects related to the corresponding categories.
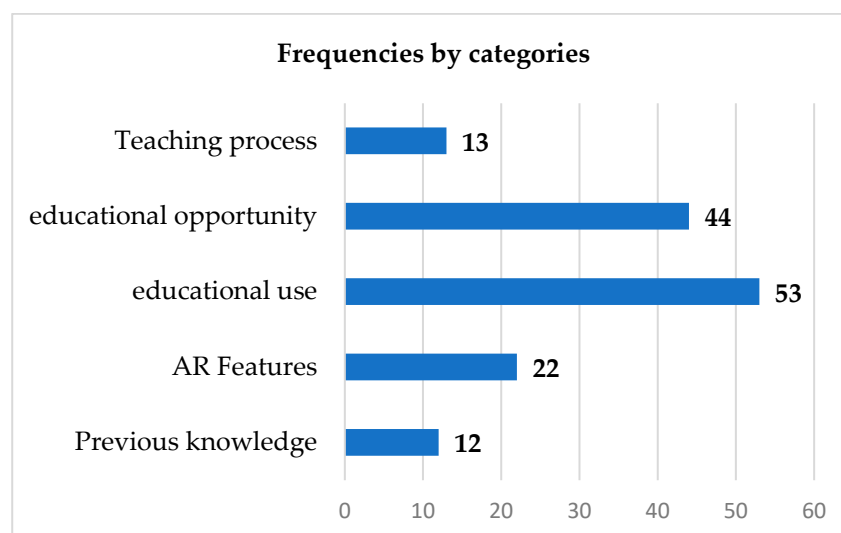
Figure 8. Frequencies of the categories obtained in the interviews.

Based on the results, the category with the most references is "Educational use", with a total of 53, followed closely by the category "Teaching process", with 44 indications. With far fewer references (specifically, 22), the category "Augmented Reality Characteristics" appears, and finally the categories "Teaching process" and "Previous knowledge" are shown, with 13 and 12 references, respectively.

The categories are divided into the corresponding subcategories in such a way that they retain the frequency of their references, as shown in Figure 9.
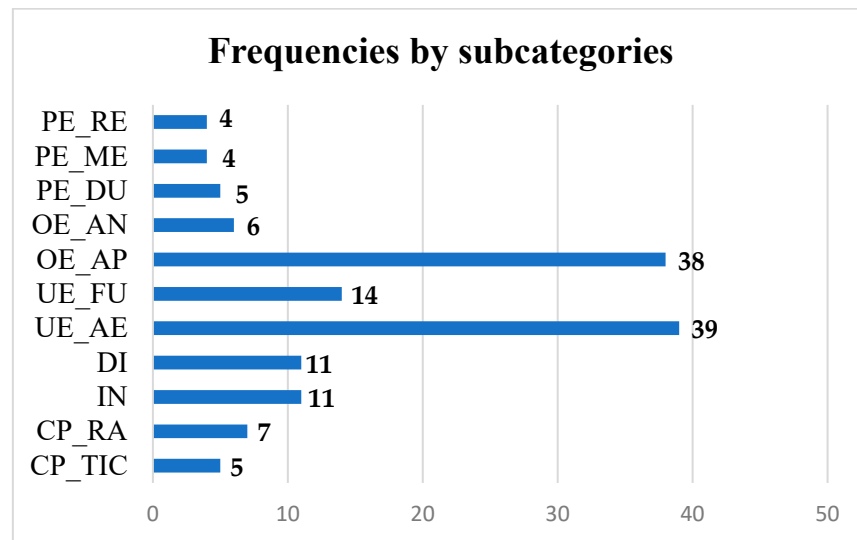
Figure 9. Frequencies of the subcategories obtained in the interviews.

The subcategories most cited by students are the *educational application* within "Educational use", with 39 references, and the *positive aspects* within "Educational opportunities", with 38 indications. At a great distance appear the subcategories *ease of use* located within "Educational use", with 14 citations, and the subcategories *innovation* and *fun* within "Augmented Reality Characteristics", with 11 references for both. On the other hand, the subcategories that obtain fewer references are the *negative aspects* grouped in "Educational opportunities", with six references, *previous knowledge about ICT* within "Previous knowledge", with five citations, and the subcategories *duration*, *methodology*, and *resources* under "Teaching process", with five and four indications, respectively.

Table 11 provides the percentages for categories and subcategories obtained through the frequencies.

Table 11. Percentages of the categories and subcategories obtained in the interviews.

Categories	Percentage	Subcategories	Percentages
Previous knowledge	8.33%	PK_TIC PK_AR	3.47% 4.86%
AR Features	15.28%	IN FU	7.64% 7.64%
Educational use	36.81%	EU_EA EU_EU	27.08% 9.72%
Educational opportunity	30.56%	EO_PA EO_NA	26.39% 4.17%
Teaching process	9.03%	TP_DU TP_ME TP_RE	3.47% 2.78% 2.78%

These data reflect that "Educational use" and "Educational opportunities" were the most frequently cited categories, comprising 36.81% and 30.56% of the total, respectively. However, the least referenced categories were "AR Characteristics" (15.28%), followed by "Teaching process" (9.03%), and lastly, "Previous knowledge", comprising 8.33% of the total.

Regarding the subcategories, the highest percentages appear in the *educational application* under "Educational use", with 27.08%, and in *positive aspects* grouped under "Educational opportunities", with 26.39% of the total. The subcategories *ease of use* under

"Educational use", with 9.72%, and *innovation* and *fun*, which correspond to the category "AR Features", with 7.64% of the total for both. Finally, the lowest percentages of citations appear in the subcategories *previous knowledge about ICTs* grouped under "Previous knowledge" and *duration*, with 3.47% each. This last subcategory, together with *methodology* and *resources*, which make up 2.78% of the total, is under the category "Teaching process".

In summary, the data obtained through the interviews reflect a positive assessment concerning the use of augmented reality as an educational technology as well as the experience carried out, highlighting a number of positive aspects based on motivation, academic performance, and the resources used.

5. Discussion

This discussion of the results has been subdivided according to the data collection instruments used. The data obtained from the pre- and post-test tests of both groups and the qualitative evidence of the semi-structured interviews will be discussed in turn to enable a view of each process and its respective characteristics.

5.1. Student Grades Increase after Using AR as a Learning Tool (H1)

The impact of augmented reality throughout the teaching process has been verified by the grades students obtained at the end of the educational experience. In this sense, the students who used the ComputAR mobile application obtained higher scores than did the students who worked in a learning environment with slides. These data are consistent with the results achieved in other studies [33,39,43,55].

Likewise, the average test scores of the experimental group were higher than those of the control group, and all the students who used augmented reality as a learning tool passed the post-test. On the contrary, several students in the control group failed the test. However, it is noteworthy that half of the students who worked on this educational technology obtained a score higher than 8.5. These results are further proof of the potential of Augmented Reality, which verifies the first hypothesis of this research.

On the other hand, both groups started with similar prior knowledge or cognitive abilities, since no significant differences were observed in the scores obtained in the corresponding pre-tests. However, the mean of the control group was significantly higher than that of the experimental group, although further comparisons that were carried out showed that the difference was not significant.

The students who used the ComputAR mobile application together with the graphic markers to visualize the 3D objects obtained a higher average grade than the students whose learning was based on the slides. This difference that occurred showed high significance, which highlights the influence of augmented reality on the learning process if the students' grades are taken as the basis of comparison. This fact further enhances the success of this research proposal and is consistent with other research [30,40,45,53]. In short, the first proposed objective was met since this study was able to assess whether the use of AR in the learning process influenced the academic performance of students based on an improvement in grades.

The first implication of this study is that secondary schools must implement the use of augmented reality through an active methodology, where various electronic devices are used that allow the students to participate in dynamic, engaging, and innovative learning.

5.2. Gender Does Not Present a Significant Difference in Academic Performance Based on the Use of AR (H2)

To evaluate this research and its conclusions, the mean scores of the pre-test were analysed to determine whether their test score values were noticeably different and therefore started from different cognitive levels. In this regard, the data confirm that male and female students do not present a significant difference with respect to their grades. This indicates that the prior knowledge of all the students in the experimental group was similar based on gender.

From this moment on, the average scores were taken based on the gender of the post-test, and although the values of the averages were not identical, the means of the corresponding comparison revealed that the difference was not significant. Therefore, the students who used augmented reality as a learning tool did not present significant differences according to gender based on the students' grades. These findings coincide with the results of other investigations [70,71] and, therefore, verify the second hypothesis.

Regarding academic performance, [67,68] affirm that men and women obtain the same qualifications when augmented reality is applied in the classroom. This means that the academic performance of students is invariably based on their gender. These results are in accordance with those obtained in this project, as reflected in the results discussed. In conclusion, the second proposed objective was met since the results reveal that gender presents a significant difference in academic performance based on grades when AR is used in the learning process.

The second implication is that teachers can implement this educational technology without having to consider the gender of the students. However, one must always be aware of the disparity that exists in each of the classrooms since differences can sometimes be found between male and female students in the acquisition of knowledge [65,70].

5.3. The Evaluation of the Students Regarding the Use of AR in Education and the Experience Itself Is Highly Positive (H3)

The use of semi-structured interviews made it possible to gain first-hand knowledge of the evaluations and perceptions that the use of augmented reality has produced in secondary school students. Likewise, the observation of the participants throughout the educational experience has shed light on certain aspects that should be considered for future research as well as the limitations of the project.

Based on the discussion of the results, we can conclude that the use and opportunities offered by augmented reality in education are high owing to its potential as a powerful teaching tool [8,43,57]. In addition, the myriad of positive aspects that augmented reality promotes and the versatility of its implementation in different subjects have been emphasized. Moreover, the design of the ComputAR mobile application has been highlighted due to its ease of use, dynamism, and innovation. These statements reflect a highly favourable assessment of the educational experience carried out, which verifies the third hypothesis of this research.

The students did, however, suggest that certain aspects be considered when working with augmented reality. They expressed the importance of having prior knowledge of how to use augmented reality, including the ComputAR mobile application and the graphic markers designed for the experience. Students also commented on several negative aspects, such as the design of some of the 3D models, the timing of some of the tasks to be performed, and the consequences of excessive use of screens for long periods of time.

Finally, most of the students cited the importance of using augmented reality in the educational field and in other fields, the motivation that promotes the use of these educational technologies due to the dynamism they provide, and the help these technologies provide in shortening the time it takes to understand certain abstract concepts. These findings coincide with the results of other investigations [59,62]. In short, the third objective was met since the perceptions presented by students regarding the use of AR as a teaching tool in the classroom have been analysed.

The third implication is that the perceptions and impressions of the students regarding the use of this educational technology were extremely positive, highlighting the improved academic performance students achieved as a result of its implementation in the teaching and learning process.

6. Conclusions

Regarding academic performance, particularly in the grades students achieved when using augmented reality as a learning tool, the results achieved after applying the respective

pre- and post-tests indicate that this educational technology has a direct influence on academic achievement.

Clearly, it has been verified that both the experimental group and the control group started with the same previous knowledge since there was no significant difference in the pre-test scores. However, the scores obtained in the post-test do show significant differences between the students of the experimental group and those of the control group. The students who implemented augmented reality in the classroom have achieved better grades than the students who worked with slides. These results support those of other similar investigations [40,53,55].

Regarding the gender predictor variable, students who used augmented reality as a learning tool showed no significant difference in grades based on gender. These findings coincide with the results of other investigations [69,70].

Finally, regarding the perceptions of students on the use of augmented reality as a teaching tool in the classroom, the results show a high level of satisfaction on the part of the students. This is due to the educational opportunities that augmented reality provides, along with the ease of use of the developed mobile application.

The potential use of augmented reality in the educational field is vast. This research can be replicated in other secondary schools, and the degree of acceptance of this technology can be analysed. Moreover, augmented reality objects that are designed by the students can be introduced, which can help to ensure the quality of the objects that are produced. Finally, the degree of motivation that students express toward using augmented reality could be evaluated.

Appendix A

(PRE-TEST) Select the correct option in each of the following questions:

1. The ROM is:

   a. Type of memory where the data of the programs you are using at the moment are temporarily stored.

   b. Type of memory where the programs necessary for the computer to boot are permanently stored.

   c. Type of secondary memory where programs and data are permanently stored on large capacity supports.

   d. Type of memory where the necessary programs are temporarily stored so that the computer can start up.

2.　Among the functions of the control unit are:

a. Select the instructions to be executed.
b. Provide the appropriate data to the arithmetic-logical unit.
c. Send the control signals to all the devices involved in the process so that it is carried out correctly.
d. All of the above are correct.

3.　Within the computer equipment or machines worked in this unit, which permit was decisive in the 2nd World War?

a. Apple II
b. Enigma
c. Altair 8800
d. Atari 800

4.　The chipset as the communications centre of a computer's motherboard allows:

a. Determine the compatibility of the computer elements.
b. Control the flow of data between the microprocessor, the graphics card, and the rest of the devices.
c. Organize the data between the processor and the rest of the components.
d. All of the above are correct.

5.　The most important input devices are:

a. Keyboard, mouse, graphics card, scanner, webcam
b. Keyboard, mouse, microphone, scanner, webcam
c. Keyboard, mouse, graphics card, microphone, scanner, webcam
d. Keyboard, mouse, microphone, scanner, webcam, printer

6.　The physical elements of a computer are called:

a. Operating system
b. Applications
c. Software
d. Hardware

7.　Secondary memories are classified into:

a. Magnetic support
b. Optical support
c. Flash support
d. All of the above are correct.

8.　The most relevant output devices are:

a. Monitor, microphone, printer, speakers
b. Monitor, microphone, graphics card, printer, speakers
c. Monitor, graphics card, printer, speakers
d. All the answers are correct.

9.　Find out what processor it has and the processing speed in GHz of the computer that are you using:

a. Intel (R) Core(TM) i3-5005U CPU @ 2.00 GHz
b. Intel(R) Core(TM) i7-9750H CPU @ 2.60GHz
c. Intel(R) Core(TM) i5-7260U CPU @ 2.20 GHz
d. None of the answers is correct.

10.　If you want to buy a computer, you must establish some priorities when choosing its most important components. In what order should you choose?

a. Microprocessor, Motherboard, Hard Drive, RAM Memory, Graphics Card
b. Motherboard, Microprocessor, RAM Memory, Hard Drive, Graphics Card
c. Microprocessor, RAM Memory, Hard Drive, Graphics Card, Peripherals
d. Hard drive, graphics card, power supply, microprocessor, motherboard

Appendix B

(POST-TEST) Select the correct option in each of the following questions:

1. Find out what processor it has and the processing speed in GHz of the computer that you are using:

   a. Intel (R) Core(TM) i3-5005U CPU @ 2.00 GHz
   b. Intel(R) Core(TM) i7-9750H CPU @ 2.60GHz
   c. Intel(R) Core(TM) i5-7260U CPU @ 2.20 GHz
   d. None of the answers are correct.

2. The chipset as the communications centre of a computer's motherboard allows:

   a. Determine the compatibility of the computer elements.
   b. Control the flow of data between the microprocessor, the graphics card, and the rest of the devices.
   c. Organize the data between the processor and the rest of the components.
   d. All of the above are correct.

3. The physical elements of a computer are called:

   a. Operating system
   b. Applications
   c. Software
   d. Hardware

4. The most important input devices are:

   a. Keyboard, mouse, graphics card, scanner, webcam
   b. Keyboard, mouse, microphone, scanner, webcam
   c. Keyboard, mouse, graphics card, microphone, scanner, webcam
   d. Keyboard, mouse, microphone, scanner, webcam, printer

5. The ROM is:

   a. Type of memory where the data of the programs you are using at the moment are temporarily stored.
   b. Type of memory where the programs necessary for the computer to boot are permanently stored.
   c. Type of secondary memory where programs and data are permanently stored on large capacity supports.
   d. Type of memory where the necessary programs are temporarily stored so that the computer can start up.

6. If you want to buy a computer, you must establish some priorities when choosing its most important components. In what order should you choose?

   a. Microprocessor, Motherboard, Hard Drive, RAM Memory, Graphics Card
   b. Motherboard, Microprocessor, RAM Memory, Hard Drive, Graphics Card
   c. Microprocessor, RAM Memory, Hard Drive, Graphics Card, Peripherals
   d. Hard drive, graphics card, power supply, microprocessor, motherboard

7. Among the functions of the control unit are:

   a. Select the instructions to be executed.
   b. Provide the appropriate data to the arithmetic-logical unit.
   c. Send the control signals to all the devices involved in the process so that it is carried out correctly.
   d. All of the above are correct.

8. Secondary memories are classified into:

    a. Magnetic support
    b. Optical support
    c. Flash support
    d. All of the above are correct.

9. Within the computer equipment or machines worked in this unit, which permit was decisive in the 2nd World War?

    a. Apple II
    b. Enigma
    c. Altair 8800
    d. Atari 800

10. The most relevant output devices are:

    a. Monitor, microphone, printer, speakers
    b. Monitor, microphone, graphics card, printer, speakers
    c. Monitor, graphics card, printer, speakers
    d. All the answers are correct.

References

1. Area-Moreira, M.; Cepeda-Romero, O.; Feliciano-García, L. Perspectivas de los alumnos de Educación Primaria y Secundaria sobre el uso escolar de las TIC. *Rev. Educ. Siglo XXI* **2018**, *36*, 229–253. [CrossRef]
2. Cabero-Almenara, J. Reflexiones educativas sobre las tecnologías de la información y la comunicación (TIC). *Rev. Tecnol. Cienc. Educ.* **2015**, *1*, 19–27. [CrossRef]
3. Macías-González, L.; Manresa-Yee, C. Mayores y nuevas tecnologías: Motivaciones y dificultades. *Ariadna* **2013**, *1*, 6–11. [CrossRef]
4. Amores-Valencia, A.; De-Casas-Moreno, P. El uso de las TIC como herramienta de motivación para alumnos de enseñanza secundaria obligatoria. *Estudio de caso Español. Hamut'ay* **2019**, *6*, 37–49. [CrossRef]
5. Colás-Bravo, M.P.; De-Pablos-Pons, J.; Ballesta-Pagán, J. Incidencia de las TIC en la enseñanza en el sistema educativo español: Una revisión de la investigación. *Rev. Educ. Distancia* **2018**, *56*, 1–23. [CrossRef]
6. Schaffernak, H.; Moesl, B.; Vorraber, W.; Koglbauer, I.V. Potential Augmented Reality Application Areas for Pilot Education: An Exploratory Study. *Educ. Sci.* **2020**, *10*, 86. [CrossRef]
7. Amores-Valencia, A.; Burgos, D.; Branch-Bedoya, J. Influence of motivation and academic performance in the use of Aug-mented Reality in education. A systematic review. *Front. Psychol.* **2022**, *13*, 1011409. [CrossRef]
8. Aguilar-Acevedo, F.; Flores-Cruz, J.A.; Hernández-Aguilar, C.A.; Pacheco-Bautista, D. Diseño e implementación de un si-mulador basado en realidad aumentada móvil para la enseñanza de la física en la educación superior. *Rev. Elec. Tecnol. Educ.* **2022**, *80*, 66–83. [CrossRef]
9. Mojarro-Aliaño, A. Mobile Learning en la Educación Superior: Una Alternativa Educativa en Entornos Interactivos de Aprendizaje. Ph.D. Thesis, Universidad de Huelva, Huelva, Spain, 2019. Available online: https://bit.ly/3pC0cbW (accessed on 2 March 2023).
10. Ditrendia: Digital Marketing Trends, 2021. Informe Mobile en España y en el Mundo. Available online: https://bit.ly/3z7IP5K (accessed on 9 December 2022).
11. Tuzel, S.; Hobbs, R. El uso de las redes sociales y la cultura popular para una mejor comprensión intercultural. *Comunicar* **2017**, *51*, 63–72. [CrossRef]
12. Sanz, J.J. Percepciones y valoraciones de la utilización de los libros digitales en Educación Superior. *Rev. Cient. Iberoam. Tecnol. Educ.* **2017**, *6*, 39–50. Available online: https://bit.ly/3pAB1Gs (accessed on 4 March 2023).
13. Ripoll-Gómez, S.; Mayoral-García, O.; Azkárraga, J.M. Proyecto Quick Natura. Tecnologías móviles aplicadas a rutas botánicas urbanas. *Model. Sci. Educ. Learn.* **2017**, *10*, 185–192. [CrossRef]
14. Moreno-Martínez, N.M.; Onieva-López, J.L. Herramientas y propuestas de innovación basadas en la tecnología de realidad aumentada aplicadas a la literatura infantil y juvenil. *Tejuelo* **2017**, *25*, 217–244. [CrossRef]
15. Colás-Bravo, M.P.; Reyes-De-Cózar, S.; Conde-Jiménez, J. Los usos de las TIC en las aulas como factor predictivo del estado emocional de los estudiantes. *Currículum* **2018**, *31*, 9–30. [CrossRef]
16. Azuma, R.T. A survey of augmented reality. *Presence Teleoper. Virtual Environ.* **1997**, *6*, 355–385. [CrossRef]
17. Huang, T.L.; Liao, S.L. Creating e-shopping multisensory flow experience through augmented-reality interactive technology. *Internet Res.* **2017**, *27*, 449–475. [CrossRef]
18. Juan, M.C.; Charco, J.L.; García-García, I.; Mollá, R. An augmented reality app to learn to interpret the nutritional information on labels of real packaged foods. *Front. Comput. Sci.* **2019**, *1*, 1–16. [CrossRef]
19. McLean, G.; Wilson, A. Shopping in the digital world: Examining customer engagement through augmented reality mobile applications. *Comput. Hum. Behav.* **2019**, *101*, 210–224. [CrossRef]

20. Rezaee, S.; Sadeghi, A.; Shakeri, M.; Choi, S.M. Personalized Augmented Reality Based Tourism System: Big Data and User Demographic Contexts. *Appl. Sci.* **2021**, *11*, 6047. [CrossRef]

21. Cabero-Almenara, J.; Barroso-Osuna, J. The educational possibilities of Augmented Reality. *J. New Approaches Educ. Res.* **2016**, *5*, 44–50. [CrossRef]

22. Citarella, A.; Maldonado-Briegas, J.J.; Sánchez-Iglesias, A.I.; Vicente-Castro, F. A motivación y su relación con la autoeficacia académica y orientación a las metas en una muestra de estudiantes de escuela secundaria en el sur de Italia. *Int. J. Dev. Educ. Psychol.* **2020**, *2*, 479–488. [CrossRef]

23. Musitu, G.; Jiménez, T.I.; Murgi, S. Funcionamiento familiar, autoestima y consumo de sustancias en adolescentes: Un modelo de mediación. *Salud Publica Mex.* **2007**, *49*, 3–10. [CrossRef]

24. Usán-Supervía, P.; Salavera-Bordás, C. Motivación escolar, inteligencia emocional y rendimiento académico en estudiantes de educación secundaria obligatoria. *Actual. Psicol.* **2018**, *32*, 95–112. [CrossRef]

25. Wirthwein, L.; Sparfeldt, J.R.; Pinquart, M.; Wegerer, J.; Steinmayr, R. Achievement goals and academic achievement: A closer look at moderating factors. *Educ. Res. Rev.* **2013**, *10*, 66–89. [CrossRef]

26. Caso-Niebla, J.; Hernández-Guzmán, L. Variables que inciden en el rendimiento académico de adolescentes mexicanos. *Rev. Latinoam. Psicol.* **2009**, *39*, 487–501. Available online: https://bit.ly/3JMjN1l (accessed on 2 March 2023).

27. Tilano, L.M.; Henao, G.C.; Restrepo, J.A. Prácticas educativas familiares y desempeño académico en adolescentes escolarizados en el grado noveno de instituciones educativas oficiales del municipio de Envigado. *Ágora* **2009**, *9*, 35–51. Available online: https://bit.ly/3JKKQtP (accessed on 5 March 2023). [CrossRef]

28. Adell, M.A. *Estrategias Para Mejorar el Rendimiento Académico de los Adolescentes*, 2nd ed.; Pirámide: Madrid, Spain, 2006; ISBN 978-84-368-2066-9.

29. Corredor-García, M.S.; Bailey-Moreno, J. Motivación y concepciones a las que alumnos de educación básica atribuyen su rendimiento académico en matemáticas. *Fuentes* **2020**, *22*, 127–141. [CrossRef]

30. Barca-Lozano, A.; Peralbo-Uzquiano, M.; Porto-Rioboo, A.M.; Brenlla-Blanco, J.C. Metas académicas del alumnado de Educación Secundaria Obligatoria (ESO) y Bachillerato con alto y bajo rendimiento escolar. *Rev. Educ.* **2011**, *354*, 341–368. Available online: https://bit.ly/3zRyD2i (accessed on 4 March 2023).

31. Quevedo-Blasco, V.J.; Quevedo-Blasco, R. Influencia del grado de somnolencia, cantidad y calidad de sueño sobre el rendimiento académico en adolescentes. *Int. J. Clin. Health Psychol.* **2011**, *11*, 49–65. Available online: https://bit.ly/3paXM2V (accessed on 2 March 2023).

32. Córdoba-Caro, L.G.; García-Preciado, V.; Luengo-Pérez, L.M.; Vizuete-Carrizosa, M.; Feu-Molina, S. Cómo influyen la trayectoria académica y los hábitos relacionados con el entorno escolar en el rendimiento académico en la asignatura de educación física. *Retos* **2012**, *9*, 9–13. [CrossRef]

33. Jerez-Carrillo, M.S. Motivación y Rendimiento Académico en el alumnado de Educación Secundaria. Master's Thesis, Universidad de Sevilla, Sevilla, Spain, 2021.

34. Elfeky, A.I.M.; Elbyaly, M.Y.H. The effectiveness of virtual classrooms in developing academic motivation across gender groups. *Ann. For. Res.* **2023**, *66*, 2005–2020.

35. González-Pienda, J.A. El rendimiento escolar. Un análisis de las variables que lo condicionan. *Rev. Port. Psicol. Educ.* **2003**, *7*, 247–258. Available online: https://bit.ly/3BXHLEZ (accessed on 5 March 2023).

36. Martínez-Herrera, M.G. Análisis de los Hábitos de Estudio y su Impacto en el Rendimiento Escolar: Caso de Estudio, Alumnos del Programa de Negocios Internacionales de FACPyA, UANL. *Daena* **2018**, *13*, 440–466.

37. Toscano-Ruíz, D.F.; Peña-Nivicela, G.E.; Lucas-Aguilar, G.A. Convivencia y rendimiento escolar. *Remca* **2019**, *2*, 62–68.

38. Padilla-Fuentes, G.; Rodríguez-Garcés, C. Clima de convivencia escolar en Chile: Un análisis desde el nuevo marco de medición de calidad educativa. *Rev. Educ.* **2019**, *43*, 557–573. [CrossRef]

39. González-Vidal, I.M. Influencia de las TIC en el rendimiento escolar de estudiantes vulnerables. *Rev. Iberoam. Educ. Distancia* **2021**, *24*, 351–365. [CrossRef]

40. Koç, Ö.; Altun, E.; Yüksel, H.G. Writing an expository text using augmented reality: Students' performance and perceptions. *Educ. Inf. Technol.* **2021**, *1*, 1–22. [CrossRef]

41. Lin, H.C.K.; Lin, Y.H.; Wang, T.H.; Su, L.K.; Huang, Y.M. Effects of incorporating Augmented Reality into a Board Game for High School Students' Learning Motivation and Acceptance in Health Education. *Sustainability* **2021**, *13*, 3333. [CrossRef]

42. Akçayır, M.; Akçayır, G. Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educ. Res. Rev.* **2017**, *20*, 1–11. [CrossRef]

43. Cabero-Almenara, J.; Barroso-Osuna, J.; Llorente-Cejudo, C.; Fernández-Martínez, M. Educational uses of augmented reality (AR): Experiences in educational science. *Sustainability* **2019**, *11*, 4990. [CrossRef]

44. Cheng, Y.; Bololia, L. The Effects of Augmented Reality on Social Skills in Children with an Autism Diagnosis: A Preliminary Systematic Review. *J. Autism Dev. Dis.* **2023**, *53*, 1–15. [CrossRef]

45. Di Serio, A.; Ibáñez, M.B.; Delgado-Kloos, C. Impact of an augmented reality system on students' motivation for a visual art course. *Comput. Educ.* **2013**, *68*, 586–596. [CrossRef]

46. Baabdullah, A.M.; Alsulaimani, A.A.; Allamnakhrah, A.; Alalwan, A.A.; Dwivedi, Y.K.; Rana, N.P. Usage of augmented reality (AR) and development of e-learning outcomes: An empirical evaluation of students' e-learning experience. *Comput. Educ.* **2022**, *177*, 1–43. [CrossRef]

47. Hadi, S.H.; Permanasari, A.E.; Hartanto, R.; Sakkinah, I.S.; Sholihin, M.; Sari, R.C.; Haniffa, R. Developing augmented reality-based learning media and users' intention to use it for teaching accounting ethics. *Educ. Inf. Technol.* **2022**, *27*, 643–670. [CrossRef]

48. Lave, J.; Wenger, E. *Situated Learning. Legitimate Peripheral Participation*; Cambridge University Press: New York, USA, 1991; ISBN 9780521413084.

49. Buchner, J. Generative learning strategies do not diminish primary students' attitudes towards augmented reality. *Educ. Inf. Technol.* **2021**, *26*, 1–17. [CrossRef]

50. Sat, M.; Ilhan, F.; Yukselturk, E. Comparison and evaluation of augmented reality technologies for designing interactive materials. *Educ. Inf. Technol.* **2023**, *28*, 1–23. [CrossRef]

51. Sánchez-Cortés, R.S.; García-Manso, A.; Sánchez-Allende, J.; Moreno-Díaz, P.; Reinoso-Peinado, A.J. B-Learning y Teoría del Aprendizaje Constructivista en las disciplinas informáticas: Un esquema de ejemplo a aplicar. Recent Res. *Dev. Learn. Technol.* **2005**, *1*, 1–6.

52. Tarng, W.; Lin, Y.J.; Ou, K.L. A virtual experiment for learning the principle of daniell cell based on augmented reality. *Appl. Sci.* **2021**, *11*, 762. [CrossRef]

53. Cagiltay, N.E.; Ozcelik, E.; Berker, M.; Menekse-Dalveren, G.G. The underlying reasons of the navigation control effect on performance in a virtual reality endoscopic surgery training simulator. *Int. J. Hum. Comput. Interact.* **2019**, *35*, 1396–1403. [CrossRef]

54. Lampropoulos, G.; Keramopoulos, E.; Diamantaras, K.; Evangelidis, G. Augmented Reality and Gamification in Education: A Systematic Literature Review of Research, Applications, and Empirical Studies. *Appl. Sci.* **2022**, *12*, 6809. [CrossRef]

55. Bursztyn, N.; Walker, A.; Shelton, B.; Pederson, J. Augmented reality instructional tool in enhancing geography learners' academic performance and retention in Osun state Nigeria. *Educ. Inf. Technol.* **2020**, *25*, 3021–3033. [CrossRef]

56. Chen, M.P.; Wang, L.C.; Zou, D.; Lin, S.Y.; Xie, H.; Tsai, C.C. Effects of captions and English proficiency on learning effectiveness, motivation and attitude in augmented-reality-enhanced theme-based contextualized EFL learning. *Comput. Assist. Lang. Learn.* **2020**, *35*, 381–411. [CrossRef]

57. Abad-Segura, E.; González-Zamar, M.D.; Luque-De la Rosa, A.; Morales-Cevallos, M.B. Sustainability of Educational Technologies: An Approach to Augmented Reality Research. *Sustainability* **2020**, *12*, 4091. [CrossRef]

58. Fonseca-Escudero, D.; Redondo-Domínguez, E.; Valls, F. Motivación y mejora académica utilizando realidad aumentada para el estudio de modelos tridimensionales arquitectónicos. *Educ. Knowl. Soc.* **2016**, *17*, 45–64. [CrossRef]

59. Hsieh, M.C.; Chen, S.H. Intelligence augmented reality tutoring system for mathematics teaching and learning. *J. Internet Technol.* **2019**, *20*, 1673–1681.

60. Ventoulis, E.; Xinogalos, S. AR The Gods of Olympus: Design and Pilot Evaluation of an Augmented Reality Educational Game for Greek Mythology. *Multimodal Technol. Interact.* **2023**, *7*, 2. [CrossRef]

61. Huang, T.C.; Chen, C.C.; Chou, Y.W. Animating eco-education: To see, feel, and discover in an augmented reality-based experiential learning environment. *Comput. Educ.* **2016**, *96*, 72–82. [CrossRef]

62. Ibáñez, M.B.; Di Serio, Á.; Villarán, D.; Delgado-Kloos, C. Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. *Comput. Educ.* **2014**, *71*, 1–13. [CrossRef]

63. Jerábek, T.; Rambousek, V.; Wildová, R. Specifics of visual perception of the augmented reality in the context of education. *Procedia Soc. Behav. Sci.* **2014**, *159*, 598–604. [CrossRef]

64. Kirikkaya, E.B.; Başgül, M.S. The effect of the use of augmented reality applications on the academic success and motivation of 7th grade students. *J. Balt. Sci. Educ.* **2019**, *18*, 362–378. [CrossRef]

65. Chen, J.J.; Hsu, Y.; Wei, W.; Yang, C. Continuance intention of augmented reality textbooks in basic design course. *Educ. Sci.* **2021**, *11*, 208. [CrossRef]

66. Hohlfeld, T.; Ritzhaupt, A.; Barron, A. Are gender differences in perceived and demonstrated technology literacy significant? It depends on the model. *Educ. Technol. Res. Dev.* **2013**, *61*, 639–663. [CrossRef]

67. Del-Rio-Guerra, M.S.; Martin-Gutiérrez, J.; Lopez-Chao, V.A.; Flores-Parra, R.; Ramírez-Sosa, M.A. AR graphic representation of musical notes for self-learning on guitar. *Appl. Sci.* **2019**, *9*, 4527. [CrossRef]

68. Gómez-Tone, H.C.; Martin-Gutiérrez, J.; Valencia-Anci, L.; Mora-Luis, C.E. International comparative pilot study of spatial skill development in engineering students through autonomous augmented reality-based training. *Symmetry* **2020**, *12*, 1401. [CrossRef]

69. Dirin, A.; Alamäki, A.; Suomala, J. Gender differences in perceptions of conventional video, virtual reality and augmented reality. *Int. J. Interact. Mob. Technol.* **2019**, *13*, 93–103. [CrossRef]

70. Hsu, T.C. Effects of gender and different augmented reality learning systems on English vocabulary learning of elementary school students. *Univ. Access Inform. Soc.* **2019**, *18*, 315–325. [CrossRef]

71. López-García, A.; Miralles-Martínez, P.; Maquilón, J. Design, application and effectiveness of an innovative augmented reality teaching proposal through 3P model. *Appl. Sci.* **2019**, *9*, 5426. [CrossRef]

72. Marín-Díaz, V.; Cabero-Almenara, J.; Gallego-Pérez, O.M. Motivación y realidad aumentada: Alumnos como consumidores y productores de objetos de aprendizaje. *Aula Abierta* **2018**, *47*, 337. [CrossRef]

73. Bisquerra-Alzina, R. *Metodología de la Investigación Educativa*, 2nd ed.; La Muralla: Madrid, Spain, 2009; pp. 167–192.

74. McMillan, J.H.; Schumacher, S. *Investigación Educativa*, 5th ed.; Pearson AdisonWesley: Madrid, Spain, 2005; pp. 127–357.

75. Díaz-Bravo, L.; Torruco-García, U.; Martínez-Hernández, M.; Varela-Ruiz, M. La entrevista, recurso flexible y dinámico. *Investig. Educ. Med.* **2013**, *2*, 162–167. Available online: https://bit.ly/2TBKZEZ (accessed on 4 March 2023). [CrossRef]

76. Vergara-Espinoza, C.M. Elementos Pragmadiscursivos en la Adaptación de Instrumentos que Miden Alfabetización en Salud: Formulación y Aplicación del Cuestionario Newest Vital Sign. Grado's Thesis, Universidad de Concepción, Concepción, Chile, 2018. Available online: https://bit.ly/3WQDmey (accessed on 3 March 2023).

77. Millapi, A.; Tardon, M. Uso de Realidad Aumentada en el Ámbito Educativo Para el Desarrollo de Aplicaciones que Enseñen y Entretengan (Edutainment). Grado's Thesis, Universidad Nacional de la Patagonia, San Juan Bosco, Tierra del Fuego, Argentina, 2015. Available online: https://bit.ly/3pocTpU (accessed on 5 March 2023).

78. Keller, J.M. *Motivational Design for Learning and Performance: The ARCS Model Approach*; Springer: New York, NY, USA, 2010; ISBN 978-1-4419-1250-3.

79. Berlanga-Silvente, V.; Rubio-Hurtado, M.J. Clasificación de pruebas no paramétricas. Cómo aplicarlas en SPSS. *Reire* **2012**, *5*, 101–113. [CrossRef]

80. Joo-Nagata, J.; García-Bermejo Giner, J.R.; Martínez-Abad, F. Patrimonio Virtual del Territorio: Diseño e implementación de Recursos Educativos en Realidad Aumentada y Navegación Peatonal Móvil. *VAEP-RITA* **2015**, *3*, 46–51.