education sciences

MDPI

Article

# The Use of Augmented Reality to Strengthen Competence in Data Analysis and Problem Solving in Engineering Students at the Universidad del Valle de México

**Marco Antonio Zamora-Antuñano [1,†], Rossana Barros-Baertl [2,†], Belzabeth Tovar-Luna [3,†], Carlos Alberto González-Gutiérrez [1,†], Nestor Efren Mendez-Lozano [1,†] and Miguel Ángel Cruz-Perez [1,*,†]**

1 Engineering and Graduate Areas, Centro de Investigación, Innovación y Desarrollo Tecnológico de UVM (CIIDETEC), Universidad del Valle de México, Santa Rosa Jauregui, Querétaro 76230, Mexico
2 School of Education, Universidad Peruana de Ciencias Aplicadas, Prolongación Primavera 2390, Lima 15023, Peru
3 School of Health Sciences, Universidad del Valle de Mexico, Santa Rosa Jauregui, Querétaro 76230, Mexico
* Correspondence: miguel_cruzp@my.uvm.edu.mx
† These authors contributed equally to this work.

**Abstract:** The objective of this research was to analyze the improvement in the data analysis and problem-solving competence of students of industrial and systems engineering (IIS) and mechatronics engineering (IMEC) through the use of this technology and its impact on the results of the undergraduate general examination (EGEL). A training course was held for teachers and students for the design of learning objects (LO), and a questionnaire on the use of AR and the improvement in learning was administered. AR is a technology that has begun to be introduced in different contexts and at different educational levels. The results obtained through the Wilcoxon test and the multiple correspondence analysis (MCA) showed that there were improvements in academic performance with the use of AR and an interest in this tool being used during the academic training process.

**Keywords:** augmented reality (AR); learning objects (LO); data analysis and problem-solving skills; academic development; EGEL results

check for updates

**Citation:** Zamora-Antuñano, M.A.; Barros-Baertl, R.; Tovar-Luna, B.; González-Gutiérrez, C.A.; Mendez-Lozano, N.E.; Cruz-Perez, M.Á. The Use of Augmented Reality to Strengthen Competence in Data Analysis and Problem Solving in Engineering Students at the Universidad del Valle de México. *Educ. Sci.* **2022**, *12*, 755. https://doi.org/10.3390/educsci12110755

Academic Editor: Diego Vergara

Received: 26 September 2022
Accepted: 21 October 2022
Published: 27 October 2022

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

## 1. Introduction

This paper presents the achievements made in the development of a project entitled application of augmented reality (AR) tools to strengthen the skills and abilities of engineering students at the Universidad del Valle de México (UVM) Campus Querétaro and improve their academic performance. The project was the winner of the international stage of the David Wilson Award 2018–2019, an educational research contest sponsored by Laureate International Universities. For this project, a 24-month period was established for its completion and execution (August 2019–August 2021); however, due to the pandemic, there were delays in the execution time. In Stage 1, the work plan of the project was shown at a general level; this research corresponds to Stages 2 and 3. As a result of the COVID-19 crisis, there was a paradigmatic change in higher education institutions throughout the world. There was a shift from face-to-face education schemes to emergency remote teaching (ERT) [1]. The use of electronic educational resources in the teaching–learning process is growing, especially in higher or university education [2]. This has increased the need to apply new technologies for the development of educational materials and the use of technological tools that support the strengthening of skills, such as data analysis and problem solving, in higher education students and, in our particular case, students of industrial and systems engineering (IIS) and mechatronics engineering (IMEC) [3,4]. There is a need for quality digital learning resources that are effective and can be used by teachers in their educational practices. Their design must take into account ease of use; ease of learning; and, above all, the integration with the knowledge involved, with the need for a process of digital literacy for the development and application of knowledge that is increasingly framed in the field of digital platforms, information exchange, access to open resources, and free access to educational software [5,6]. It is necessary to design virtual learning environments that can examine individual traits and that are adapted to the behavioral characteristics of students to the greatest possible degree, benefiting those who, due to their cognitive style and personality traits, tend to have low academic performance and experience difficulties with adaptation to certain educational environments [7]. This can translate into students more actively participation in the classroom, and consequently in the improvement of academic performance. One of these emerging technologies is augmented reality (RA, with AR being its acronym in English) [8].

### *1.1. Literature Review*

Some of the first AR publications appeared in 1993, and several works related to the educational field and teaching–learning with AR support tools include: "Tracking Requirements for Augmented Reality" (Azuma, 1993) [9]; "Knowledge-Based Augmented Reality" [10]; and "Augmenting Reality-Adding Computational Dimensions to Paper" [11]. Currently, AR offers endless new possibilities for interaction and is present in many areas [12]. Thus, it represents a recent form of visualization that functionally combines virtuality with reality itself, generating new possibilities for the interpretation of previously unavailable information, which opens up novel ways to learn and recognize data, process them into information, and easily convert them into knowledge. The different methods used to carry out experiences in augmented reality are produced by different computer and telecommunications platforms, which facilitate projects quickly and economically [13].

AR is not a new concept; it gained presence in the scientific world in the early 1990s using technology based on (a) fast-processing computers, (b) real-time graphics rendering techniques, and (c) systems' portable precision tracking devices that allow the combination of images generated by the computer to be implemented in the user's vision of the real world. In 2005, the Massachusetts Institute of Technology (MIT) and Harvard University developed applications of AR in game format in their programs and education groups; these games sought to engage high school students in situations that combined real-world experiences with additional information presented to them on their mobile devices. Students could interact with virtual objects in an augmented real environment and develop their learning abilities by experimenting with new methods of gaining knowledge. In 2010, the HIT Lab in New Zealand developed the MagicBook, where a student could read a real book through a handheld viewer and see virtual content on the real pages [14].

AR emerged for the first time in the 1970s as technology-oriented experiences in virtual worlds. AR is a term used to describe the set of technologies that allow a user to visualize part of the real world through a technological device, with graphic information added by this device. The term was coined by Tom Caudell in 1992, and from then on, different applications and platforms followed one another to develop more augmented reality technology and applications. Between 2006 and 2008, owing to the world of video games and the improvement in the computational capabilities of computers and graphics cards, it was possible to create high-quality augmented reality experiences. These machines were capable of moving three-dimensional scenes of more than 100,000 polygons while simultaneously tracking the visual elements. Marketing applications were very popular in those years, both at points of sale and events on-stage, as well as integrated into web pages. Then, the first high-level augmented reality programming tools appeared on the market (D'Fusion by Total Immersion or Metaio SDK) and companies specializing in this field proliferated. In this project, the development of augmented reality (AR) and LO applications for the teaching–learning process was proposed to increase the speed of the process of generating knowledge and improve the academic performance of students in IIS and IMEC programs at the UVM Campus Querétaro.

The use of AR in training activities and teaching–learning processes depends on a series of variables, such as the degree of motivation, which, according to [14], refers to the magnitude and direction of the behavior. According to the premises established by Keller, there are three variables that will decisively determine the motivation that a subject has to learn: attention, relevance, and confidence. These variables are directly related to the degree of satisfaction achieved by the students, which will condition a greater or lesser continued motivation to learn, understanding motivation as "the personal perception of usefulness that leads the individual to develop actions and involves him or her in activities, which in the educational context would be the reasons that predispose students to participate in the activities that take place in the class" [15].

The educational approach to AR applications should consider:

- Learning utilities;
- Audiovisual and telematic language;
- The analysis and representation of reality.

In each subject that is defined for the development of the project, the correct application of pedagogical models will have a common axis, which allows for the development of special skills, incorporation of animations and audiovisual effects to generate an environment that promotes learning, and inclusion of evaluations to keep track of the impact it has on users. Through AR, real environments mixed with virtual environments can be developed for various different platforms, from computers to mobile devices. They are all easily accessible and inexpensive.

The teaching and learning sequence, enriched with AR, proposes the manipulation, interaction, and integration of three-dimensional information formats, which allows a better connection between the theoretical aspects and the practical experience that guides the process of transformation of scientific phenomena. Thus, learning, linked to access mediated by augmented reality towards mental representations, takes a step forward compared to other known and studied processes, such as attention, concentration, and memory, and gives rise to the elaboration of mental representations that are the basis of learning and in direct relation to the "embodied" representations already investigated. Thus, augmented reality, by using virtual objects that simulate a real environment, could have a far-reaching influence on education [15]. Appendix A.2. shows examples of the applications that have been developed by teachers and students at UVM since 2019, when the AR application project began.

### 1.2. Purpose of the Study and Research Questions

Based on the need to improve the academic performance of IIS and IMEC students, achieve better results in evaluations, such as the general examination for bachelor's degree (CENEVAL, 2018) [16,17], and strengthen students' competence in analysis and problem solving, it is feasible to use AR tools and applications through LO in the teaching–learning process to encourage the attention and concentration of students in their eighth and ninth semesters, complying with the knowledge and skills established in the graduate profile [3,4] and achieving the goals and objectives outlined in the proposal. Higher education in Mexico, in the international context, is contrasting. On the one hand, it has similar or higher investment than most developed countries, such as Germany, Japan, and England; on the other hand, it presents serious drawbacks, with reduced graduation rates, lower educational achievement among the adult population, and the lowest percentages of schooling, according to the indicators of the Organization for Economic Cooperation and Development (OECD). The level of schooling is not the only factor that reflects the educational backwardness of Mexico compared to the rest of the world. While in Mexico, the graduation rate at the undergraduate level is 20%, in countries such as Germany, Austria, Italy, and Spain, this percentage is equal to or greater than 30%. Iceland's graduation rate of 60% stands out as the highest in the OECD. A fundamental aspect of higher education in engineering is to develop young peoples' ability to generate innovative solutions that involve the use of technology. This aspect favors the adoption of technological alternatives in a space where the articulation and application of knowledge to solve problems converge.

*1.3. Learning Assessment*

Understood as a process, education requires inputs, where the process is planned depending on what is to be obtained (output), based on a study of needs. For Lieberman, Levin and Luna-Bazaldua [18], the evaluation of student learning is "the process of collecting and evaluating information about what students know, understand and can do, in order to make informed decisions about the next steps to take in the educational process" [18]. In this understanding, evaluation represents a feedback mechanism, where stakeholders verify progress and compliance with the objectives by monitoring the process created for the resolution of a previously identified situation, or as stated by Norman and Vand der Vlauten, Christie and De Graaf, various modalities of assessments should be aligned with assessment methods that are compatible with learning processes [19,20].

Assessment becomes relevant by understanding the particular learning needs and those of all learners as a whole, taking into account the environment in which that need arises. Assessment conducted prior to the health crisis, by teachers themselves in the classroom, ranged from instructor observations to constant feedback to assignments [18]. After the closure of schools due to the health contingency, it has been necessary to look for alternatives for feedback.

While all types of assessment of student learning are critical, having substantive assessments at this time is important because learning needs to take place outside the classroom, and both teachers and parents need to understand whether students understand the content that has been delivered to them in formats that are contrasted with those to which they have become accustomed [18]. During confinement, objectives and new forms of organization and planning must be incorporated given the circumstances. That is, needs must be identified for the current context, as well as the contents or the way they are addressed and evaluated. This does not necessarily mean that the social needs of professionals with duly developed knowledge and skills change, but rather those circumstances in which such knowledge and skills must be developed. In this regard, Lintorf et al. (2021) say that "As tutors, we have to consider how the learning environment supports the student's development of learning, and the skills and attitudes that shape professional identity and practice" [21], considering that changes should also be made in the format of examinations and in the principles of the selection of materials [22]. In this way, "the model will be a coherent structural practice" (p. 28).

The evaluation must be timely since it is concerned with taking quick actions and helping to meet the learning objectives, i.e., there is a formative assessment to identify opportunity areas for students. Finally, the specificity of formative assessment refers to its ability to inform teachers and students whether specific learning goals are being achieved or, if so, what is needed if they are not yet achieved, i.e., feedback is required.

The results of the EGEL represent the level of achievement of professional skills developed by UVM students. In particular, the level represents their ability to analyze data and solve problems under the guidance of teachers throughout their studies, measured with respect to high-quality standards. The EGEL results for the IIS and IMEC students during the period 2017–2021 are shown in Table 1.

**Table 1.** Results of the EGEL for IIS and IMEC students (2017–2021).

| Engineering Industrial and Systems | | | | |
|---|---|---|---|---|
| School Period | Without | Satisfactory | Outstanding | Hired |
| 01-2017 | 4 | 3 | 0 | 4 |
| 03-2017 | 4 | 5 | 0 | 4 |
| 01-2018 | 4 | 0 | 1 | 2 |
| 03-2018 | 4 | 7 | 4 | 7 |
| 01-2019 | 8 | 4 | 3 | 12 |
| 01-2020 | 2 | 12 | 7 | 13 |
| 01-2021 | 0 | 10 | 6 | 12 |
| 03-2021 | 4 | 6 | 5 | 11 |
| Engineering Mechatronics Engineering | | | | |
| School Period | Without | Satisfactory | Outstanding | Hired |
| 01-2017 | 4 | 2 | 2 | 7 |
| 03-2017 | 14 | 3 | 1 | 5 |
| 01-2018 | 5 | 5 | 1 | 4 |
| 03-2018 | 15 | 5 | 3 | 6 |
| 01-2019 | 10 | 6 | 1 | 8 |
| 01-2020 | 6 | 5 | 0 | 4 |
| 01-2021 | 12 | 9 | 0 | 10 |
| 03-2021 | 10 | 7 | 2 | 12 |

One way to measure achievement levels at UVM's institutional level is through the EGEL. Appendix A explains what the EGEL is and the areas of knowledge that are evaluated. The results of the EGEL (Table 1) represent the level of achievement of professional skills developed by UVM students, in particular, their ability to analyze data and solve problems under the guidance of teachers throughout their studies, measured with respect to high-quality standards. The necessary EGEL scores for the IIS and IMEC students are shown in Table A2.

### *1.4. Research Question*

How will the use of augmented reality influence the teaching–learning process, improve academic performance, and strengthen competence in the ability to analyze and solve problems in IIS and IMEC students in their eighth and ninth semesters at the UVM Campus Querétaro?

Variables

Independent variable: AR

- Conceptualization: AR as a teaching resource is the mixture of reality with a virtual space, in which a computer processes nurturing digital information in the physical world with visual experiences and better communication quality. This application can be used on smartphones and tablets.
- Audiovisual and telematic language.
- Category: Technological tools. The analysis and representation of reality.

Dependent variable: Improvements in learning

- Conceptualization: Workshops or courses to achieve improvements in learning and strengthen the ability to analyze and solve problems through AR.
- Category: Training, learning, and the ability to analyze and solve problems.

### *1.5. Objectives*

The proposed general objective of the project was to generate and promote learning environments with AR and LO in the classroom that allow students in their eighth and ninth semesters of IIS and IMEC to integrate different areas of knowledge, favoring the development of the competence to analyze and solve problems and improving their academic performance.

Specific Objectives

- Develop LO through AR models created by teachers that can be used by IIS and IMEC students at the UVM Campus Querétaro inside and outside the classroom as a teaching resource to improve and strengthen their analysis and problem-solving skills.
- Improve the academic performance of IIS and IMEC students and measure the development of their analysis and problem-solving skills.

## 2. Method

For the project in general, 5 steps were proposed, which are shown in Figure 1 below. For the purposes of this collaboration, the results of step 1–5 are shown, which were executed in the period of July 2020–June 2021. A working group was formed consisting of teachers and students from IIS and IMEC. A training course was held to learn how to develop AR applications through Unity 2018.4.20.

### *2.1. Research Method*

This research used a quantitative approach, with descriptive and explanatory results, and aimed to analyze the causes of the problems or the issues closely related to them. The problem was determined based on the use of technological and AR tools. The modality of the investigation was developed in five steps for the project:

- The first step included a documentary investigation based on the consultation of books, scientific articles, indexed magazines, and the web, among other resources, which served as a reference in the research process and supported the operationalization of the dependent and independent variables [21].
- The second step involved field work at the scene where the research phenomenon occurred. It was carried out during the training stage of students and teachers at the UVM Campus Querétaro. In this particular case, the training process was carried out.
- In the third step, field work, training of teachers and students, and use of AR and data census were carried out.
- In the fourth step, the data analysis was carried out.
- The fifth step was the replication of learning and knowledge transfer.

### *2.2. Participants*

First Stage (July 2020–March 2021): A population of 5 teachers and 45 students from the last semesters of the IIS and IMEC programs at the UVM Campus Querétaro were chosen, which corresponds to the first groups of project work and students who wrote the EGEL in December 2020 and March 2021. This is Group A. The sample was defined using a convenience method due to the limitations caused by COVID-19. The students who wrote the EGEL in December 2020 and March 2021 also completed the AR training course. Second Stage (April–October 2021): 32 students (16 IIS and 16 IMEC) who wrote the EGEL in October 2021 did not take the AR course. Two weeks before each group wrote the EGEL, some tasks related to the contents of the EGEL were applied to reinforce student's knowledge. This is Group B.

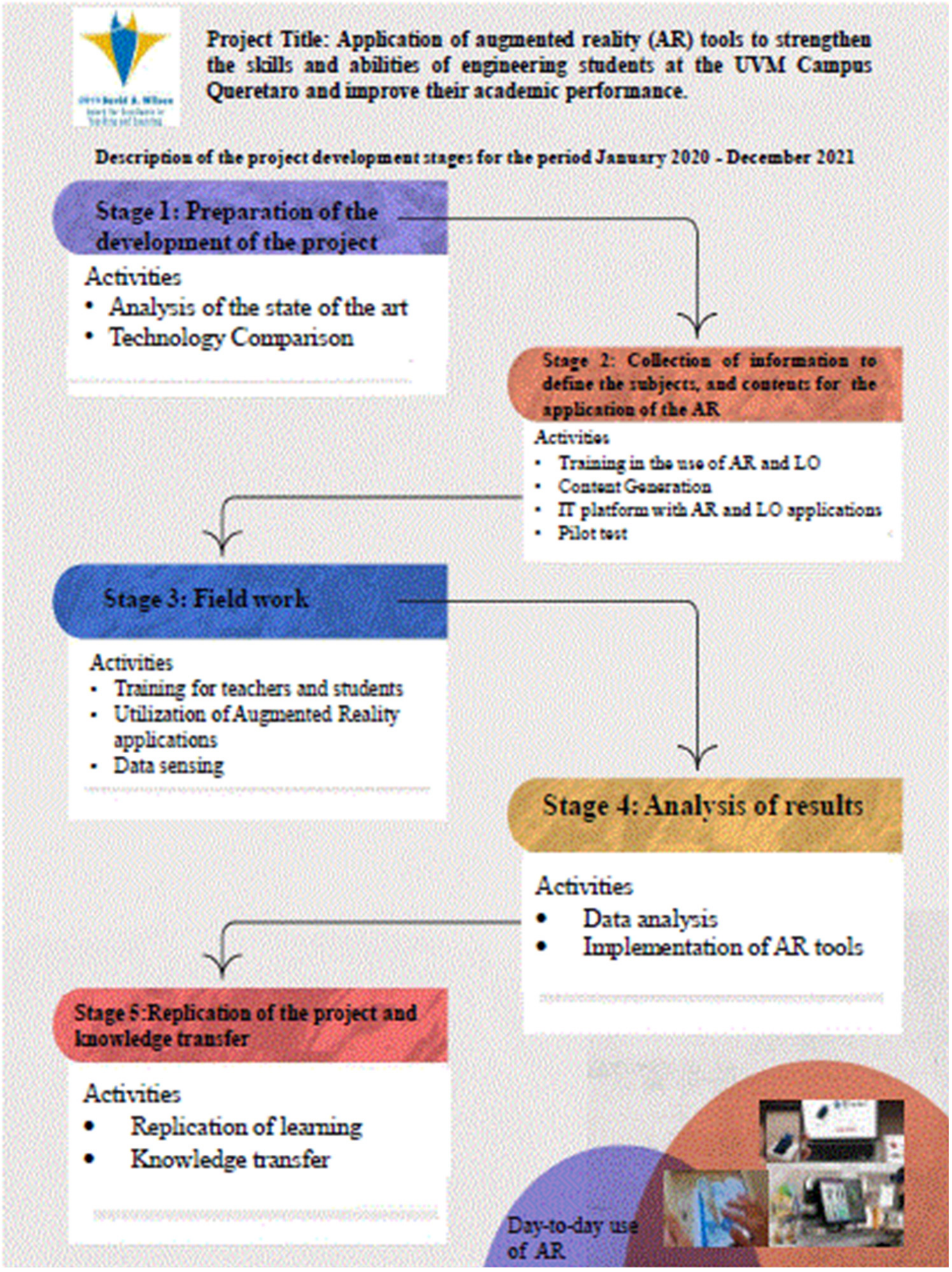


**Figure 1.** Project execution.

## 2.3. Data Collection Instruments

For this stage of the research, a search was carried out and a state-of-the-art questionnaire used by Gómez-García (2021) was replicated with adjustments, and was called the Data Collection Instrument on the use of AR and the improvement of learning [8] (see Appendix A, Table A1).

### Data Collection and Analysis

The questionnaire consisted of 2 sections: (I) technological tools and mobile devices and (II) teaching–learning process on data analysis and problem-solving competence. Each section had 5 questions with a Likert scale response item. This was a first approximation in the achievement of the objectives and goals set forth in the project. To validate the reliability of the instrument, a panel of experts was assembled and a measurement was made using Cronbach's alpha coefficient, which gave a result of 0.881.

Data Collection Instrument for data analysis and problem solving: A checklist was developed and applied three weeks before the CENEVAL EGEL. Results are shown in Figure 2. The checklist consisted of items that verified the students' ability to solve problems. The reliability of both instruments was validated using the expert panel technique.

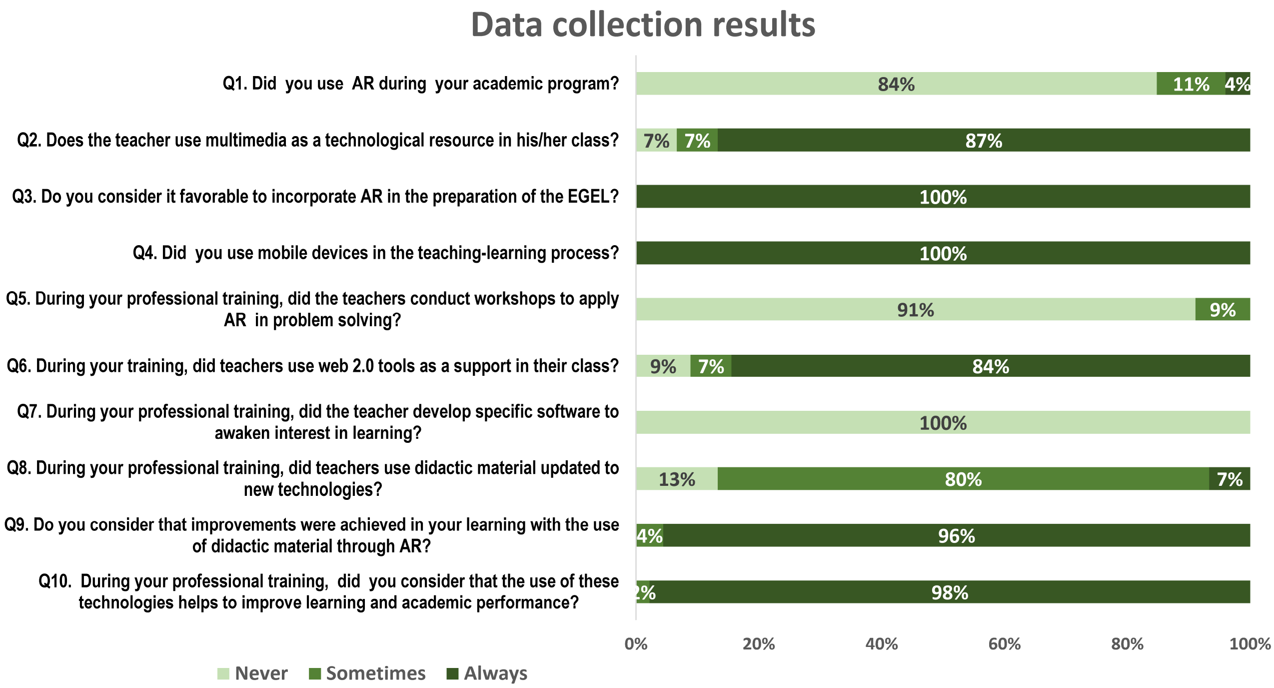


**Figure 2.** Data collection results.

### *2.4. Multiple Correspondence Analysis (MCA)*

Multiple correspondence analysis (MCA) is an extension of correspondence analysis (CA) that allows analysis of the pattern of relationships of several categorical dependent variables. As such, it can also be seen as a generalization of principal component analysis when the variables to be analyzed are categorical instead of quantitative [23]. Because MCA has been (re)discovered many times, equivalent methods are known under several different names, such as optimal scaling, optimal or appropriate scoring, dual scaling, homogeneity analysis, scalogram analysis, and the quantification method.

Technically, MCA is obtained by using a standard correspondence analysis of an indicator matrix (i.e., a matrix whose entries are 0 or 1) where the percentages of the explained variance need to be corrected. The correspondence analysis interpretation of interpoint distances should be adapted accordingly [23].

## 3. Results

The descriptive analysis presented the following results: 27 students from Group A were from IIS and 18 from IMEC, 52% (27 students) were male and 48% were female, and 85% were in the last semester of their degree. The ages of the students ranged between 22 and 23 years. Regarding the content of the training course, 100% of the students answered that they were satisfied with the course, 95% (43 students) stated that the materials were adequate, 100% of the students were satisfied with the performance and knowledge of the instructor, and 100% of students would have liked to continue training in AR. In relation to the topic of AR, the results of the data collection questionnaire are presented in Figure 2.

In question 1, 84% (38 students) of students reported that they had never used augmented reality in their academic training, 11% (5 students) indicated sometimes, and only 5% (2 students) stated that they always use this type of technology. Based on the aforementioned data, it was verified that the vast majority of students never or only sometimes used augmented reality in their academic training. This would indicate that when teachers do not use new teaching methods with cutting-edge technology in order to improve student performance, they miss out on the potential of this technology that covers student's needs step by step. In question 2, the answers showed that 87% of the students had teachers that used multimedia as a technological resource in their classes. A significant percentage of the students indicated that their teachers used multimedia as technological resources in their classes, which reflects an implicit strength that must be better exploited to educate the new generation of young digital natives. In question 3, 100% of the students considered it necessary to incorporate augmented reality in learning environments, which reflects the interest of the population studying this technology, which enriches the visual experience, positively improves the information processing capabilities of new content, favors autonomous work, increases collaboration and interaction, develops investigative skills, and promotes the constructivist and inquisitive approach of students. In question 4, all the students surveyed used mobile devices in the teaching process. This resource should be promoted as an educational mediator that facilitates the advancement of knowledge and the development of skills and abilities, making the most of the fact that the students, as digital natives, have technological accessibility and the required digital skills. In question 5, only 9% of students answered that during their training process, and that their teachers sometimes held workshops related to the use of technology, such as AR. According to the aforementioned data, it can be asserted that most teachers have never carried out these workshops, which indicates that they have never used AR, but have developed educational applications with attractive, interactive content that captivates the attention of their students with greater ease in order to improve their teaching work. For question 6, 84% of the population responded that their teachers always used Web 2.0 tools as support in their classes. Based on the data presented, it was interpreted that teachers use Web 2.0 tools for assistance in their classes as alternatives to support teaching. In question 7, 100% of the students answered that their teachers had never developed any specific software to arouse interest in learning; however, it should be considered that the IIS and IMEC teacher profile is not that of a developer or programmer. In question 8, 87% of the students mentioned that their teachers sometimes used teaching tools. The students indicated that their teachers used didactic material according to their level of learning, which indicates that educators are aware of the importance of designing, creating, or selecting material adapted to the learning style of each student; in other words, it cannot be based on the standard methodologies of teaching models. In question 9, 96% of the respondents considered that they always achieved improvements in their learning from using AR.

The students reasoned that they learned better when the teacher used didactic material to explain the content of their subject, since these materials are means or resources that facilitate the acquisition of concepts, abilities, attitudes, and skills within an educational context. In question 10, 98% of the students affirmed that this type of AR tool would always help them in their training.

The analyzed data showed that the majority of students would like to use didactic material with AR, which indicates a predisposition to become involved with these types of emerging tools as new means to convey learning. In addition, for professionals, such as educators, this could be a useful resource with great potential to assist them in performing their duties. For the students who wrote the EGEL in October 2021, the AR course was not taught, and we observed the results achieved using the different preparation activities. The results are shown in Figure 3, where participating teachers graded the activities and calculated the average of what all students achieved in all the activities. During the training period, teachers did not develop software and there were no workshops developed, which led to the responses given for questions 7 and 5, respectively.

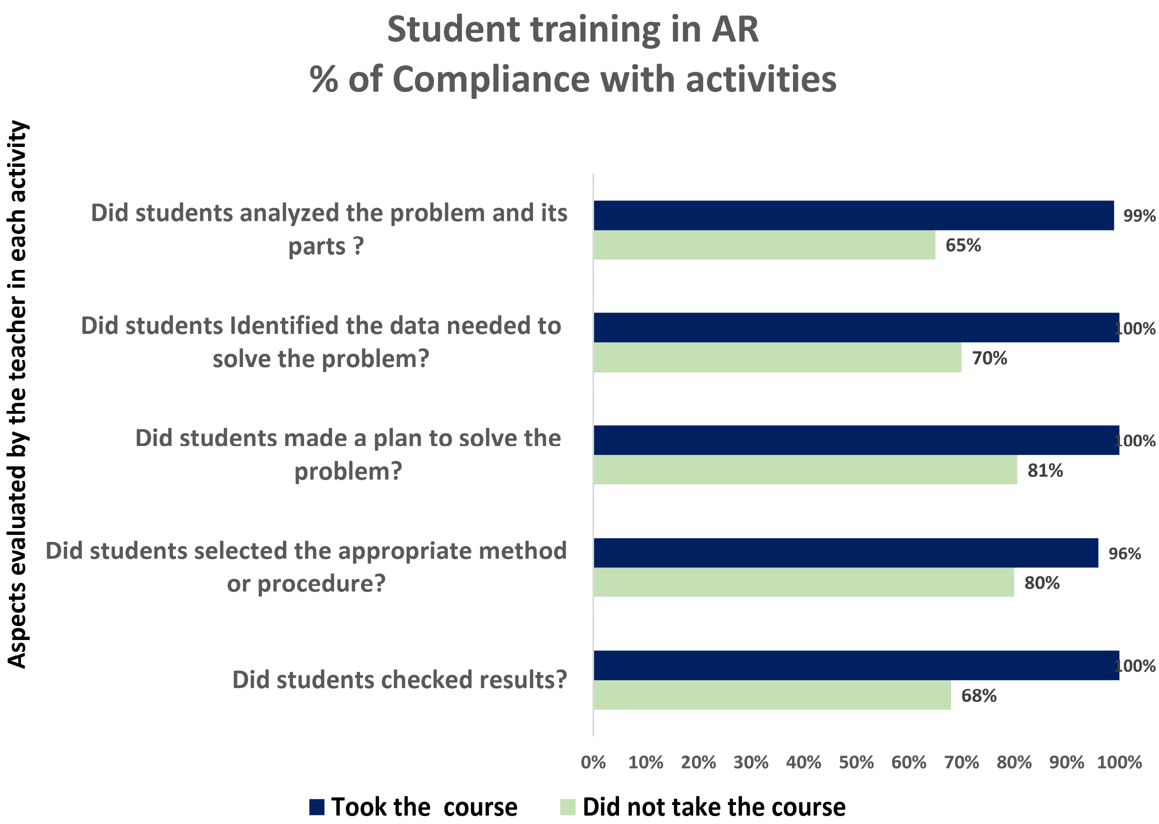


**Figure 3.** Percentage compliance in the activities.

### 3.1. *Data Analysis*

#### 3.1.1. Analysis of Variance

An ANOVA showed no significance differences between students that actually took the AR course and those who did not. See Tables 2 and 3. The difference can be noticed in the activities done before the EGEL test: students who took the AR course showed improved performance prior to the preparation for the EGEL compared with those with no AR preparation; see Figure 3.

**Table 2.** Descriptive analysis.

| Data Analysis | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | Mean | Standard Deviation | Standard Error | 95% Confidence Interval for Mean | | Minimum | Maximum | Inter-Component Variance |
| | | | | | Lower Limit | Upper Limit | | | |
| Did not attend course | 32 | 13.5 | 1.3678 | 0.2418 | 13.007 | 13.993 | 10 | 16 | |
| Attended the course | 45 | 13.4 | 1.0313 | 0.1537 | 13.09 | 13.71 | 10 | 15 | |
| Total | 77 | 13.442 | 1.1753 | 0.1339 | 13.175 | 13.708 | 10 | 16 | |
| Fixed effects | | | 1.1821 | 0.1347 | 13.173 | 13.71 | | | |
| Random effects | | | | 0.1347 a | 11.730 a | 15.153 a | | | −0.0324 |

a. Warning: the between-component variance is negative. It was replaced by 0.0 in the calculation of this random effects measure.

**Table 3.** Analysis of variance.

| ANOVA | | | | | |
|---|---|---|---|---|---|
| | Sum of Squares | gl | Quadratic Mean | F | Sig. |
| Between groups | 0.187 | 1 | 0.187 | 0.134 | 0.716 |
| Inside groups | 104.8 | 75 | 1.397 | | |
| Total | 104.987 | 76 | | | |

3.1.2. Wilcoxon Text

Using Excel, a Wilcoxon test was performed, where two questions from the survey of students from the Universidad del Valle de México were entered: questions five and seven. A value of z or significance value of 0.063 was obtained, and, considering that the calculated value of ($p = 0.063$) was greater than the confidence level (0.05), we decided to accept the null hypothesis stating that the use of AR would improve academic performance, and strengthen the ability to analyze and solve problems by students in the IIS and IMEC programs at the UVM Campus Querétaro.

Figure 4 shows the results of a multiple correspondence analysis (MCA) of the questions determined by the institution. It can be seen that questions 3, 4, and 7 were related, which makes sense because they were the questions that indicated that the user agreed to use the technologies for education and also used them. In addition, it can be seen from the perspective of question 5 that the students considered using RA to be positive regardless of whether the respondent were familiar with the use of technology in education. The distance of question 1 from the remaining questions, shows that the respondents were familiar with education technology and the use of AR.

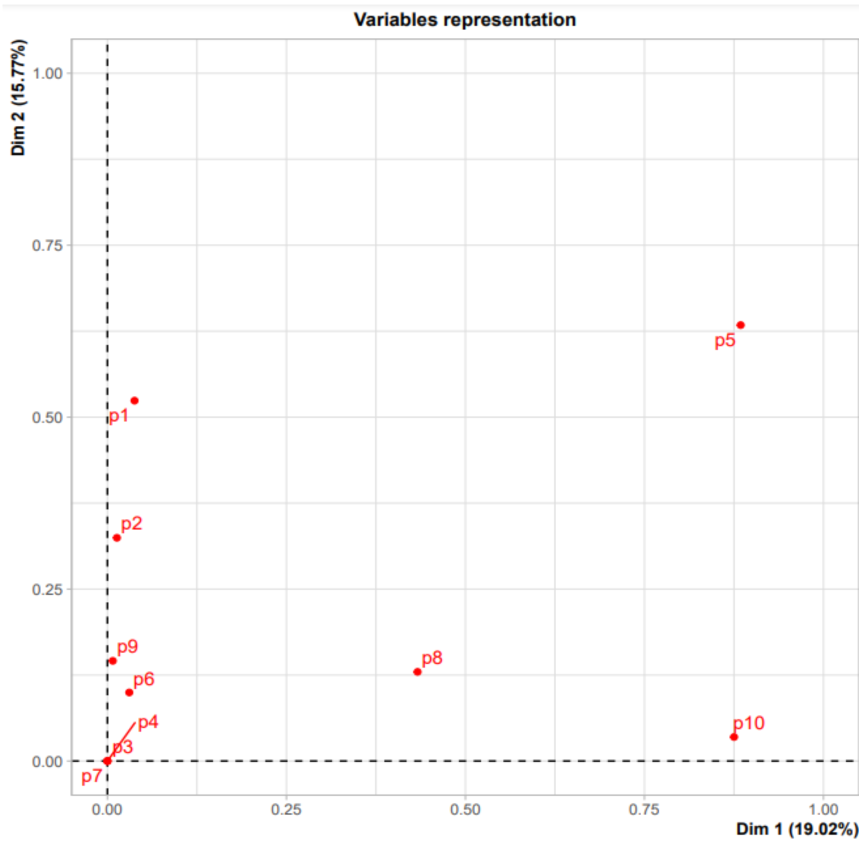


**Figure 4.** MCA analysis.

### *3.2. Answer to Research Question*

How will the use of AR influence the teaching–learning process, improve academic performance, and strengthen the analysis and solving problems competence in IIS and IMEC students during their eighth and ninth semesters at the UVM Campus Querétaro? Figure 3 shows that the students who took the AR course and were able to apply the concepts in the fulfillment of the activities according to the evaluation instruments for the assignments had better performance in the activities, thus answering the research question posed. For the teachers, the use of AR provided new ways and strategies to achieve the assessment objectives. During the practical sessions, the way in which teachers changed the means of interacting with the learning objects created for the practice suggests they are aware of different ways in which students interact with. When something is different to what was planned it is considered for the next session, and it also helps to find out the interest students might have in different approaches to learn and interact with the learning objects. To summarize, the teaching–learning process changes to make teachers more aware of the process because it is with new approaches that awareness is created of variations between the plan and what actually occurred. By analyzing the variations, the problem-solving competence is also the way in which the whole process is taking place, by both teachers and students.

## 4. Discussion

From this study and the analysis of the information, evidence was generated to explain the educational practices carried out by university students with the implementation of AR, with the aim of determining how much it improved competence in data analytics and problem solving in IIS and IMEC students at the UVM Campus Querétaro. The students considered the inclusion of AR technologies to be favorable in their learning process. Iqbal et al. (2021) [24] determined that the students in their study managed to strengthen a series of competencies, both general and specific, that were developed in the training area by combining the curricular contents and the specific disciplinary contents of the student training area through the development of applications with AR [24].

Lin (2018) was able to determine that students' interaction with learning objects produced using AR technology significantly improved the scores they achieved in learning assessments [7]. Portuguez-Castro (2022) verified the design of a didactic experience with new technologies in higher education and training actions that contribute to the preparation of the student in the design, production, and use of virtual resources with AR technology [25].

The final assessment is that this technology brings the student closer to an appropriate visual understanding of the problem presented, because in the traditional way that these exercises are presented, there are many aspects that cannot be easily visualized. With the application of the LO, there is a positive impact on students' ability to solve problems, taking into account the opportunities they have to visualize elements that support their development and analysis capacity [26]. It can be concluded that the development of AR experiences for the teaching–learning process of IIS and IMEC strengthened students' skills in the field of data analysis and problem solving. In the field of higher education, the characteristics of AR technology offer an effective and significant way of improving results in terms of learning achievement.

### *4.1. Study Limitations*

Most of the activities carried out in this study did not take place in person, and the material for the online training had to be generated. Normally, through teacher–student interactions, students can achieve a personal closeness to their teacher's experiences in their daily and professional lives. Another limitation was the number of students who participated in the workshop, given the limited number of students in the generation. We intend to replicate these activities with more students and at more UVM campuses to allow for a more reliable data analysis for inferences and improvements. One limitation is that, for this study, we assumed that the EGEL—CENEVAL is an assessment that measures the analysis and problem-solving skills, and by successfully passing the test, those skills are certified.

### *4.2. Implications for Theory and Practice*

AR can be very useful for situations such as those experienced in this study, where the physical presence in workshops is difficult. If AR is implemented such that the workshops can be used once certain skills are achieved, the efficiency in time, material, and resources in general will be greater. If practice can be linked with theory, with everyone undertaking a general review of the contents of the course, then it is important to link everything with practice. It is for the above reasons that performance can be measured within AR, without accessing the physical workshops in the facilities and with a teacher's guide for each activity. Once this is completed, the interactions with the AR that have the most impact on students for their academic achievement can be improved in the process of continuous development for future strengthening workshops upon graduation.

## 5. Conclusions

The present work fulfilled the following objectives: develop LO through AR models created by teachers that can be used by IIS and IMEC students at the UVM Campus Queretaro inside and outside the classroom as a didactic resource to improve and strengthen their analysis and problem-solving skills; and improve the academic performance of IIS and IMEC students and measure the development of their analysis and problem-solving skills.

A statistical analysis of the results was carried out and the proposed hypothesis was verified: the use of AR improved academic performance and strengthened the ability of students in the IIS and IMEC programs at UVM Campus Querétaro to analyze and solve problems.

As part of the role of the main actors in education (teachers), it is very important to integrate new technologies that promote the advancement of knowledge in students for the development of the general and specific skills required in their disciplinary field. This work, as part of an improvement project, provides contributions and possibilities for those teachers who have an interest in exploring the benefits of AR in the educational process. Similar studies in other areas of professional training should also be carried out to analyze the implications and applications of cutting-edge technologies in more disciplinary fields. We conclude that AR brings the student closer to an appropriate visual understanding of the problem presented because, in the traditional way in which these exercises are presented, there are many aspects that cannot be easily visualized.

**Author Contributions:** Conceptualization, M.A.Z.-A.; methodology, M.A.Z.-A. and M.Á.C.-P.; validation, M.Á.C.-P. and R.B.-B.; formal analysis, M.A.Z.-A., M.Á.C.-P. and R.B.-B.; investigation, B.T.-L., C.A.G.-G., N.E.M.-L. and R.B.-B.; resources, M.A.Z.-A.; data curation, M.A.Z.-A. and R.B.-B.; writing—original draft preparation, M.A.Z.-A., M.Á.C.-P. and R.B.-B.; writing—review and editing, M.Á.C.-P.; visualization, M.A.Z.-A.; supervision, M.Á.C.-P.; project administration, M.A.Z.-A.; funding acquisition, M.A.Z.-A. and B.T.-L. All authors have read and agreed to the published version of the manuscript.

**Funding:** This project has been funded by David-Willson Award (sponsored by Laureate International Universities).

**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki, and was approved by the Campus Chancellor's Office by official letter dated 19 February 2019. Ethical review and approval of this study was waived because the study did not involve human or animal experimentation.

**Informed Consent Statement:** Informed consent was obtained from all subjects who participated in the study. The call for participation in the Augmented Reality (AR) Training Course was under the consent of the participating students and teachers.

**Acknowledgments:** The authors acknowledge the support of the National Vice-Rectory for Research, Innovation and Business Incubator of UVM.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Abbreviations

| | |
|---|---|
| AR | Augmented Reality |
| OL | Learning Objects |
| IIS | Industrial and Systems Engineering |
| IMEC | Mechatronics Engineering |
| CENEVAL | National Evaluation Center of Mexico |
| EGEL | General Bachelor's Degree exit examination |

## Appendix A

### *Appendix A.1. Evaluation*

Data Collection Instrument

The EGEL CENEVAL grants 3 types of testimony (result of the evaluation) based on the score achieved. For an IIS student to obtain a Satisfactory Testimony (DS), they must achieve a score of 1000–1149 in at least 3 of the 5 areas of knowledge evaluated by the EGEL CENEVAL, and a IMEC student must be in at least two of the three areas of knowledge [16,17].

**Table A1.** Data collection instrument.

| Section I: Technological Tools and Mobile Devices | Never | Sometimes | Always | Total |
|---|---|---|---|---|
| Q1. Did you use AR during your academic program | | | | |
| Q2. Does the teacher use multimedia as a technological resource in his/her class? | | | | |
| Q3. Do you consider it favorable to incorporate AR in the preparation of the EGEL? | | | | |
| Q4. Did you use mobile devices in the teaching-learning process? | | | | |
| Q5. During your professional training, did the teachers conduct workshops to apply AR in problem solving? | | | | |
| Section II: Teaching-learning process on data analysis and problem-solving competence | Never | Sometimes | Always | Total |
| Q6. During your training, did teachers use web 2.0 tools as a support in their class? | | | | |
| Q7. During your professional training, did the teacher develop specific software to awaken interest in learning? | | | | |
| Q8. During your professional training, did teachers use didactic material updated to new technologies? | | | | |
| Q9. Do you consider that improvements were achieved in your learning with the use of didactic material through AR? | | | | |
| Q10. During your professional training, did you consider that the use of these technologies helps to improve learning and academic performance? | | | | |

**Table A2.** Necessary score for each area of knowledge determined by the EGEL CENEVAL.

| **Criteria for Determining Performance Levels by Area** | |
|---|---|
| Not yet satisfactory (ANS) | 700–999 |
| Satisfactory (DS) | 1000–1149 |
| Outstanding (DSS) | 1150–1300 |

Table A3 presents the areas of knowledge and the number of items per area. The application of the EGEL CENEVAL is carried out in two sessions, one in the morning and the other in the afternoon.

**Table A3.** EGEL-CENEVAL, Sections for IIS and IMEC.

| CENEVAL-EGEL IIS Contents | | | | |
|---|---|---|---|---|
| Areas of Knowledge/Subareas | % in the Exam | Number of Items | Distribution of Items per Session | |
| | | | 1a. | 2a. |
| A. Work study | 14% | 21 | 21 | |
| 1. Work design and measurement | 9% | 13 | 13 | |
| 2. Ergonomics and industrial hygiene and safety | 5% | 8 | 8 | |
| B. Supply chain management | 23% | 34 | 34 | |
| 1. Forecast models | 4% | 6 | 6 | |
| 2. Capacity planning | 8% | 12 | 12 | |
| 3. Inventory management | 4% | 6 | 6 | |
| 4. Production and logistics management | 7% | 10 | 10 | |
| C. Project formulation and evaluation | 19% | 28 | 19 | 9 |
| 1. Market analysis | 5.3% | 8 | 8 | |
| 2. Project feasibility study | 7.3% | 11 | 11 | |
| 3. Analysis of the feasibility of the projects | 6% | 9 | | 9 |
| D. Production systems | 24% | 36 | | 36 |
| 1. Process engineering | 9% | 14 | | 14 |
| 2. Facility design and productivity measurement | 7% | 10 | | 10 |
| 3. Manufacturing systems | 4% | 6 | | 6 |
| 4. Material handling and maintenance systems | 4% | 6 | | 6 |
| E. Industrial management | 21% | 32 | | 32 |
| 1. Strategic planning | 7% | 11 | | 11 |
| 2. Human capital management | 5% | 8 | | 8 |
| 3. Total quality management | 8.6% | 13 | | 13 |
| Total | 100% | 151 | 74 | 77 |

| CENEVAL-EGEL INMEC Contents | | | | |
|---|---|---|---|---|
| Area/Subarea | No. of Reagents | % in the Exam | Distribution of Item per Season | |
| | | | 1a. | 2a. |
| A. Integration of technologies for mechatronic design | 81 | 41% | 81 | |
| 1. Technologies for the solution of a mechatronic problem | 27 | **14%** | **27** | |
| 2. Design of mechatronic models and prototypes | 54 | **27%** | **54** | |
| B. Systems automation | 63 | 32% | 18 | 45 |
| 1. Systems instrumentation and supervision | 24 | **12%** | **18** | **6** |
| 2. Industrial control | 39 | **20%** | | **39** |
| C. Development and coordination of mechatronic projects | **53** | **27%** | | **53** |
| 1. Research methodology for mechatronic projects and technological innovation | 17 | **8.6%** | | **17** |
| 2. Coordination of mechatronic projects | 19 | **9.6%** | | **19** |
| 3. Evaluation of mechatronics | 17 | **8.60%** | | **17** |
| Total | 197 | 100% | 99 | 98 |

### *Appendix A.2. AR Applications*

All the AR applications mentioned in this annex were in Spanish. Our aim is to replicate the results of the project in different UVM campuses.

Figure A1: during the period July–August 2020, a training process in RA was carried out for teachers and students. The sessions were recorded and published on YouTube. 5a https://youtu.be/gwDP_ueHW8k/ (accessed on 1 July, 2020), 5b https://youtu.be/Ac0w9KOyRkc (accessed on 1 July 2020), 5c https://youtu.be/b6y2nuCUlPI (accessed on 1 July 2020), 5d https://youtu.be/XaBuP27nvIA (accessed on 1 July 2020). After the training, different developments began to take place.

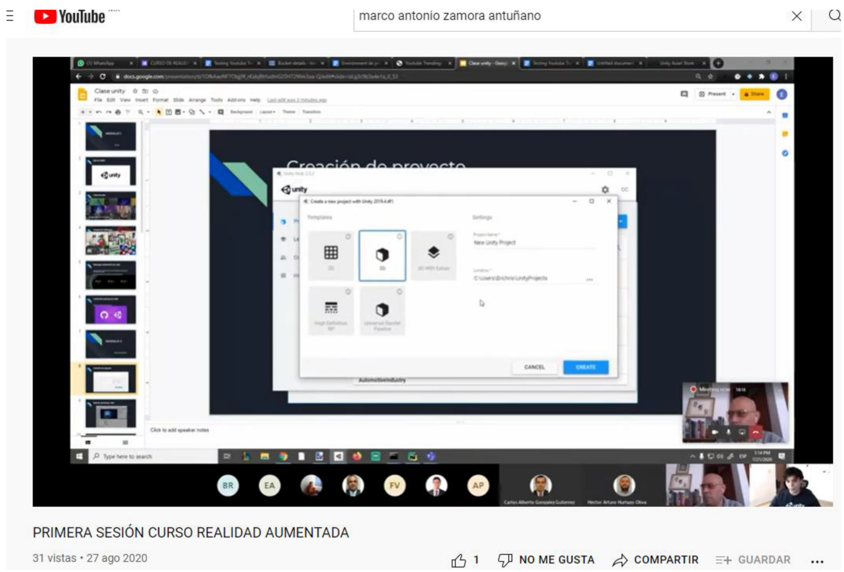


**Figure A1.** AR training sesion.

The multimodal virtual training platform (see Figure A2) can be accessed through https://uvmexpo.herokuapp.com/expo/CongresoInternacionalUVM2022 (accessed on 11 July 2021). Originally it was an only PC app. The Android app can be downloaded from https://play.google.com/store/apps/details?id=com.ikigai.ExpoHall (accessed on 11 July 2021).


**Figure A2.** Multimodal virtual training platform.

## References

1. Hodges, C.B.; Moore, S.; Lockee, B.B.; Trust, T.; Bond, M.A. The Difference between Emergency Remote Teaching and Online Learning. Available online: https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning (accessed on 20 January 2020).
2. Zambrano, J.; Ramirez, E.; Orrego, T. Experiences of mobile learning in rural contexts. In Proceedings of the World Conference on Mobile and Contextual Learning, Delft, Netherlands, 16–18 September 2019; pp. 110–117.
3. UVM. 22 de Agosto, 2016. Perfil de Egreso de Ingeniería Mecatrónica. Available online: https://uvm.mx/storage/app/uploads/public/608/b39/510/608b395101b96216056532.pdf (accessed on 7 March 2020).
4. UVM. Perfil de egreso del Ingeniero Industrial y de Sistemas. 22 de Agosteo de 2016. Available online: https://uvm.mx/oferta-academica/licenciaturas-ingenierias/ingenierias-uvm/ingenieria-industrial-y-de-sistemas (accessed on 8 March 2020).
5. Cadavieco, J.F.; Sevillano, M.Á.P.; Amador, M.F.M.F. Realidad aumentada, una evolución de las aplicaciones de los dispositivos móviles. In *Pixel-Bit. Revista de Medios y Educación*; Dialnet: Los Angeles, CA, USA, 2012; pp. 197–210.

6. Bacca Acosta, J.L.; Baldiris Navarro, S.M.; Fabregat Gesa, R.; Graf, S.; Kinshuk. Augmented reality trends in education: A systematic review of research and applications. *J. Educ. Technol. Soc.* **2014**, *17*, 133–149.
7. Lin, T.J.; Duh, H.B.L.; Li, N.; Wang, H.Y.; Tsai, C.C. An investigation of learners' collaborative knowledge construction performances and behavior patterns in an augmented reality simulation system. *Comput. Educ.* **2013**, *68*, 314–321. [CrossRef]
8. Gómez-García, G.; Hinojo-Lucena, F.J.; Alonso-García, S.; Romero-Rodríguez, J.M. Mobile Learning in Pre-Service Teacher Education: Perceived Usefulness of AR Technology in Primary Education. *Educ. Sci.* **2021**, *11*, 275. [CrossRef]
9. Azuma, R.T. Making augmented reality a reality. In *Applied Industrial Optics: Spectroscopy, Imaging and Metrology, Optical Society of America, Proceedings of the Maging and Applied Optics 2017 (3D, AIO, COSI, IS, MATH, pcAOP), San Francisco, CA, USA, 26–29 June 2017*; Optical Society of America: Washington, DC, USA, 2017; p. JTu1F–1.
10. Feiner, S.; MacIntyre, B.; Seligmann, D. Knowledge-based augmented reality. *Commun. ACM* **1993**, *36*, 53–62. [CrossRef]
11. Mackay, W.; Velay, G.; Carter, K.; Ma, C.; Pagani, D. Augmenting reality: Adding computational dimensions to paper. *Commun. ACM* **1993**, *36*, 96–97. [CrossRef]
12. Lara, L.H.; Benítez, J.L.V. Realidad Aumentada: Una tecnología en espera de usuarios. *Rev. Digit. Univ.* **2007**, *8*, 6.
13. Proske, A.; Roscoe, R.D.; McNamara, D.S. Game-based practice versus traditional practice in computer-based writing strategy training: Effects on motivation and achievement. *Educ. Technol. Res.* **2014**, *62*, 481–505. [CrossRef]
14. Keller, J.M. Motivational design research and development. In *Motivational Design for Learning and Performance*; Springer: Berlin/Heidelberg, Germany, 2010; pp. 297–323.
15. Cheng, Y.C.; Yeh, H.T. From concepts of motivation to its application in instructional design: Reconsidering motivation from an instructional design perspective. *Br. J. Educ. Technol.* **2009**, *40*, 597–605. [CrossRef]
16. CENEVAL. Guía Para el Sustentante IIS. 2018. Available online: https://ceneval.edu.mx/wp-content/uploads/2022/08/GUIA-EGEL-IINDU.pdf (accessed on 20 September 2021).
17. CENEVAL. Guía Para el Sustentante IMEC. 2018. Available online: https://ceneval.edu.mx/wp-content/uploads/2022/08/GUIA-EGEL-IMECATRO.pdf (accessed on 20 September 2021).
18. Luna Bazaldua, D.; Levin, V.; Liberman, J. *Guidance Note on Using Learning Assessment in the Process of School Reopening*; World Bank Group: Washington, DC, USA, 2020.
19. Norman, G.; Van der Vleuten, C.; De Graaff, E. Pitfalls in the pursuit of objectivity: Issues of validity, efficiency and acceptability. *Med. Educ.* **1991**, *25*, 119–126. [CrossRef] [PubMed]
20. Christie, M.; De Graaff, E. The philosophical and pedagogical underpinnings of Active Learning in Engineering Education. *Eur. J. Eng. Educ.* **2017**, *42*, 5–16. [CrossRef]
21. Lintorf, K.; van Ophuysen, S.; Osipov, I. Comparing Assessment Methods of Attribute Importance in Teachers' Decisions: The Importance of Different Criteria for Tracking Recommendations after Primary School. *Educ. Sci.* **2021**, *11*, 566. [CrossRef]
22. Ellingsen, P.; Tonholm, T.; Johansen, F.R.; Andersson, G. Learning from Problem-Based Projects in Cross-Disciplinary Student Teams. *Educ. Sci.* **2021**, *11*, 259. [CrossRef]
23. Rosa, P.J.; Morais, D.; Gamito, P.; Oliveira, J.; Saraiva, T. The immersive virtual reality experience: A typology of users revealed through multiple correspondence analysis combined with cluster analysis technique. *Cyberpsychol. Behav. Soc. Netw.* **2016**, *19*, 209–216. [CrossRef] [PubMed]
24. Iqbal, M.Z.; Mangina, E.; Campbell, A.G. Current Challenges and Future Research Directions in Augmented Reality for Education. *Multimodal Technol. Interact.* **2022**, *6*, 75. [CrossRef]
25. Portuguez-Castro, M.; Hernández-Méndez, R.V.; Peña-Ortega, L.O. Novus Projects: Innovative Ideas to Build New Opportunities upon Technology-Based Avenues in Higher Education. *Educ. Sci.* **2022**, *12*, 695. [CrossRef]
26. Alvarez-Marin, A.; Castillo-Vergara, M.; Pizarro-Guerrero, J.; Espinoza-Vera, E. Realidad aumentada como apoyo a la formación de ingenieros industriales. *Form. Univ.* **2017**, *10*, 31–42. [CrossRef]