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Augmented Reality: An Emergent Technology for Students' Learning Motivation for Chemical Engineering Laboratories during the COVID-19 Pandemic

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Abstract: In higher education, the learning of Unit Operations in Chemical Engineering and the development of practical activities became a real challenge. Therefore, the use of emerging technologies became necessary to develop practical laboratory activities of the Unit Operations due to the inaccessibility to the equipment infrastructure. In this study, Project-Based Learning methodology was assisted with the Augmented Reality (AR) technology for the development of subjects. The development of a real educational experiment for the application of a basic topic of the course as a project for each subject was proposed. The results were presented using the Zappar application, and a unique rubric was used for the evaluation of project. The evaluation of students' motivation for learning was measured using Keller's Attention, Relevance, Confidence and Satisfaction (ARCS) model of motivation by Instructional Materials Motivation Survey (IMMS). The attention, confidence and satisfaction demonstrate an acceptable reliability in comparison to relevance, which was considered as moderate reliability. Above 96% of students considered that the activities, materials, and organization of information used for the AR project caught their attention and encouraged their interest towards the fundamentals applied in the project. Around 80% of students expressed concern about the ease of AR technology use, and understood the learning aim of the project. Above 85% of students recognized the relevance of activities and their usefulness, and considered AR as a meaningful educational tool. 90% of students considered that AR technology helped them to develop the subject competencies. Cronbach's Alpha was used to indicate an acceptable reliability of IMMS instrument. Regarding IMMS, values were superior to 0.7, which could be considered acceptable. For the individual ARCS dimensions, values of Cronbach's alpha reached values of 0.94.

Keywords: education; Unit Operations; augmented reality; COVID-19; project-based learning

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1. Introduction

The United Nations established the educational goal as essential part of its sustainable development agenda. Accordingly, learners must acquire knowledge and skills through education [1]. At higher education, the incorporation of new educational methodologies has become essential to promote the Education for Sustainable Development (EDS), turning students into active participants of this process [2]. Conventionally, in engineering sciences, education has been mainly based on the acquisition of hard skills such as data analysis, and problem-solving skills. However, methodological techniques are necessary to motivate the development of professional skills in the students, according to the 21st century requirements [3]. In engineering education, the incorporation of activities that stimulate soft skills is also essential. Therefore, students must be involved in academic environments in which innovation and application of knowledge occur [4].

Project-Based Learning (PBL) has been widely reported as an effective pedagogic strategy that motivates learning in engineering students [5] since learners have the opportunity to develop a practical work based on the combination of knowledge integration-application [6]. PBL also motivates the development of some abilities such as teamwork and the use of interdisciplinary knowledge to solve problems or to obtain a final product [7]. The learning scenario of PBL allows the performance of real work activities, critical learning and decision-making associated with the learners' occupational field [8,9]. The obtaining of successful results has been reported from other Project-Based Learning experiences in combination with the use of information and communications technology (ICTs) [10]. Communication using ICTs has become easier, removing geographical barriers between teachers and students [11].

Information technologies have the ability to potentiate the PBL methodology due to digital and multimedia resources that can be incorporated into projects [5]. Particularly, advanced information technologies, such as immersive technologies, allow the digital transformation in engineering academic and industrial fields [12]. Immersive technologies are related to the interaction of the physical and virtual worlds providing the user with an experience of immersion [13]. Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) have been the preferred immersive technologies used for the interaction in engineering systems [14]. Immersive technologies provide learners with access to information at any time and using low-cost tools [15]. Students can interact in a virtual site with no space restriction nor physical resources requirements [16]. Nowadays, many applications are based on immersive technologies for the construction of new learning communities with interactive resources [17].

In the educational background, Augmented Reality (AR) has been reported to be a technology with positive effects on learning [18]. AR is a 3D visualization technology commonly used for projecting virtual objects in the real world. AR is the overlaying of digital information onto the actual physical world [19]. Conventionally, the images are overlaid by AR, allowing the possibility of multimedia learning in several contexts [20]. The incorporation of information such as graphics, audio and video enriches the learning resources for users who interact with digital elements [21]. Besides, a great advantage of AR is the accessibility since it can be implemented through numerous devices such as desktop computers and mobile devices [22]. Mobile Augmented Reality is a rapidly-developing technology which is highly preferred in comparison to non-mobile AR systems [23]. The main reason is the potential advantage of mobility because more users can be involved in these activities without restrictions [15]. Thus, mobile Augmented Reality applications have become preferred for several education fields [24,25]. For the evaluation of students' learning motivation in Augmented Reality experiences, Keller's ARCS has become the preferred Instructional Materials Motivation Survey (IMMS) [26]. Keller's survey takes into account: Attention, Relevance, Confidence and Satisfaction (ARCS) as potential constructs of educational motivation [27]. "Attention" refers to the involvement of students with the topic, focused on the learning objectives of an activity. "Relevance" is related to the connectivity of learners with the resources keeping them permanently interested. "Confidence" is related to the acquisition of confidence by learners in the achievement of knowledge goals. Finally, "Satisfaction" is associated with the experimentation of positive feelings through incentives after the development of learning activities. These four aspects have been identified as fundamental for students to be long-term motivated within learning scenarios [28,29].

In Chemical Engineering education, the Unit Operations field is the key for the development of professional skills [30]. Thus, the design and application of academic strategies becomes critical to enhance the student's motivation in learning scenarios. Technical skills of Unit Operations are related to fluids transport, heat exchangers, mass transfer and reactor design, which includes calculations and laboratories [31]. Most of the Chemical Engineering classes require hands-on experimentation and a face-to-face teaching environment [32]. However, laboratories have always been associated with some physical and economical restrictions owing to equipment maintenance. The limited amount of equipment for the students that can experiment on it has also translated into a serious restriction of physical space [33]. Thus, technological intervention of new teaching strategies that supply the physical experiments for student's learning is necessary.

Due to the unexpected arrival of coronavirus disease 2019 (COVID-19), face-to-face learning scenery was suddenly taken to the virtual environment [34]. However, in Ecuador, the pandemic affected education critically owing to inequitable access to internet. Therefore, new academic strategies had to be used for both synchronous and asynchronous activities while online classes were performed [35]. Particularly, at higher education, the performance of in-situ laboratory activities that involve Unit Operation were restricted.

Within this scenario, the pandemic scenario promoted the restriction of face-to-face activities in the academic field, which became a serious problem for the development of practical laboratory activities as part of the professional skills development. Thus, the use of innovative methodologies emerged as a solution, which is why the present work proposed the use of Problem-Based Learning methodology assisted with Augmented Reality technology for the development of practical activities by students. In Section 2, a wide description of the implications of using Problem-Based Learning as powerful learning methodology is presented. Section 3 addresses a revision of the potentialities of using Augmented Reality in learning scenarios. Finally, in Section 4, Problem-Based Learning assisted with Augmented Reality was approached as an academic strategy that has been previously used by other researchers in Chemical Engineering educational field, highlighting its potential to improve learning and to motivate the students.

1.1. Learning Methodologies: Project-Based Learning (PBL)

There are many educational methodologies used by educators and course designers around the world to facilitate student learning and skills development. Some of the most common educational methodologies include online learning, autonomous learning, collaborative learning, problem-based learning (PBL), and project-based learning (PBL), among others. [36]. Project-Based Learning (PBL) is an educational approach that focuses on the development of meaningful and practical projects for students. Therefore, instead of learning by memorizing abstract concepts, students learn through the completion of projects that allow them to apply knowledge in a practical and relevant setting [37].

PBL is a very popular educational approach in STEM (science, technology, engineering, and mathematics) education, as it allows students to work in teams in order to investigate a specific problem or topic, design and plan a solution to the problem, and then implement and evaluate your solution [38]. During this process, students are able to work on a variety of competencies and skills, including problem-solving, critical thinking, communication, and collaboration, which are key to their future careers [6]. Similarly to other learning methodologies, there can be challenges associated with the implementation of PBL in engineering programs; however, it has been shown that the benefits provided by PBL are significant for the learning of students who are pursuing these degrees [39].

1.2. Learning Technologies: Augmented Reality (AR)

Technological tools for learning are increasingly popular in education, as they allow students to access a wide variety of educational resources and activities [40]. Some of the most common technological tools for learning include: online learning platforms, video conferencing tools (Zoom, Microsoft Teams, and Google Meet), online collaboration tools (Google Drive, Dropbox, and OneDrive), gamification tools (Kahoot, Quizlet, and Classcraft), and Virtual, Mixed and Augmented Reality tools, among others [9].

Particularly, augmented reality (AR) is a technology that allows virtual elements to be combined with the real world, creating an interactive and enriched experience for the user. AR is based on superimposing digital information, such as images, graphics, text, videos, or sounds, on top of the user's vision of the real world through a device, such as a screen or smart glasses. Some common AR applications include gaming, advertising, education, tourism, architecture, design, and healthcare, among others. AR technology has expanded tremendously in recent years, and it is now possible to find commercial applications and devices that make use of AR technology [41].

Augmented reality (AR) can certainly be used to create interactive and immersive educational experiences that allow students to explore abstract concepts in a more visual and tangible way [42]. In addition, AR can be used to gamify learning, creating games that involve student interaction with virtual elements in the real world. This can make learning more engaging and entertaining, which can motivate students to actively participate and learn more effectively [43]. Without doubt, augmented reality (AR) can be a valuable tool for engineering learning at the university level, as it can help students understand abstract concepts, learn practical skills, and improve their ability to work with systems and process complexes. However, it is important to consider the challenges AR can present for students, such as access to devices and software, a learning curve, lack of content, and technical issues. Hence, educators and course designers must work to address these challenges and ensure that technology is used effectively in student learning [44].

1.3. Project-Based Learning (PBL) Assisted by Augmented Reality (AR)

There are various learning methodologies that can be assisted by learning technologies, that is, technologies that support and improve the teaching and learning process, allowing educators to personalize this process and providing more effective and meaningful educational experiences for students. As mentioned above, Project-Based Learning (PBL) is a teaching methodology that involves the development of practical and meaningful projects for students, which allow them to apply what they have learned in real-world situations. When combined with augmented reality (AR), this methodology can be even more effective, as augmented reality can help students visualize and understand abstract concepts in a more concrete way, which can increase their motivation and engagement with learning [45].

Project-Based Learning (PBL) assisted by Augmented Reality (AR) can be especially effective in teaching Chemical Engineering. Since this program involves the design, development, and optimization of chemical and physical processes, AR can be used to help students better visualize and understand these processes [31]. Some examples of how AR can be used in Chemical Engineering projects are the following [26,46,47]:

1. Experiment simulation: Augmented reality can be used to simulate real-world experiments and situations that can be dangerous or expensive to carry out in the classroom. For example, chemistry students could use augmented reality to simulate dangerous chemical reactions in a safe environment.
2. Simulation of chemical processes: AR can be used to simulate chemical and physical processes, allowing students to see how they work and how their components interact. For example, Chemical Engineering students could use AR to simulate distillation processes, gas separation, and chemical reactions, among others.
3. Equipment Design and Visualization: AR can be used to create interactive 3D models and overlay them in the real world, allowing students to see what equipment looks like in real life and manipulate it to see how it works. For example, Chemical Engineering students could use AR to visualize and manipulate models of chemical reactors, heat exchangers, distillation columns, and more.
4. Viewing 3D models: AR can be used to create interactive 3D models and overlay them on the real world, allowing students to see what models look like in real life and to manipulate them to see how they work. For example, Chemical Engineering students could use augmented reality to visualize and manipulate molecular models in the real world.
5. Contextual Learning: AR can be used to provide additional contextual information about student projects, helping students better understand their importance and how they relate to the real world. For example, Chemical Engineering students could use AR to see and understand how a chemical production facility relates to its environment.

It is clear that Augmented Reality can be a powerful tool to support project-based learning, as it can provide a more concrete and meaningful experience for students while allowing them to apply what they have learned in real situations. Therefore, in this study, an educational strategy based on the application of Project-Based Learning (PBL) assisted by Augmented Reality (AR) was used for the development of Unit Operations laboratories in the Chemical Engineering curricula of the Universidad Técnica Particular de Loja (UTPL, Ecuador). This educational experience was applied to courses on mass and energy balance, chemical kinetics, fluid mechanics, heat transfer, mass transfer, and reactor design. Students' learning motivation was evaluated through ARCS as the main IMMS in order to validate the effectiveness of the use of Project-Based Learning (PBL) methodology assisted with Augmented Reality (AR) technology as an academic strategy for the development of Unit Operations laboratories.

2. Materials and Methods

2.1. Preparation of the Project-Based Learning (PBL) Assisted with Augmented Reality (AR)

Project-Based Learning methodology assisted with Augmented Reality technology was designed using the PBL Canvas tool, and the diagram is shown in Figure 1. The PBL Canvas provided complete information about the project, thus, the participants were involved with a common communication framework during the implementation of the project. In this way, improvisations could be reduced and, consequently, both the time invested and the use of resources among all those involved in the project were optimized.

2.2. Description of Participants

The Project-Based Learning (PBL) methodology assisted with Augmented Reality (AR) technology was applied to Chemical Engineering students according to the information of Table 1. Chemical engineer students registered in Unit Operation (UO) courses taught during two academic semesters of the program: October 2020–February 2021 (O20F21) and April–August 2021 (AA21), were chosen for the academic strategy application described in this study.

Table 1. Detailed information of the participants of the PBL assisted with AR experience.

Semester	Course	Number of Participants	Work Hours per Week		
			Theoretical	Practical	Autonomous
(O20F21) 4th	Mass and energy balance	24	3	2	4
(AA21) 5th	Fluid mechanics	24	3	2	4
(O20F21) 5th	Heat transfer	15	3	2	4
(O20F21) 6th	Chemical kinetic	24	3	2	4
(AA21) 6th	Mass transfer	24	4	2	6
(AA21) 7th	Reactor design	24	3	2	4

Four professors participated in this study, who have 10-year teaching experience of UO courses. The students were grouped according to their preference for classes work. Three-student teams were formed. Group roles were assigned within each group without any the interference from the professor.

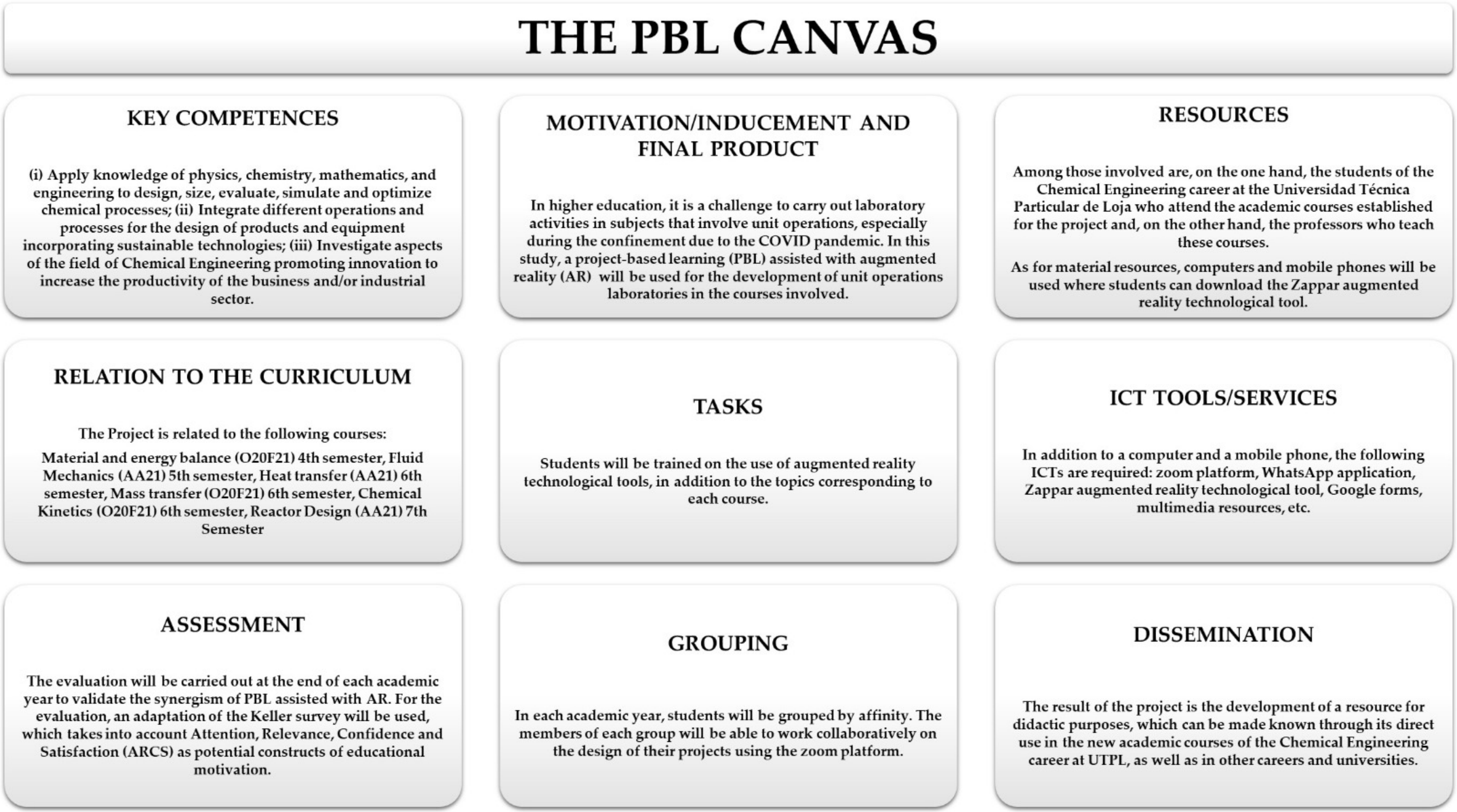


Figure 1. Project design using PBL Canvas tool.

2.3. Description of the Project

This educational experience was developed during the two semesters O20F21 and AA21. The syllabus of the courses above described was developed considering the incorporation of the PBL methodology assisted with AR technology as academic strategy. The theoretical component where basic concepts were explained and applied through application using AR technology was established. Restrictions related to COVID-19 pandemic constricted the practice component of each course, which was performed through experiments at home. However, the limited access to the laboratory to professors allowed the performance of a single practice activity using the laboratory equipment through AR. Finally, the autonomous learning component was established based on the assignments for students (solution to exercises, workshops, reports, and the final project). At UTPL, a general distribution for the assessment of each learning component of courses is established in the syllabus: 35% for theoretical, 35% for experimental, and 30% for autonomous work. PBL assisted with AR (the final project) was part of the autonomous work.

In this study, the "Zappar" technology was used to create the proposed academic strategy. The choice of Zappar was due to its availability as a free mobile application, which allowed all students to access it without restrictions. In addition, its use did not require programming skills on the part of the students and was already widely used by teachers for academic purposes, which allowed for rapid training. The implementation of the academic strategy was carried out in two stages during two academic semesters. The first stage lasted four weeks, during which students were trained in Augmented Reality through learning resources that addressed both theoretical concepts and application exercises. Likewise, a session was dedicated to teaching students how to design materials in Augmented Reality. The second stage focused on the practical application of Augmented Reality through a final project. The second phase, from the fifth to sixteenth week, the final project was performed. The project was established to design and develop a real experiment on the application of a basic topic of the course. Thus, students built a home prototype or used laboratory equipment while explaining they theoretical fundamentals of an experiment, its parts, its operation and applications in the industry. The project was presented using Augmented Reality technology through Zappar app as the technological resource, demonstrating a specific fundamental topic of each subject. Particularly, a qualification rubric for the evaluation of the final project was established, which is summarized in Table 2.

Table 2. Rubric used for the evaluation of the final project.

Category	Excellent (10–7)	Satisfactory (6.9–4)	Not-Enough (<3.9)
Content	The objective of the project is described. The resource is easily understood. The work presented demonstrate a fundamental principle.	The objective of the project is partially clear. The resource is not clearly understood. The work presented demonstrate partially a fundamental principle.	The objective of the project is not described. The resource is not easily understood. The work presented does not demonstrate a fundamental principle.
Structure	The resource has a title. There is a brief and concise description. The presentation is sequential. The presentation is within 10 min.	The resource title is not clear enough. There is not a brief and concise description. The presentation does not follow an order. The presentation is within 15 min.	The resource has not a title. There is not description. The presentation is not sequential. The presentation exceeds 15 min.
Multimedia elements	There are included two or more multimedia elements	There are included at least 2 multimedia elements	There are not included multimedia elements
Organization of information	The information presented is clear	The information presented is partially clear	The information presented is not clear

2.4. Measurements

An adaptation of Keller's ARCS was used as Instructional Material Motivation Survey (IMMS) in this study. A questionnaire was designed considering the most relevant aspects of student's learning motivation according to the PBL methodology assisted with AR technology academic strategy. An adaptation of the questionnaire of Barroso [48] was performed. Questions were accurately selected and adapted to the present study. A detailed description of the questionnaire used for this study is summarized in Table 3. Four answering options for the questionary were established, and the following scale was used: 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree.

Table 3. Detailed Keller's ARCS questionnaire used for the evaluation of students' learning motivation by PBL methodology assisted with AR technology academic strategy.

Attention (10 Questions)	**Confidence (9 Questions)**
There was something interesting about the AR materials. The AR technology catches my attention. The quality of the AR material keeps my attention. The images, videos and texts that I have discovered through the activity are attractive. The organization of information using AR helped me to keep my attention. Information discovered through experience encouraged my interest. The repetition of activities tires me. I have learned new things from AR that were surprising. The audiovisual material helped keep my attention on the activity. There is so much information that it is irritating.	When I saw the exercises performed in AR, it was easy for me The AR material is more difficult to understand. The introductory information help me to felt confident to learn from this activity. The information was so much that it was difficult for me to remember the important points. Working on this activity help me to be confident to learn the content. It was difficult to discover the digital information linked with the real image. After working with AR resources, I would be able to pass the final test. For me was really difficult to understand the material in this activity. The good organization of the AR material helped me to learn the content.
Relevance (9 questions)	Satisfaction (6 questions)
The AR material helped me to know information that I do not known before. The images, videos and texts used in the AR materials were relevant for knowledge. When I complete the activity successfully it was important to me. The content of this material is relevant to me. After the AR experience is clear for me how people use the knowledge of these activities. The audiovisual material used in the resources encouraged the knowledge. This activity was relevant because it helped to knew new content. I have been before the content presented by AR material. The information presented in this activity is useful to me.	It was satisfying for me to complete the activities. I would like to know and practice more about it because I have enjoyed this activity. I really enjoyed studying the AR resources. I feel an achievement as consequence of my effort in these activities. It was successful for me to complete these activities. I believe this was a well-designed activity.

2.5. Statistic Analysis

The data was exported to Microsoft Excel and Minitab 17 (Version 17.1.0., Minitab LLC., State College, PA, USA) was used to calculate the measures of central trend. A construct validity analysis was performed through exploratory factor analysis (EFA), following the KMO (Kaiser-Meyer-Olkin) criteria and sphericity according to the non-orthogonal Oblimin Method. The reliability was analyzed with Cronbach's alpha coefficient. SPSS (Statistical Package for the Social Sciences, version 25, SPSS Inc., Chicago, IL, USA) statistical program was used to calculate the validity and reliability of the results.

3. Results and Discussion

3.1. Results of a Sample Project

Among all the projects, this study presented one of the most representative ones prepared by a group of students, which was based on the description of the laboratory equipment called Catalyst Regeneration Plant (CRP). The objective of this particular project was to make use of Augmented Reality to describe the CRP equipment, which is mainly composed of a furnace and a continuous flow reactor. For this, students were asked to develop a learning resource using the Zappar application in which they described the parts of the equipment, their operation and the main industrial applications. In this way, the students approached the central theme of the project by incorporating the theoretical knowledge reviewed in each one of the courses involved in this study.

The Zappar application of all projects, including the sample project, was performed combining physical resources (photographs) and the design of a digital interface where text and videos were appropriately organized in order to digitalize the experiment. The purpose of using Zappar application as the Augmented Reality application was not to completely replace a real experiment, but to develop a practical experiment without having the access to the laboratory equipment and other materials. However, we do believe that the experimental activity was performed and the operation of the equipment was understood as well as its application at industrial level in concordance with Chemical Engineering field.

Figure 2 shows the flowchart of the CRP found in the New Materials Laboratory of the Universidad Técnica Particular de Loja.

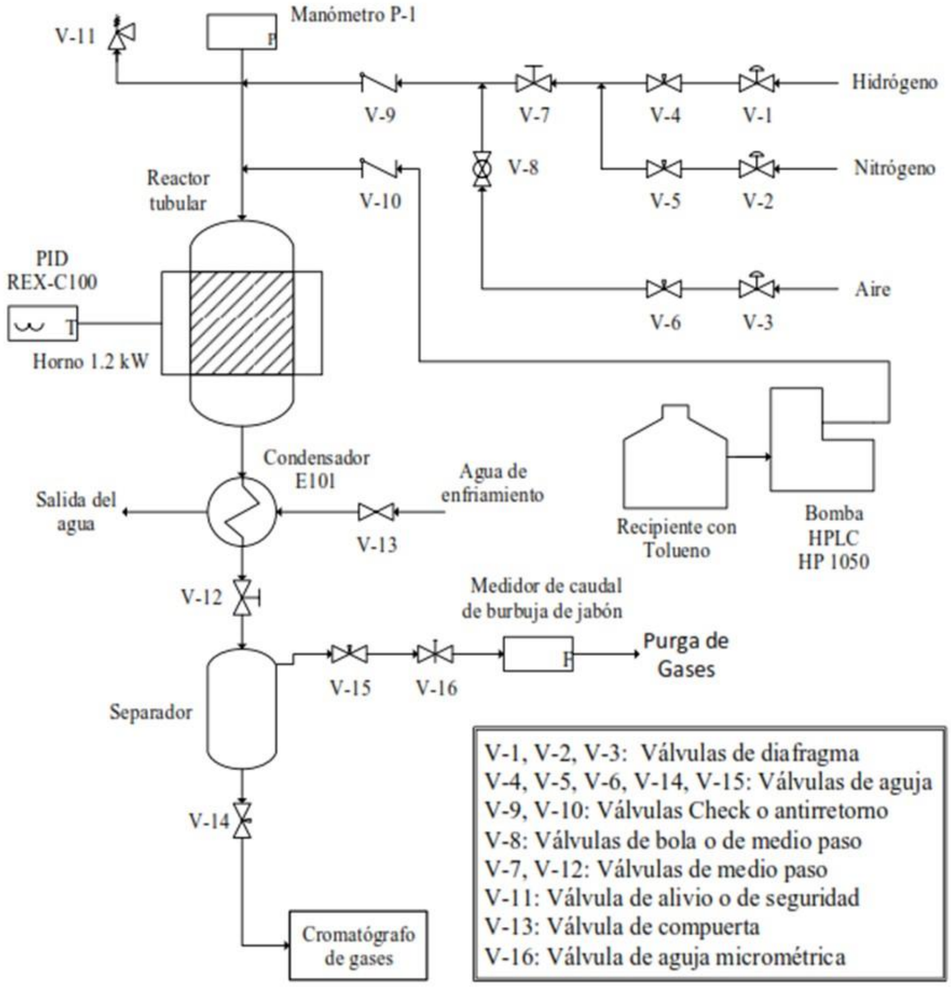


Figure 2. Flowchart of the Catalyst Regeneration Plant (CRP).

Figure 3a shows the front view of the CRP while the two main units, the furnace and the continuous flow reactor, are shown in Figure 3b,c, respectively.

In order to run the Augmented Reality application described in this article, it is necessary to have the Zappar application, which is available on Google Play and the App Store (Figure 4a). Once the user has installed the app on a mobile device, they need to open the app and point the camera of the device at the zapcode shown in Figure 4b. After the app tells the user that the zapcode has been successfully scanned, they will be able to view Augmented Reality content designed by the student authors of the sample project.

(**a**) (**b**) (**c**)

Figure 3. Catalyst Regeneration Plant (CRP), (**a**) front view of the equipment and main units (**b**) furnace and (**c**) continuous flow reactor.

(**a**) (**b**)

Figure 4. (**a**) View of Zappar app and (**b**) Zapcode to scan with Zappar app.

All projects, including the sample project, were considered as an indicator of students' conceptual understanding as part of course achievement. In these projects, theoretical and practical knowledge was contemplated as cognitive learning as part of the category of the evaluation rubric. On the other hand, the skills, commitment, and performance of the artifacts developed through augmented reality technology were conceived by the structure, multimedia elements, and information organization sections of the rubric. The summary of the grades obtained by the students in the projects (Table 4), shows that almost every student had excellent performance in the development of their projects. Thus, the achievement of skills by students can be associated with the integration of knowledge, teamwork, and the use of innovative learning to improve professional skills [10].

Table 4. Summary of project grades according to the rubric used in the study.

Semester	Course	Grades		
		Excellent (10–7)	**Satisfactory (6.9–4)**	**Not-Enough (<3.9)**
(O20F21) 4th	Mass and energy balance	100	-	-
(AA21) 5th	Fluid mechanics	100	-	-
(O20F21) 5th	Heat transfer	93	7	-
(O20F21)6th	Chemical kinetic	100	-	-
(AA21) 6th	Mass transfer	100	-	-
(AA21) 7th	Reactor's design	100	-	-

The Zappar application of the sample project has also been classified according to the evaluation criteria of AR-teaching-learning settings (AR-LLS) developed by Krug [49], in the context of education sustainability. We believe this evaluation is necessary to provide information about the characteristics of Augmented Reality which are responsible for the possitive effect on teaching-learning process within this work. In accordance with previous reports about Augmented Reality, conventional AR applications allowed to: "enrich the experiments", "making visible the invisible" and "support paper-based learning", as it occurred in this work. However, we considered that the use of the parameters of evaluation of AR-LLS allowed to relate them with the United Nation teaching learning scenarios which is neccesary to validate its contribution to the learning process. The parameters that have been evaluated in this study are: inmersion, interactivity, congruence with the reality, closeness to reality in terms of content, adaptivity, gamification and complexity. These parameters are represented in a heptagon and are qualified accordling to the percentage of the different characeristics of the sample project presented of the PBL assited with AR of this work (Figure 5).

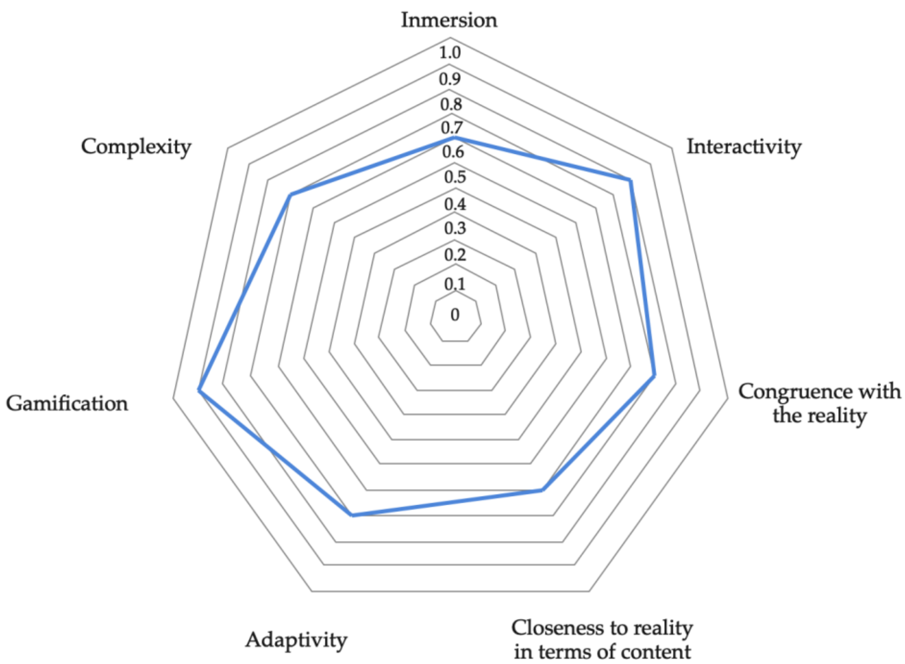


Figure 5. Rating of the sample project presented of the PBL assisted with AR.

3.2. Measurement of Validity and Reliability of IMMS

The validity of the results was quantified by KMO (Kaiser-Meyer-Olkin) measurement and Bartlett's test of sphericity. KMO sampling adequacy is a statistic that indicates the proportion of variance in variables that can be caused by underlying factors. KMO gives values between 0 and 1, high values (close to 1.0) generally indicate that a factor analysis can be useful with the data. Values between 0 and 0.5 indicate that factor analysis should not be used with the data from our sample, values between 0.51 and 0.7 indicate that the adequacy is mediocre, between 0.71 and 0.8 is acceptable, 0.81 to 0.9 is good, and greater than 0.91 is excellent. Bartlett's Test of Sphericity tests the hypothesis that the correlation matrix is an identity matrix, which would indicate that the variables are unrelated and therefore not suitable for structure detection. Small values (less than 0.05) of the significance level indicate that a factor analysis may be useful with the data [50]. The Exploratory Factor Analysis (EFA) for the responses denoting increase (I) showed KMO values of 0.927 and Bartlett is <0.0001, which would allow a factor analysis. The non-orthogonal analysis with the Oblimin method determined a factorial structure of 1 single factor made up of all the items on the scale, which explained 64% of the variance. A similar result was obtained from the analysis for the responses that denote a decrease (D) where the KMO was 0.874, Bartlett is <0.0001, and the factorial structure of 1 single factor made up of all the items on the scale explains 61% of the variance.

The reliability of the IMMS instrument based on the ARCS dimensions was quantified by Cronbach's alpha to evaluate the internal consistency of the questionnaire [51]. Table 5 shows Cronbach's alpha value for the overall instrument separating the responses that denote increasing (I) and decreasing (D) of the ARCS dimensions. Cronbach's Alpha is used for indicating an acceptable reliability of an instrument [52], it could present values between 0 and 1; values nearest to the unit are acceptable since they indicate reliability of the instrument [53]. For the overall instrument IMMS the values were superior to 0.7, which could be considered as acceptable [54]. As the instrument had different dimensions, Cronbach's alpha must be calculated for each of the ARCS dimensions [55]. Possibly, the values were between 0.59 to 0.94. The Relevance decreasing (RD) dimension shows values of 0.59 for both evaluation periods. Even though the value is less than 0.7 it could be considered as moderate reliability; particularly, this value for RD was due to the fact that the questions were designed in negative wording, which could have been misinterpreted by the students, as was pointed out by Tavakol & Dennick [55]. Possibly, this low value would be corrected if the questions were proposed in positive sense (increase) and if a great number of questions were considered.

Table 5. Average and standard deviation of IMMS.

Dimension	April 2020–February 2021			April 2021–February 2022		
	Mean	SD	Cronbach's Alpha	Mean	SD	Cronbach's Alpha
Total instrument (I)	3.5	0.6	0.93	3.4	0.8	0.96
Total instrument (D)	2.1	1.0	0.89	2.1	1.1	0.92
Attention (AI)	3.5	0.6	0.79	3.4	0.8	0.94
Attention (AD)	2.0	0.9	0.83	1.9	1.0	0.90
Confidence (CI)	3.3	0.6	0.68	3.3	0.7	0.76
Confidence (CD)	2.3	1.0	0.70	2.1	1.0	0.82
Relevance (RI)	3.4	0.6	0.76	3.4	0.8	0.87
Relevance (RD)	2.1	1.0	0.59	2.2	1.2	0.59
Satisfaction (SI)	3.5	0.6	0.82	3.4	0.8	0.93

3.3. Evaluation of Students Learning Motivation

The IMMS instrument was applied as a survey via internet; responses were registered anonymously after the presentation of the final project to a total of 115 students. The responses for the 34 items were tabulated and categorized based on ARCS dimension and are presented in Tables 6–9. Results are organized by academic year (two semesters) April 2020–February 2021 and April 2021–February 2022. Table 5 shows the results as mean and standard deviation for each dimension and for the globality of the instrument. The mean values of the instrument and for every dimension (AI, CI, RI, and SI) are over the central value of the scale which indicates some grade of agreement with the Project-Based Learning assisted with Augmented Reality academic strategy.

Table 6. Students' opinions about attention, results are expressed as a percentage (%) for each value of the scale.

Attention													
		Increase							Decrease				
S	**Semester**	**AI1**	**AI2**	**AI3**	**AI4**	**AI5**	**AI6**	**AI7**	**AD1**	**AD2**	**AD3**	**AD4**	**AD5**
1	April 2020–February 2021	1	0	0	0	1	1	0	30	31	28	59	56
2		6	6	4	3	3	3	3	31	37	39	22	23
3		32	30	37	45	44	38	35	27	23	23	14	16
4		61	64	59	51	52	57	62	11	9	10	5	6
1	April 2021–February 2022	3	7	3	0	3	10	7	53	33	40	60	63
2		17	3	3	13	3	7	7	17	23	33	23	10
3		20	23	43	23	40	27	33	20	37	13	3	17
4		60	67	50	63	53	57	53	10	7	13	13	10

S: Scale.

Table 7. Students' opinions about confidence, results are expressed as a percentage (%) for each value of the scale.

Confidence										
		Increase					Decrease			
S	**Semester**	**CI1**	**CI2**	**CI3**	**CI4**	**CI5**	**CD1**	**CD2**	**CD3**	**CD4**
1	April 2020–February 2021	3	0	0	2	0	19	17	27	46
2		16	4	3	7	7	30	40	30	28
3		57	54	45	52	41	34	32	33	19
4		24	42	52	39	52	17	11	10	7
1	April 2021–February 2022	0	3	3	0	0	37	40	20	57
2		20	17	7	3	10	30	20	33	17
3		57	33	27	53	33	23	23	37	17
4		23	47	63	43	57	10	17	10	10

S: Scale.

Table 8. Students' opinions about relevance, results are expressed as a percentage (%) for each value of the scale.

Relevance (%)										
		Increase							Decrease	
S	**Semester**	**RI1**	**RI2**	**RI3**	**RI4**	**RI5**	**RI6**	**RI7**	**CI5**	**CD1**
1	April 2020–February 2021	2	0	4	2	0	0	0	29	50
2		9	2	7	10	3	5	4	23	23
3		61	26	46	43	36	53	33	36	18
4		29	72	43	44	61	42	63	13	10
1	April 2021–February 2022	3	0	3	3	0	0	3	37	40
2		13	0	13	13	13	13	7	20	23
3		33	33	30	23	23	43	30	20	23
4		50	67	53	60	63	43	60	23	13

S: Scale.

The results of the IMMS survey are analyzed as mean of the two academic years considering the responses to Agree (scale 3) and Strongly agree (scale 4). In general, Project-Based Learning assisted with Augmented Reality demonstrated to be an innovative academic strategy according to the responses for ARCS dimensions; similar results were published by Laurens-Arredondo [54] when applied Augmented Reality in an end-of-year project for Industrial design and Technical drawing subjects.

Table 6 presents the results for the Attention dimension questionnaire; the responses are grouped as increase (AI1 to AI7) or decrease (AD1 to AD5) of the criterium. Figure 6 shows the mean value for the responses that represent increase (a) and decrease (b) of the criterium. According to the students, between 80% and 96% of the students considered that the activities, materials, and organization of information used for Project-Based Learning assisted with Augmented Reality caught their attention and encouraged their interest to the fundamentals applied in the project. Barroso reported that the applications and development of AR tools attracts the attention of students [48]. Low mentioned a positive impression of the students with new, fun, and attractive of AR lessons, also remarking that visual aids for technical content provide benefits as extension of attention [26]. Bacca suggested that the learning experience of using AR technology captures interest, creates curiosity and helps students to focus in the fundamental information [56].

Table 9. Students' opinions about satisfaction, results are expressed as a percentage (%) for each value of the scale.

Satisfaction (%)							
		Increase					
S	**Semester**	**SI1**	**SI2**	**SI3**	**SI4**	**SI5**	**SI6**
1	April 2020–February 2021	0	0	0	0	1	0
2		4	5	10	2	3	4
3		35	42	32	36	42	36
4		61	53	58	63	54	60
1	April 2021–February 2022	7	10	7	3	0	7
2		0	7	3	0	7	0
3		40	37	37	50	33	33
4		53	47	53	47	60	60

S: Scale.

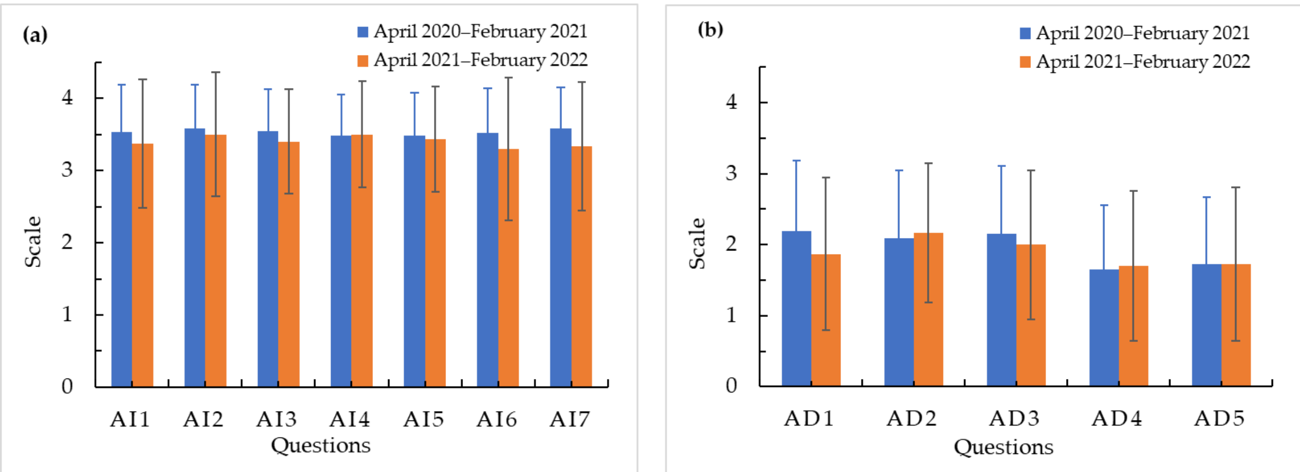


Figure 6. Means of students' opinions about attention, (**a**) increased attention and (**b**) decreased attention.

Regarding the material used in AR, between 34% and 38% of responses (AD1 and AD2) indicate a decrease in attention due to the unattractive materials. In regards to the development of activities (AD3 and AD4) between the 14.5% and 17.5% indicate that the repetition of activities could be tiring, which is related to the 24.5% that indicates that some information (AD5) could be irritating.

Students' opinions on confidence are shown in Table 7; the responses indicate increase (CI1 to CI5) and decrease of confidence (CD1 to CD4). Figure 7 shows the mean value for the responses that represent increase (a) and decrease (b) of the criterium. Between 80.5% and 80.0% (CI1 and CI2) of students indicate they get confidence since the first impression concerning AR technology shown to be easy, and they understood the learning aim of the project. Similarly, 93.5%, 93.5% and 91.5% (CI3, CI4 and CI5) indicate that the organization of information and work in the activities allows to create confidence in learning and the capability for passing the final test. In general, students demonstrated confidence in their abilities and knowledge for participating in the Project-Based Learning assisted with

Augmented Reality as academic strategy, in a way they understood the project aims and approved the final test with high scores. Low also reported the confidence of students who feel confidence to learn content with the use of AR technology [26]; however, when they were asked about confidence in taking a graded assessment the results diminished significantly. Bacca considers that AR tools supporting confidence in the students allow them to learn at their own pace and explore multiple possibilities for solving problems [56].

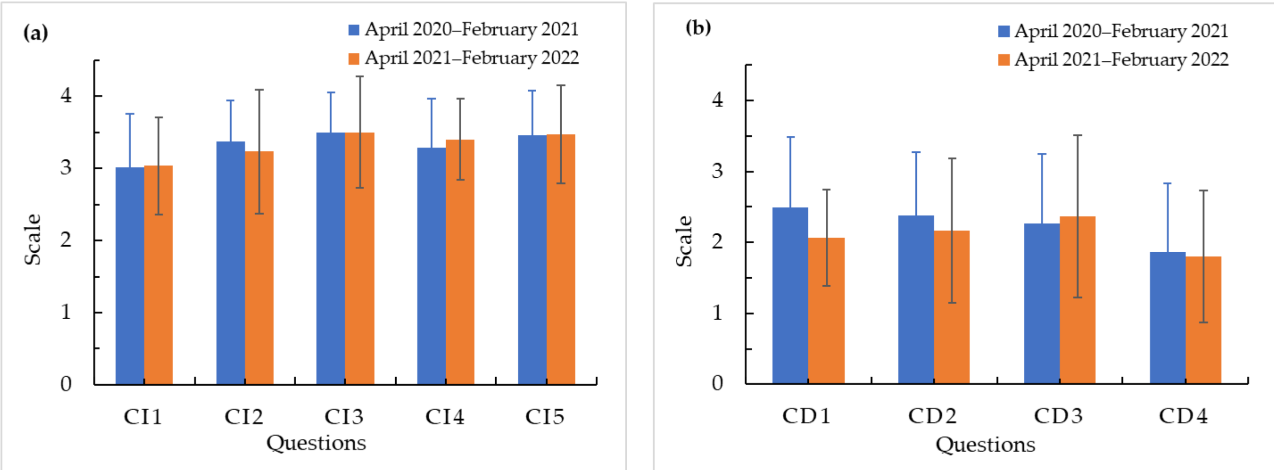
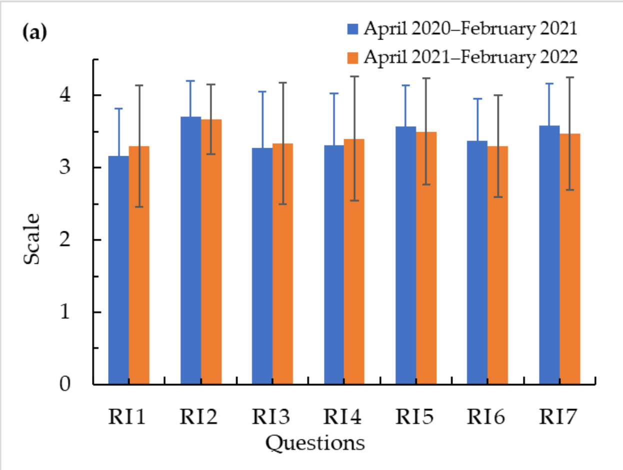


Figure 7. Means of students' opinions about confidence, (**a**) increased attention and (**b**) decreased attention.

Regarding the decrease of confidence, for CD1, the 42% of answers indicate that the material was more difficult than what they would prefer, CD2 41.5% reflect on the difficulty for remembering important points due to abundance of information, while 26.5% (CD4) did not understand the material. Moreover, in relation to the use of the AR objects, the 45% (CD3) mention that it was difficult for them to discover the digital information linked to the real image. This shows the necessity of improving the material used or adapting the complexity level, as reported by Laurens-Arredondo, to correctly implement AR and increase the confidence in the participants [54].

Responses about relevance are shown in Table 8; the responses for RI1 to RI7 indicate increase of this criterion, while responses for RD1 and RD2 correspond to decrease of perceived relevance. Figure 8 shows the mean value for the responses that represent increase (a) and decrease (b) of the criterium. Between 89% and 90.5% (RI1 and RI6) indicate that the content of the material was related to information they knew before. Similarly, students identified the activities and content as important (RI2, 99%, RI5, 91.5%), of interest (RI3, 86%) and useful (RI7, 93%). Regarding the use of AR as a technology tool, 85% (RI4) of students identified how the knowledge of AR is used as educational tool. The results show that the students perceived that Project-Based Learning assisted with Augmented Reality as relevant for their academic interest and their professional skills; similar results were reported by Low [26], who also mentioned that "these results were as the target group comprised of Chemical Engineering students with some background knowledge on the subject matter". Laurens-Arredondo mentioned that students perceived that what they were learning through AR technology was useful in achieving this learning [54]. Additionally, Bacca reported that students perceived similar relevance for their learning process between AR learning experiences and traditional learning experiences [56].



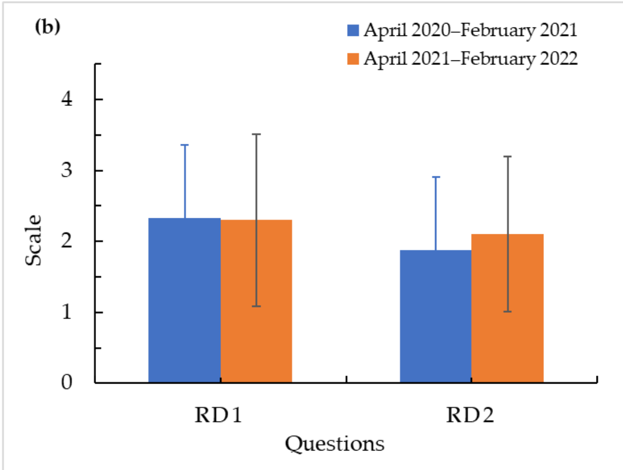


Figure 8. Means of students' opinions about relevance, (**a**) increased attention and (**b**) decreased attention.

Referring to decrease of relevance, 46% (RD1) considered that the images, videos, or text information was not enough to know the importance of the activity, which indicates the necessity of improving the educational material used, as previously discussed in the confidence dimension. Another group of students (RD2) considered the AR activities were not relevant (32%) because they had been previously prepared to perform the AR activities. This response could have been given by the students who applied AR tools in the first semester of this study or in other subjects.

For the satisfaction criterion, Table 9 shows the responses for questions SI1 to SI6, while Figure 9 shows the mean value for the responses for each question. More than 90% of the students consider to be satisfied in aspects as achievement of skills (SI1 and SI5), reward for effort (SI4), interest in knowing more about the subject (SI2, SI3 and SI6). Students' satisfaction with the inclusion of AR tools in their learning was also showed by Low [26]; however, they also mentioned that providing immediate feedback to continuous evaluation could provide better memory retention of fundamental information and sense of satisfaction.

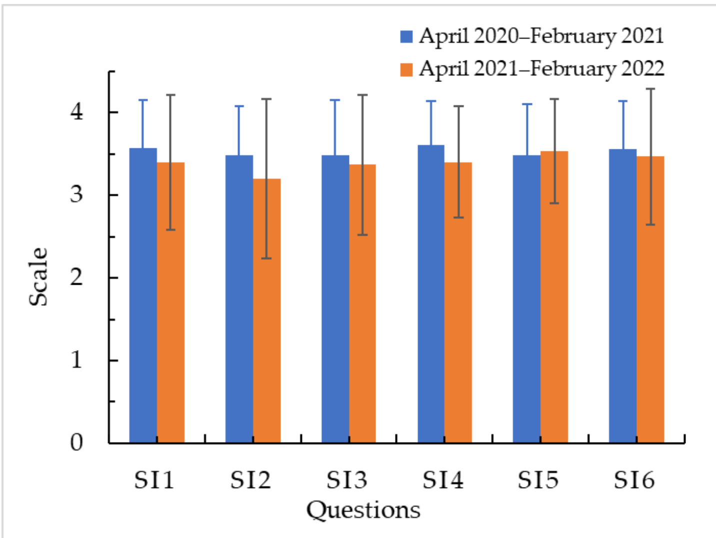


Figure 9. Means of students' opinions about relevance.

For the second academic year (April 2021 to February 2022), two additional questions were considered in the questionnaire, regarding the continuity between semesters. The responses are shown in Figure 10. 93.3% (CO1) of students believe their ability for using

AR technology was improved. Furthermore, 83.4% (CO2) considered that AR technology help them develop the subject competencies. Anuar reported the increase of motivation from a moderate score level to a high score level in students of Basics of electricity and electronics after using AR teaching material [57].

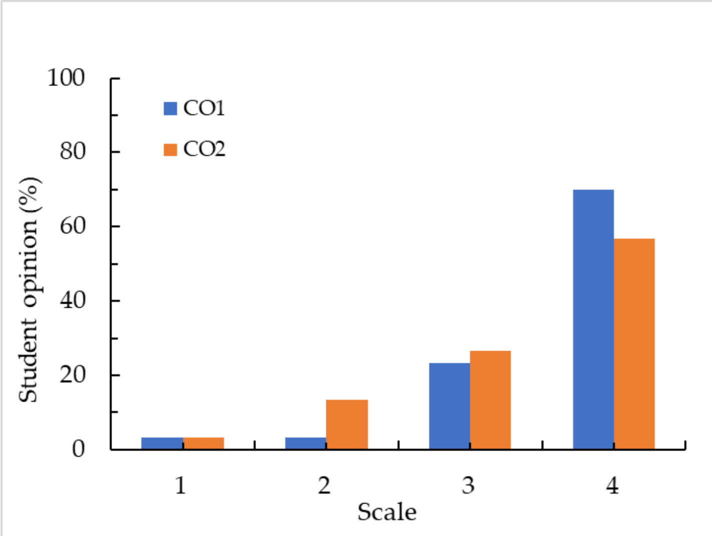


Figure 10. Means of students' opinions about continuity.

The implementation of the teaching strategy Project-Based Learning assisted with Augmented Reality as academic strategy proposed for the UO courses at Chemical Engineering program resulted in an effective and motivational strategy during the severe health restrictions imposed by the COVID-19 pandemic.

4. Conclusions

ARCS model is based on four components that increase students' intrinsic motivation: attention (A), relevance (R), confidence (C) and satisfaction (S). These components focus on motivation to foster student learning. The evidence from this study shows that Project-Based Learning methodology assisted with Augmented Reality (AR) technology as academic strategy for learning Unit Operations in Chemical Engineering is certainly supported by the ARCS model. Indeed, the activities proposed for the use of the AR technological tool allowed students to maintain attention during instruction, develop a sense of relevance to their interests, generate confidence in achieving their goals, and promote a high level of satisfaction. In this study and according to the data provided by the 96 students, the average level of motivation was 3.45. This value is higher than the central value (2.0) of the assessment scale, which suggests a positive level of motivation, being an indicator that the students were satisfied with the development of the proposed activities. The Attention dimension reported an average score of 3.45, which can be considered as an indicator that the proposed activities met the expectations of the students by covering their learning needs. The Confidence dimension presented an average score of 3.33, being an indicator that the proposed activities promoted the confidence of students to adapt positively to a new learning environment. In the Relevance dimension, an average score of 3.42 was reported, suggesting that the educational strategies used helped students to relate knowledge in an interdisciplinary way. Finally, the Satisfaction dimension, with an average score of 4.46, was an indicator that the students felt quite satisfied with the activities carried out. In general, the results of this study suggest that the proposed activities and the technological tools provided allowed to promote a very good motivation in the students towards learning the contents of each one of the subjects.

Finally, the present study shows that Project-Based Learning methodology assisted with Augmented Reality technology used as academic strategy can stimulate motivation in students, and therefore, it can be a resource to use in teaching Unit Operations in the Chemical Engineering program since it stimulates attention, confidence, interest and curiosity towards learning.

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References

1. United Nations Sustainable Development Goals. Available online: http://www.undp.org/content/undp/en/home/sustainable-development-goals.html (accessed on 24 September 2022).
2. Khandakar, A.; Chowdhury, M.E.H.; Khalid, M.D.S.; Zorba, N. Case Study of Multi-Course Project-Based Learning and Online Assessment in Electrical Engineering Courses during COVID-19 Pandemic. *Sustainability* **2022**, *14*, 5056. [CrossRef]
3. Castro-Schez, J.J.; Redondo, M.A.; Jurado, F.; Albusac, J. Experience Applying Language Processing Techniques to Develop Educational Software That Allow Active Learning Methodologies by Advising Students. *J. Netw. Comput. Appl.* **2014**, *41*, 65–79. [CrossRef]
4. Ocampo-López, C.; Castrillón-Hernández, F.; Alzate-Gil, H. Implementation of Integrative Projects as a Contribution to the Major Design Experience in Chemical Engineering. *Sustainability* **2022**, *14*, 6230. [CrossRef]
5. Goyal, M.; Gupta, C.; Gupta, V. A Meta-Analysis Approach to Measure the Impact of Project-Based Learning Outcome with Program Attainment on Student Learning Using Fuzzy Inference Systems. *Heliyon* **2022**, *8*, e10248. [CrossRef]
6. Gomez-del Rio, T.; Rodriguez, J. Design and Assessment of a Project-Based Learning in a Laboratory for Integrating Knowledge and Improving Engineering Design Skills. *Educ. Chem. Eng.* **2022**, *40*, 17–28. [CrossRef]
7. Xi, J.; Wang, X. Development of Landscape Architecture Design Students' Pro-Environmental Awareness by Project-Based Learning. *Sustainability* **2022**, *14*, 2164. [CrossRef]
8. Ruslan, M.S.H.; Bilad, M.R.; Noh, M.H.; Sufian, S. Integrated Project-Based Learning (IPBL) Implementation for First Year Chemical Engineering Student: DIY Hydraulic Jack Project. *Educ. Chem. Eng.* **2021**, *35*, 54–62. [CrossRef]
9. Beneroso, D.; Robinson, J. Online Project-Based Learning in Engineering Design: Supporting the Acquisition of Design Skills. *Educ. Chem. Eng.* **2022**, *38*, 38–47. [CrossRef]
10. Guo, P.; Saab, N.; Post, L.S.; Admiraal, W. A Review of Project-Based Learning in Higher Education: Student Outcomes and Measures. *Int. J. Educ. Res.* **2020**, *102*, 101586. [CrossRef]
11. Basilotta Gómez-Pablos, V.; Martín del Pozo, M.; García-Valcárcel Muñoz-Repiso, A. Project-Based Learning (PBL) through the Incorporation of Digital Technologies: An Evaluation Based on the Experience of Serving Teachers. *Comput. Hum. Behav.* **2017**, *68*, 501–512. [CrossRef]
12. Tang, Y.M.; Chau, K.Y.; Kwok, A.P.K.; Zhu, T.; Ma, X. A Systematic Review of Immersive Technology Applications for Medical Practice and Education—Trends, Application Areas, Recipients, Teaching Contents, Evaluation Methods, and Performance. *Educ. Res. Rev.* **2022**, *35*, 100429. [CrossRef]
13. Radianti, J.; Majchrzak, T.A.; Fromm, J.; Wohlgenannt, I. A Systematic Review of Immersive Virtual Reality Applications for Higher Education: Design Elements, Lessons Learned, and Research Agenda. *Comput. Educ.* **2020**, *147*, 103778. [CrossRef]
14. Fan, X.; Jiang, X.; Deng, N. Immersive Technology: A Meta-Analysis of Augmented/Virtual Reality Applications and Their Impact on Tourism Experience. *Tour. Manag.* **2022**, *91*, 104534. [CrossRef]
15. Nhan, V.K.; Tam, L.T.; Dung, H.T.; Vu, N.T. A Conceptual Model for Studying the Immersive Mobile Augmented Reality Application-Enhanced Experience. *Heliyon* **2022**, *8*, e10141. [CrossRef] [PubMed]
16. López Chávez, O.; Rodríguez, L.-F.; Gutierrez-Garcia, J.O. A Comparative Case Study of 2D, 3D and Immersive-Virtual-Reality Applications for Healthcare Education. *Int. J. Med. Inform.* **2020**, *141*, 104226. [CrossRef]
17. Liu, R.; Peng, C.; Zhang, Y.; Husarek, H.; Yu, Q. A Survey of Immersive Technologies and Applications for Industrial Product Development. *Comput. Graph.* **2021**, *100*, 137–151. [CrossRef]
18. AlFadalat, M.; Al-Azhari, W. An Integrating Contextual Approach Using Architectural Procedural Modeling and Augmented Reality in Residential Buildings: The Case of Amman City. *Heliyon* **2022**, *8*, e10040. [CrossRef]

19. Jagtap, S.; Saxena, P.; Salonitis, K. Food 4.0: Implementation of the Augmented Reality Systems in the Food Industry. *Procedia CIRP* **2021**, *104*, 1137–1142. [CrossRef]
20. Giannopulu, I.; Brotto, G.; Lee, T.J.; Frangos, A.; To, D. Synchronised Neural Signature of Creative Mental Imagery in Reality and Augmented Reality. *Heliyon* **2022**, *8*, e09017. [CrossRef]
21. Venkatesan, M.; Mohan, H.; Ryan, J.R.; Schürch, C.M.; Nolan, G.P.; Frakes, D.H.; Coskun, A.F. Virtual and Augmented Reality for Biomedical Applications. *Cell Rep. Med.* **2021**, *2*, 100348. [CrossRef]
22. Dincelli, E.; Yayla, A. Immersive Virtual Reality in the Age of the Metaverse: A Hybrid-Narrative Review Based on the Technology Affordance Perspective. *J. Strateg. Inf. Syst.* **2022**, *31*, 101717. [CrossRef]
23. Do, H.-N.; Shih, W.; Ha, Q.-A. Effects of Mobile Augmented Reality Apps on Impulse Buying Behavior: An Investigation in the Tourism Field. *Heliyon* **2020**, *6*, e04667. [CrossRef]
24. Yavuz, M.; Çorbacıoğlu, E.; Başoğlu, A.N.; Daim, T.U.; Shaygan, A. Augmented Reality Technology Adoption: Case of a Mobile Application in Turkey. *Technol. Soc.* **2021**, *66*, 101598. [CrossRef]
25. Ghaednia, H.; Fourman, M.S.; Lans, A.; Detels, K.; Dijkstra, H.; Lloyd, S.; Sweeney, A.; Oosterhoff, J.H.F.; Schwab, J.H. Augmented and Virtual Reality in Spine Surgery, Current Applications and Future Potentials. *Spine J.* **2021**, *21*, 1617–1625. [CrossRef]
26. Low, D.Y.S.; Poh, P.E.; Tang, S.Y. Assessing the Impact of Augmented Reality Application on Students' Learning Motivation in Chemical Engineering. *Educ. Chem. Eng.* **2022**, *39*, 31–43. [CrossRef]
27. Turel, Y.K.; Ozer Sanal, S. The Effects of an ARCS Based E-Book on Student's Achievement, Motivation and Anxiety. *Comput. Educ.* **2018**, *127*, 130–140. [CrossRef]
28. Keller, J.M. (Ed.) *The Arcs Model of Motivational Design BT—Motivational Design for Learning and Performance: The ARCS Model Approach*; Springer: Boston, MA, USA, 2010; pp. 43–74. ISBN 978-1-4419-1250-3.
29. Li, K.; Keller, J.M. Use of the ARCS Model in Education: A Literature Review. *Comput. Educ.* **2018**, *122*, 54–62. [CrossRef]
30. Teles dos Santos, M.; Vianna, A.S., Jr.; le Roux, G.A.C. Programming Skills in the Industry 4.0: Are Chemical Engineering Students Able to Face New Problems? *Educ. Chem. Eng.* **2018**, *22*, 69–76. [CrossRef]
31. Ballesteros, M.A.; Daza, M.A.; Valdés, J.P.; Ratkovich, N.; Reyes, L.H. Applying PBL Methodologies to the Chemical Engineering Courses: Unit Operations and Modeling and Simulation, Using a Joint Course Project. *Educ. Chem. Eng.* **2019**, *27*, 35–42. [CrossRef]
32. Zhang, M.J.; Newton, C.; Grove, J.; Pritzker, M.; Ioannidis, M. Design and Assessment of a Hybrid Chemical Engineering Laboratory Course with the Incorporation of Student-Centred Experiential Learning. *Educ. Chem. Eng.* **2020**, *30*, 1–8. [CrossRef]
33. Wiesner, T.F.; Lan, W. Comparison of Student Learning in Physical and Simulated Unit Operations Experiments. *J. Eng. Educ.* **2004**, *93*, 195–204. [CrossRef]
34. Alam, G.M.; Parvin, M. Can Online Higher Education Be an Active Agent for Change?—Comparison of Academic Success and Job-Readiness before and during COVID-19. *Technol. Forecast. Soc. Change* **2021**, *172*, 121008. [CrossRef]
35. Mukhopadhyay, U. Impact of Covid-19 Pandemic on Academic Performance and Work-Life Balance of Women Academicians. *Asian J. Soc. Sci.* **2022**, in press. [CrossRef] [PubMed]
36. Bezanilla, M.J.; Fernández-Nogueira, D.; Poblete, M.; Galindo-Domínguez, H. Methodologies for Teaching-Learning Critical Thinking in Higher Education: The Teacher's View. *Think Ski. Creat.* **2019**, *33*, 100584. [CrossRef]
37. Servant, V.F.C.; Schmidt, H.G. Revisiting 'Foundations of Problem-Based Learning: Some Explanatory Notes'. *Med. Educ.* **2016**, *50*, 698–701. [CrossRef] [PubMed]
38. Bourazeri, A.; Arnab, S.; Heidmann, O.; Coelho, A.; Morini, L. Taxonomy of a Gamified Lesson Path for STEM Education: The Beaconing Approach. In Proceedings of the 11th European Conference on Games Based Learning, ECGBL 2017, Graz, Austria, 5–6 October 2017; pp. 29–37.
39. Sharma, A.; Dutt, H.; Naveen Venkat Sai, C.; Naik, S.M. Impact of Project Based Learning Methodology in Engineering. *Procedia Comput. Sci.* **2020**, *172*, 922–926. [CrossRef]
40. Saad, A.; Zainudin, S. A Review of Project-Based Learning (PBL) and Computational Thinking (CT) in Teaching and Learning. *Lear. Motiv.* **2022**, *78*, 101802. [CrossRef]
41. Holt, S. Virtual Reality, Augmented Reality and Mixed Reality: For Astronaut Mental Health; and Space Tourism, Education and Outreach. *Acta Astronaut.* **2023**, *203*, 436–446. [CrossRef]
42. De Lima, C.B.; Walton, S.; Owen, T. A Critical Outlook at Augmented Reality and Its Adoption in Education. *Comput. Educ. Open* **2022**, *3*, 100103. [CrossRef]
43. Jääskä, E.; Lehtinen, J.; Kujala, J.; Kauppila, O. Game-Based Learning and Students' Motivation in Project Management Education. *Proj. Leadersh. Soc.* **2022**, *3*, 100055. [CrossRef]
44. Roopa, D.; Prabha, R.; Senthil, G.A. Revolutionizing Education System with Interactive Augmented Reality for Quality Education. *Mater. Today Proc.* **2021**, *46*, 3860–3863. [CrossRef]
45. Radu, I.; Yuan, J.; Huang, X.; Schneider, B. Charting Opportunities and Guidelines for Augmented Reality in Makerspaces through Prototyping and Co-Design Research. *Comput. Educ. X Real.* **2023**, *2*, 100008. [CrossRef]
46. Salazar-Peña, R.; Pedroza-Toscano, M.A.; López-Cuenca, S.; Zárate-Navarro, M.A. Project-Based Learning for an Online Course of Simulation Engineering: From Bioreactor to Epidemiological Modeling. *Educ. Chem. Eng.* **2023**, *42*, 68–79. [CrossRef]
47. Kumar, V.V.; Carberry, D.; Beenfeldt, C.; Andersson, M.P.; Mansouri, S.S.; Gallucci, F. Virtual Reality in Chemical and Biochemical Engineering Education and Training. *Educ. Chem. Eng.* **2021**, *36*, 143–153. [CrossRef]

48. Barroso Osuna, J.; Cabero Almenara, J.; Moreno Fernández, A.M. The Use of Learning Objects in Augmented Reality in the Teaching of Medicine. *Innoeduca Int. J. Technol. Educ. Innov.* **2016**, *2*, 77–83. [CrossRef]
49. Krug, M.; Czok, V.; Müller, S.; Weitzel, H.; Huwer, J.; Kruse, S.; Müller, W. Ein Bewertungsraster Für Augmented-Reality-Lehr-Lernszenarien Im Unterricht. *CHEMKON* **2022**, *29*, 312–318. [CrossRef]
50. Camargo, L.; Herrera-Pino, J.; Shelach, S.; Soto-Añari, M.; Porto, M.F.; Alonso, M.; González, M.; Contreras, O.; Caldichoury, N.; Ramos-Henderson, M.; et al. GAD-7 Generalised Anxiety Disorder Scale in Colombian Medical Professionals during the COVID-19 Pandemic: Construct Validity and Reliability. *Rev. Colomb. Psiquiatr.* **2021**, in press. [CrossRef]
51. Henson, R.K. Understanding Internal Consistency Reliability Estimates: A Conceptual Primer on Coefficient Alpha. *Meas. Eval. Couns. Dev.* **2001**, *34*, 177–189. [CrossRef]
52. Taber, K.S. The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. *Res. Sci. Educ.* **2018**, *48*, 1273–1296. [CrossRef]
53. Echauri, A.M.F.; Minami, H.; Sandoval, M.J.I. La Escala de Likert En La Evaluación Docente: Acercamiento a Sus Características y Principios Metodológicos. *Perspect. Docentes* **2012**, *50*, 31–40.
54. Laurens-Arredondo, L. Mobile Augmented Reality Adapted to the ARCS Model of Motivation: A Case Study during the COVID-19 Pandemic. *Educ. Inf. Technol.* **2022**, *27*, 7927–7946. [CrossRef] [PubMed]
55. Tavakol, M.; Dennick, R. Making Sense of Cronbach's Alpha. *Int. J. Med. Educ.* **2011**, *2*, 53–55. [CrossRef] [PubMed]
56. Bacca-Acosta, J.; Baldiris, S.; Fabregat, R.; Kinshuk, D. Framework for Designing Motivational Augmented Reality Applications in Vocational Education and Training. *Australas. J. Educ. Technol.* **2019**, *35*, 3. [CrossRef]
57. Anuar, S.; Nizar, N.; Ismail, M.A. The Impact of Using Augmented Reality as Teaching Material on Students' Motivation. *Asian J. Vocat. Educ. Humanit.* **2021**, *2*, 1–8. [CrossRef]

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