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Sustainable Teaching and Learning through a Mobile Application: A Case Study

Santiago Criollo-C [1,*], Erick Altamirano-Suarez [1], Lucía Jaramillo-Villacís [1], Kevin Vidal-Pacheco [1], Andrea Guerrero-Arias [2] and Sergio Luján-Mora [3]

[1] Escuela de Ingeniería en Tecnologías de la Información, Facultad de Ingeniería y Ciencias Aplicadas (FICA), Universidad de Las Américas, Quito 170125, Ecuador; erick.altamirano@udla.edu.ec (E.A.-S.); lucia.jaramillo@udla.edu.ec (L.J.-V.); kevin.vidal@udla.edu.ec (K.V.-P.)

[2] Departamento Inglés, Bachillerato General Unificado, Jezreel International Christian Academy, Quito 170520, Ecuador; andrea.guerrero@jezreelacademy.edu.ec

[3] Departamento de Lenguaje y Sistemas Informáticos, Universidad de Alicante, 03690 Alicante, Spain; sergio.lujan@ua.es

* Correspondence: luis.criollo@udla.edu.ec; Tel.: +593-98-471-1052

Abstract: Currently, mobile devices are widely used as a support in education for teaching and learning of multiple academic subjects. An example of this is educational mobile applications, which in recent years have been massively developed and have generated multiple downloads for use in the classroom. Despite their features and benefits, the use of mobile devices such as smartphones is not usually allowed in classrooms due to the distraction they can generate. This paper aims to evidence the use of mobile devices in education and why it should be used as a support in the educational model. To do this, it is proposed to compare two teaching-learning methodologies and identify whether the use of mobile applications can influence the specific education of an engineering subject. The methodologies were tested in the classroom, focusing on IP addressing and network numbering systems, with two groups of students: an experimental group and a control group. At the end of the experiment, their performance was evaluated using a questionnaire. The answers of this questionnaire were subjected to an analysis of variance (ANOVA) and hypotheses were proposed to identify whether the use of a mobile application used as a support in the educational model has benefits in learning. The results indicate that educational mobile applications can be helpful in the teaching-learning process and at present, education can benefit from the use of this innovative learning methodology.

Keywords: active learning; blended learning; mobile applications; mobile learning; mobile learning experiences

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1. Introduction

At present, mobile devices are widely used as a support in education for teaching and learning multiple academic subjects [1]. An example of this is the educational mobile applications, which in recent years have been massively developed and have generated multiple downloads for use in the classroom [2,3].

Mobile applications have been beneficial for users as they have simplified work, in addition to having impacted various sectors such as education at the pedagogical level [3]. A necessary feature in mobile applications is usability, this feature allows to create intention of use in users and allows to have a good experience and interaction with the application [4]. Changes in the educational model demand new teaching techniques that require new educational experiences taking advantage of the communication and creativity capacity of students with mobile devices, which can become key in this process [5]. In addition, education is complemented by ubiquitous access to information, which is one of the main characteristics of mobile devices [6].

It is important to note that the use of mobile technology has proliferated in recent years in education due to the pandemic caused by COVID-19 [7]. Mandatory confinement brought as a consequence all academic activities working online [8]. This caused both teachers and students to face an unfamiliar method, causing dissatisfaction which was reflected in learning outcomes [9]. For this reason, teachers and educational institutions have sought alternatives to innovate the educational system [10]. One response to these needs has been emerging technologies, which have been used to innovate the academic process and motivate students in their education at all educational levels, from pre-school to higher education [3].

Sustainable education can be delivered using educational environments, which were created with the objective of including a wide variety of learning resources [11]. The most widely used resources today are emerging technologies, which allow students to easily acquire educational information [12]. This educational model, supported by emerging technologies, can be an answer to innovate education and ensure access and flexibility to educational material [10]. For this reason, innovation in educational models, with the use of emerging digital technologies, can contribute to the commitment of the fourth goal for Sustainable Development of the United Nations: Ensure quality education [13].

Mobile learning (learning through the use of a mobile device) has its own pedagogical characteristics and allows students to take advantage of digital technology as a tool in education [14]. Moreover, use of digital technology in a generation that has adopted its application allows using a new tool in educational processes. These tools become a practical and novel instrument since students are familiar with its use [15].

Using mobile learning in education is a reality in the current pedagogical model. That is why it is important to investigate the use of this technology and its effects on educational innovation and the contribution it can provide to learning. The work presented here aims to demonstrate the use of mobile applications as a support in an innovative teaching model in engineering education. For this purpose, two teaching-learning models will be compared using a control group and an experimental group of students in a private university in Ecuador. The objective of this research is to demonstrate whether the use of a mobile application can influence the learning of IP addressing and binary, decimal, and hexadecimal numbering systems in students. To achieve this, a mobile application called IP LEARN was developed within an academic context. As a first step, a search for mobile applications in Google Play Store for learning the proposed topics was performed; only applications that provide a calculator to identify the numbering systems, not for learning them, were found. Using this application, students can reinforce the knowledge learned in classes; in addition, they can access the academic content at any time and place. Moreover, students can measure their knowledge using the assessments within the application and receive feedback for each mistake they make. However, using mobile applications has certain problems related to the usability of the mobile device and its small input and output interfaces, which can affect the use of this digital methodology in learning. Therefore, a post-application questionnaire was conducted to assess whether the use of the application could impact performance in an engineering degree subject. The results of this survey are encouraging and show the benefit of its use in an innovative teaching and learning model.

The rest of the article is organized as follows: Section 2 describes mobile applications in the classroom, Section 3 indicates the methodology used to evaluate the students' performance in using the mobile application in their education, Section 4 shows the design methodology of the IP LEARN mobile application, Section 5 presents the statistical results obtained, Section 6 presents the discussion of the findings, Section 7 shows the conclusions, and finally Section 8 shows the future work.

2. Mobile Applications in the Classroom

Mobile learning allows teaching through a methodology using mobile devices such as cell phones and tablets. This offers students learning in a short time and is of great help for both teachers and students thanks to its accessibility, adaptability, ubiquity, affordability, portability, etc. [16]. Mobile technologies involve smartphones or tablets that can be used portably and can connect wirelessly to the Internet [17]. Depending on the teaching strategy or methodology, this ubiquitous learning can take place outside or inside the classroom [18].

In the future, the use of digital technology will become a necessity within the educational model and mobile devices, due to their characteristics, will play an important role [19]. The most common use of this technology, applied in teaching with this type of devices, is mobile applications [20]. The development of these educational applications must take into account the quality of information, images, and sounds, as well as accessibility and usability [21].

Within the classroom, the use of a smartphone was considered a means of distraction until recently, but this idea has changed as more educational applications have been implemented and integrated into the classrooms [22]. Digital technologies as a support in education allow interaction with information and serve as a support tool for academic activities [2]. This has promoted the development of new innovative applications for education [23].

Educational mobile applications are currently used as a support in education because of their usefulness and motivation for students [24]. In the literature, some empirical studies have reported the benefits of applications in the learning of engineering students. For example, at the university of Madrid, the use of mobile devices as a learning tool has been employed, the professor monitors the progress of their students allowing interaction and incentive in empowering learning [25]. On the other hand, a methodology that includes a mobile application called Sortko was used at the University of Zagreb to support the teaching of computer science concepts [17]. The results of this research indicate that the adoption of the application effectively helped students' learning of algorithms and data structures [17].

In addition, there is research that supports the use of mobile technology in different topics, for example in environmental education using QR codes and mobile devices [26]. which allow innovating the educational model and motivating the student to get involved in their learning. On the other hand, there is a need to create educational processes that go beyond a transmission of knowledge to use mobile technologies in education [3]. Teachers must make students aware of the benefits that the integration of mobile technologies can bring to their education and how to use them to their advantage.

Mobile devices, due to their characteristics, are currently widely used; however, despite their multiple benefits, they also present certain problems that must be addressed for the correct use of this technology [27]. Among their main weaknesses are the size of the screen, battery life, very small input interfaces, which can hinder reading, writing, and the general use of these devices to support education. [28].

3. Methodology

This research aims to identify if the use of a mobile application, designed for engineering education topics, can influence the academic performance of students. To do this, two scientific methodologies were used: experimental design (design and implementation of a mobile application with a specific theme for information technology engineering students), and statistical analysis (use of statistical techniques to measure the variances obtained in the application of an evaluation instrument and the sampling of a non-probabilistic group chosen at convenience). Both methodologies have been combined to work together and provide data that allow us to arrive at new knowledge about the influence of digital technologies on personalized learning.

3.1. Demographic Analysis

During the research process, a non-probabilistic convenience sampling was used, using 72 students from a private university in Ecuador. The participants were enrolled in the subject in which the topics proposed for the mobile application were taught. Each student read and accepted an informed consent form. The total number of students consisted of two groups, the first with third semester students (36) and the second with fifth semester students (36). Out of the total number of students (72), 15 were female (20.83%) and 57 were male (79.17%). The age of the participants was between 18 and 23 years.

Out of the total number of students, we will call GR_1 for the third semester group, and we will call GR_2 for the fifth semester group. Of them, 62 had a mobile device running Android operating system, representing 86.11%, the remaining 10 had a device running iOS operating system, representing 13.89%. Finally, students indicated that 51 of them (70.83%) have previously used educational mobile applications and 21 students (29.17%) have not. The students, who had a device with the iOS operating system, used the app IP LEARN with mobile devices with Android operating system available in the laboratory. The two groups GR_1 and GR_2 are further divided into two subgroups, one experimental and one control, as follows: GR_1: CG_1 and EG_1, and GR_2: CG_2 and EG_2.

3.2. Questionnaire Validation Instrument

The work described here lasted three weeks for the familiarization and use of the application, followed by the assessment of the students' knowledge in the fourth week through a questionnaire for each of the two groups GR_1 and GR_2. Students had to download the mobile application to use it to support the educational model. The questionnaire was designed to obtain dichotomous answers and to be able to carry out the analysis of variance between the answers of the groups and to be able to compare them to draw conclusions. The questionnaires had 10 questions with a value of one point per question. The questionnaire was validated by the Kuder Richardson test, with a result of KR20 = 0.70 (acceptable between 0.70 and 0.90). In addition, the time it took each student to complete the questionnaire was measured, which will be used to analyze the results.

The Kuder Richardson formula (KR20) is used to establish the reliability of a test from its averages and variances. To do this, an instrument that scores a question dichotomously, i.e., as correct, or incorrect, must be used. This formula is based on the difficulty and number of questions, the sum of their variances and the total variance of the evaluation [29]. The responses to the two questionnaires can be found in Appendix A in Tables A1 and A2.

3.3. Tasks

To use the application, the operating system of the mobile device must be Android version 8.0 or higher, then the following steps must be followed:

- First, search for the IP LEARN application in the Google Play Store and install it on the device.
- Link: https://play.google.com/store/apps/details?id=com.udlatesisip.iplearn, (accessed on 1 April 2022)
- Second, register as a student with his/her email address.
- Third, open the app and start using it.

In a classroom session, students were shown how the mobile application works and its main features. During the session, doubts about each requested task were solved and once there were no more questions about the use and operation of the application, the research work proceeded. The two groups of students (GR_1 and GR_2) will have the face-to-face session with the teacher where they will receive the class and solve exercises and practices to reinforce the theory. The students in the experimental groups (EG_1 and EG_2) will be able to use the application in and out of the classroom. One of the most important features of mobile learning is ubiquity, so students can review the theory and perform exercises to test their learning anytime, anywhere.

3.4. Control and Experimental Group Design

The two groups (GR_1 and GR_2) of students were divided into two subgroups each, which were used to perform the proposed analysis. One subgroup used the mobile application, and the other only hade access to the regular classes. The subgroups that used the mobile application are called EG_1 and EG_2 and the subgroups that only had access to the regular classes are called CG_1 and CG_2. Each subgroup is made up of 18 students, as shown in Table 1, GR_1 had basic knowledge of networks and IPv4 numbering systems and GR_2 had more solid knowledge of IPv4 addressing, but very basic knowledge of IPv6 addressing.

Table 1. Groups.

Groups	Third Semester (GR_1)	Fifth Semester (GR_2)	Total of Students
Experimental group (EG)	18	18	36
Control group (CG)	18	18	36

3.5. Learning Scheme

Two different learning schemes were used in this research, which are:

- **Habitual learning.**
  This type of learning was used in the students of the control group (CG) of CG_1 and CG_2. The teacher performed routine work, which consisted of imparting knowledge through presentations, readings, and questionnaires, resulting in well-know and traditional learning for the students.
- **Learning with IP LEARN.**
  This type of learning was used with students in the experimental group (EG) of EG_1 and EG_2. The teacher carried out the usual teaching work but added the use of the IP LEARN application to reinforce the knowledge about IPv4 in EG_1 and about IPv6 in EG_2 in the classroom.

After this work it is important to know if the use of IP LEARN, together with the usual teaching model, developed a better understanding of IPv4 and IPv6 addressing concepts within the group of engineering students. The content of decimal, binary and hexadecimal numbering systems, IPv4 and IPv6 addressing was developed for different topics in the theoretical content. Within each topic there are definitions, exercises, and knowledge measurement through multiple choice quizzes with feedback to validate errors.

3.6. Definition of Variables

The following variables were defined for the analysis of the collected data:

(a) Independent variables

1. Learning method:
   - Habitual Learning (HL)
   - Mobile Learning (ML)
2. Academic Level (LA):
   - Initial Level Group 1
   - Intermediate Level Group 2

(b) Dependent variables

- Assessment results (Z)

4. IP LEARN Mobile Application Design

The methodology for the design, construction, and creation of IP LEARN was Scrum. There were 10 sprints lasting one to two weeks, so that the organization and review of progress was more concise. A leader was chosen to organize the tasks to be performed and a tester to test all the progress of the development. An application backlog was also created, which includes the functionalities and design.

The objective of this mobile application is learning, therefore, it is important the design is friendly and intuitive, this will allow to develop in the users a motivation for its use as an educational tool [4]. An application, which encourages education in certain subjects, has a great benefit, it can be used as a support for learning, making mobile learning a powerful educational tool [30].

4.1. Model for IP LEARN Design

For the design and implementation of the IP LEARN mobile application, the model defined by Cuello was used, which consists of five stages defined below [31].

(a) Conceptualization

This stage refers to what the user may need, identifies the main problems with respect to the design topic and, with a diagram or brainstorming, arrives at the final concept [31].

The topics selected for the construction and design of this application were chosen by the students. The topics IPv4, IPv6, and numbering systems were the most difficult and challenging in the learning process, according to a discussion with students who were about to graduate from engineering.

(b) Definition

In this stage, the users for whom the application will be targeted are identified, as well as the functionalities to be implemented [31]. The design can be carried out for two dominant operating systems in the cell phone market: the Android system with 86.8% and the iOS system with 12.5% with its different characteristics [26]. For the work presented here, a design was chosen only for the Android operating system and is aimed at engineering students.

(c) Design

One of the aspects that must be considered is the name of the mobile application, which uses a technique called "naming" is used [32]. This technique allows to create an identity for the mobile application to differentiate it from other applications. For this reason, the name IP LEARN was chosen. It is also important to place an icon or logo for the construction of an identity in the designed application.

Similarly, the graphical interface should be intuitive for the user, and if buttons are necessary, they should have striking colors that invite a specific action [33]. The buttons should be circular, rectangular or can be an icon that seeks to represent a specific and well-defined action [34]. The types of buttons can be seen in Figure 1. Colors in a mobile application are important because they have the ability to convey emotions [35]. Each color has its meaning, the white color has the ability to highlight other colors and expresses peace and tranquility, the purple color has the ability to provoke a positive response as well as the gray color [36]. Figure 1 shows the different colors used in the IP LEARN application.

Typography is another important aspect, since the shape and size of the font can produce different emotions and responses and reaction [37]. When choosing a typeface, the reader must be considered in addition to the ideas to be conveyed. The reader could perceive the different personalities of typeface families. The typeface can also be observed in Figure 1 [37].

(d) Development

The Android operating system was chosen because of its wide user reach and ease of development and publication processes [28]. In addition, development on this operating system promotes adaptive planning, evolutionary development, encourages rapid response and is very flexible to change [31].

The coding of the different functions proposed is elaborated progressively, prioritizing the most relevant functions. With the Android Studio IDE, an empty project is generated in which the APIs (Application Programming Interface) and libraries necessary for the project are called. The IP LEARN source code must be edited in Android Studio for its variety of tools for mobile development such as debugging, interface handling and device emulation.

(e) Publication

To achieve a better diffusion and use of the application among students, it is recommended to upload this educational application to Google Play Store. The publication allows users to have a better version control since improvements can be made to the application.

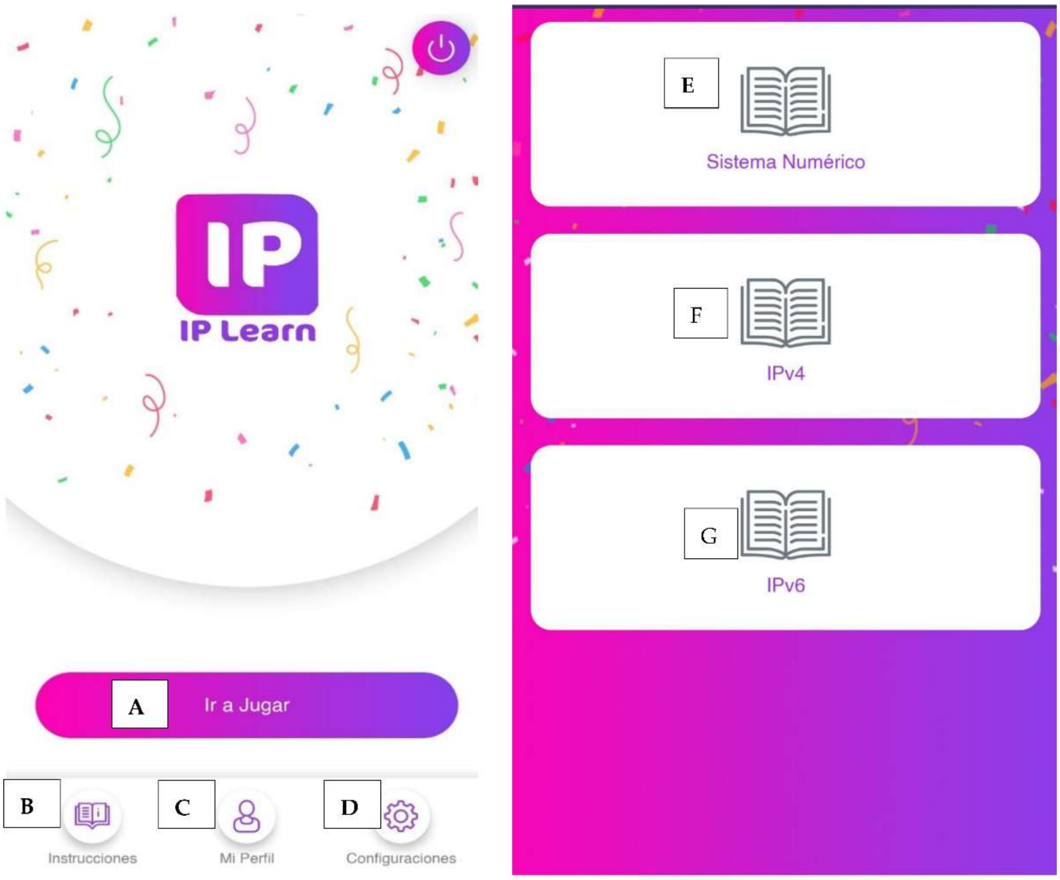

Figure 1. Design, interfaces, and features of the mobile application. (**A**): Play; (**B**): Instructions; (**C**): My profile; (**D**): Configuration; (**E**): Numbering systems; (**F**): Internet Protocol Version 4; (**G**): Internet Protocol version 6.

4.2. Tools for IP LEARN Development

The Android operating system allows configurations and customizations, due to its opensource feature and because it is based on a Linux kernel. Android is the most widely used and supported mobile operating system in several mobile device manufacturers, which allows a wider reach of users [38]. Table 2 defines the technologies adopted for the development of this work, applied to work in a coordinated manner in the development team and achieve the correct implementation of IP LEARN.

Table 2. Technologies used for the design of the application.

Name	Description
Firebase	It is a cloud-based infrastructure with several solutions for the development of mobile applications and web systems. Firebase provides a real-time non-SQL database, which is useful for storing the information generated by the application. Firebase data is in JSON (JavaScript Object Annotation) format. In addition, the Firebase Authentication service facilitates the registration and login of users of a mobile application.
Canva	Web tool for graphic design which has a free and a paid version. The free version was used for this research.

Table 2. *Cont.*

Name	Description
Google Play	Google's online store for devices with Android operating system.
Java	It is a programming language used in the development of mobile applications on Android.
IDE (Integrated development Environment)	It contains several solutions for code development such as syntax correction and error identification. Android Studio is an IDE-like tool for Android mobile application development.
Git Hub	It is a platform that enables the hosting of programming projects in the cloud. One of its advantages is to allow version control and management with Git technology. GitHub allows collaboration between developers in editing programming code.

4.3. Educational Content of the Mobile Application

The educational content selected for the mobile application was obtained from CISCO's netacad platform, which, through its academy, provides educational information on various engineering topics. The educational topics selected for the mobile application were the following:

- **Numbering systems** To work with IP addresses, version 4 and version 6, it is necessary to master the binary, decimal, and hexadecimal numbering systems. This is to recognize IP addresses that define a network, a subnet, a subnet mask, broadcast, usable IP addresses and IP addresses for special uses.
- **Internet Protocol version 4 (IPv4)** It is the logical representation of a data network, there are IP addresses for a network, subnet, mask, broadcast, and special IP addresses. To represent this protocol, the decimal and binary numbering systems are used.
- **Internet Protocol version 6 (IPv6)** It is the logical representation of a network, there are IP addresses for a network, subnet, masquerade, broadcast, multicast, and special IP addresses. To represent this protocol, the binary, decimal and hexadecimal number systems are used.

5. Results

5.1. Results of Satisfaction with the Use of IP LEARN

The students were asked to describe their perception of the use of the application using a single word. The most repeated words in this evaluation were those shown in Figure 2. These results show that the mobile application and its use is quite acceptable by the experimental group.

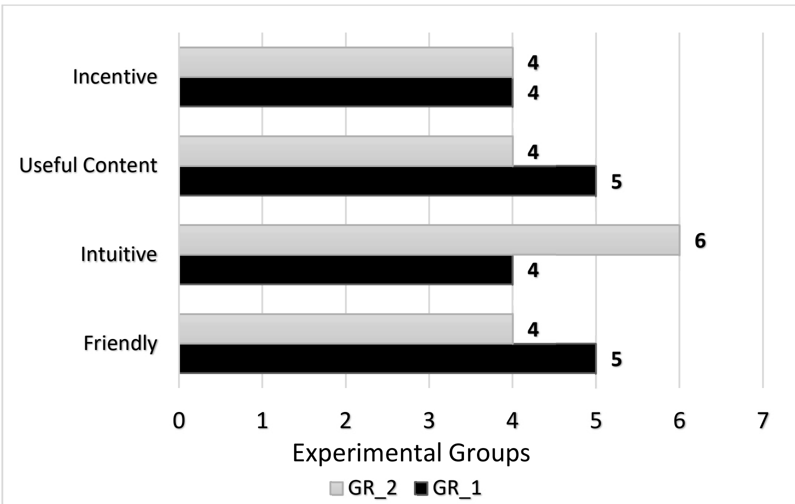

Figure 2. Descriptive words about the IP LEARN application.

5.2. Study Results in the Control Group and Experimental Group

To measure the usefulness of IP LEARN it is necessary to generate hypotheses that allow validating the effectiveness of the use of the application in the EG, and identify, if the difference between the test results between the two groups (EG: 36 students; CG: 36 students), are statistically reliable. The hypotheses proposed are the following:

- HYPOTHESIS X-HX: There is no relevant difference in the mean score of the questionnaire between EG and CG.
- HYPOTHESIS Y-HY: There is a relevant difference in the mean score of the EG and CG questionnaire.

To verify the hypothesis is fulfilled, a Z-test was performed to assess the learning performance and the IP LEARN interface for the two groups. The evidence of the test performed is shown in Table 3. For this analysis, a reliability percentage of 95% is used, which is a value commonly used in this type of statistical evidence. In addition, for the calculation of the Z-test, two variances are needed, one for each group, for which a T-test of unequal variances in both groups was used.

Table 3. Study results in control group and experimental group.

Z-Test	EG	CG
Mean	8.888888889	6
Observations	36	36
Z	8.843841471	
$P(Z \leq z)$ one queue	0	
Critical value of z (one queue)	1.644853627	
Critical value of z (two queue)	1.959963985	

The value of Z = 8.84, which is higher than the critical value of z (one queue) = 1.64, and higher than the z value (two queue) = 1.95, can be appreciated. Therefore, the null hypothesis HX is rejected and HY is accepted, confirming the statistical difference between the mean of the results of the questionnaires between the CG and GE.

It is concluded that the results are better in the experimental group and are due to the use of the mobile application as a support in regular education. The IP LEARN application proved to be a complement to education on IPv4 and IPv6 addressing and numbering systems. Therefore, to corroborate these results, new hypotheses on the teaching methods were proposed using the dependent and independent variables:

- HYPOTHESIS Z-HZ: There is a relevant difference in the scores of the four groups based on the teaching method.
- HYPOTHESIS W-HW: In the score of the four groups there is no relevant difference based on the teaching method.

To test the veracity of these hypotheses, an ANOVA (Analysis of Variance) was used, which is a statistical method that allows countering a null hypothesis where the means of different populations coincide [2]. To accept or reject the hypotheses presented (HZ and HW), an analysis was performed with 95% reliability for the four groups (independent variable). These groups were evaluated with an assessment to identify whether the use of the application (independent variable) contributed to the outcome (dependent variable) of the responses in an evaluation. Tables 4 and 5 describe the sample size and the working groups.

Table 4. Size and sample of variables.

Sample/Variable	Sample Size/Variable Size
Independent variable	Habitual learning and groups (GR_1 y GR_2).
Dependent variable	Questionnaire scores
Sample size	72

Table 5. Independent variables.

Variable	Description	Size
CG_1	GR_1—Habitual learning	18
EG_1	GR_1—IP LEARN learning	18
CG_2	GR_2—Habitual learning	18
EG_2	GR_2—IP LEARN learning	18

In Table 6, it can be seen that the data probabilities in the four groups are $p = 3.28657 \times 10^{-11}$, these data are less than σ = 0.05 and the value of F = 29.53 is higher than the critical value for F = 2.78 in the four groups. Thanks to these resulting data, it is possible to accept the HZ hypothesis and reject the HW hypothesis. This analysis indicates that there is a statistically significant difference in the groups due to the teaching method used and that IP LEARN had a directly proportional impact on the results of the questionnaires in the experimental groups.

Table 6. Analysis of variance (Anova).

Origin of Variations	Mean Squares	F	Probability	Critical Value for F
Responses to the questionnaire	32.77777778	1.107634543	0.372802414	1.827146995
Groups GR_1 y GR_2	154.2222222	29.53191489	3.28657×10^{-11}	2.786228813

Figure 3 shows the averages of the responses to the questionnaires given to the students in the control and experimental groups of GR_1 and GR_2. It can be observed the experimental groups had a better average in the responses to their respective questionnaires, which could be due to the use of the IP LEARN application as a support in regular education.

Figures 4 and 5 show the results of GR_1 and GR_2 evaluated by gender. It should be noted that the content of the questionnaires for GR_1 is focused on IPv4 and for GR_2 on IPv6. The results are divided by control and experimental group.

Figure 4 shows that there is no significant difference between men and women in the control group. On the other hand, if we compare Figures 6 and 7, we can see that the average of both males and females in the group is much better in the experimental group than the control group.

Regarding the relationship between gender and average, it cannot be concluded that one gender is better than the other. This is due to the low number of participants in this research, especially the low number of women in an engineering technology career. The number of women in this research can affect the interpretation of results because if one of them has a low grade it can greatly affect this average.

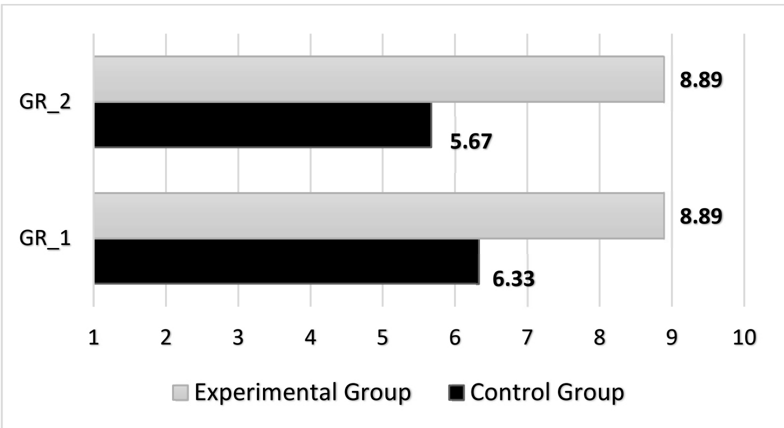

Figure 3. Average of the results of one and two groups.

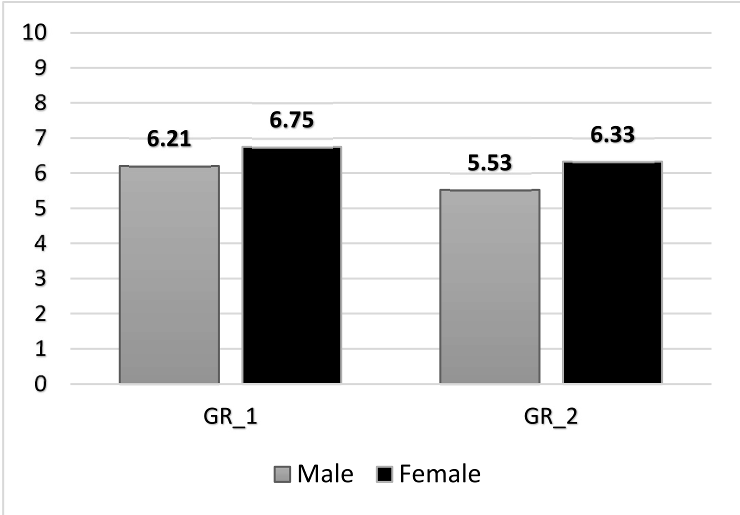

Figure 4. Average of the results by gender of the control group.

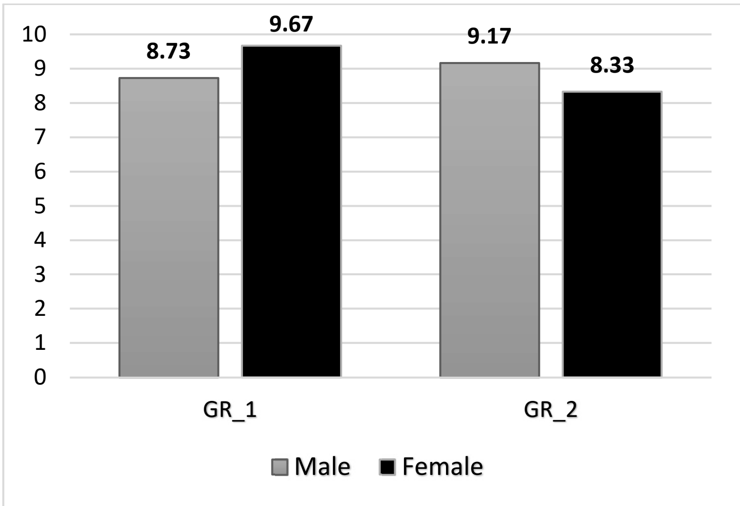

Figure 5. Average of the results by gender of the experimental group.

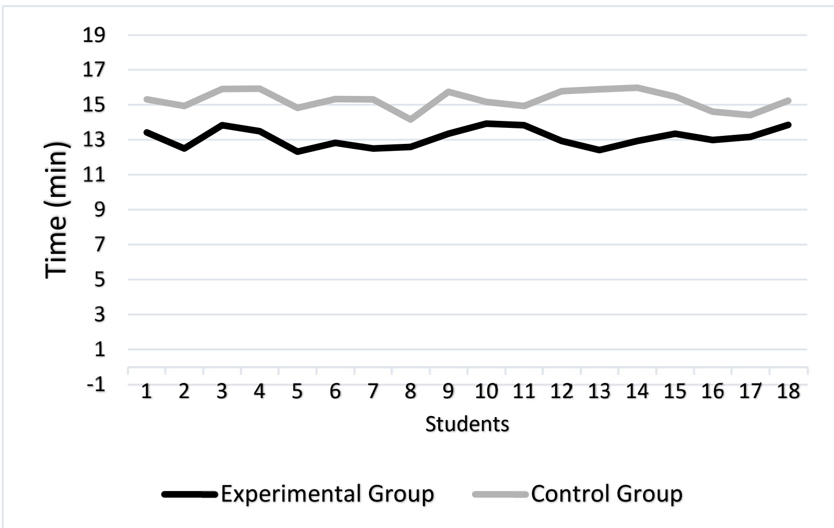

Figure 6. Time of each participant of the GR-1 to solve the questionnaire.

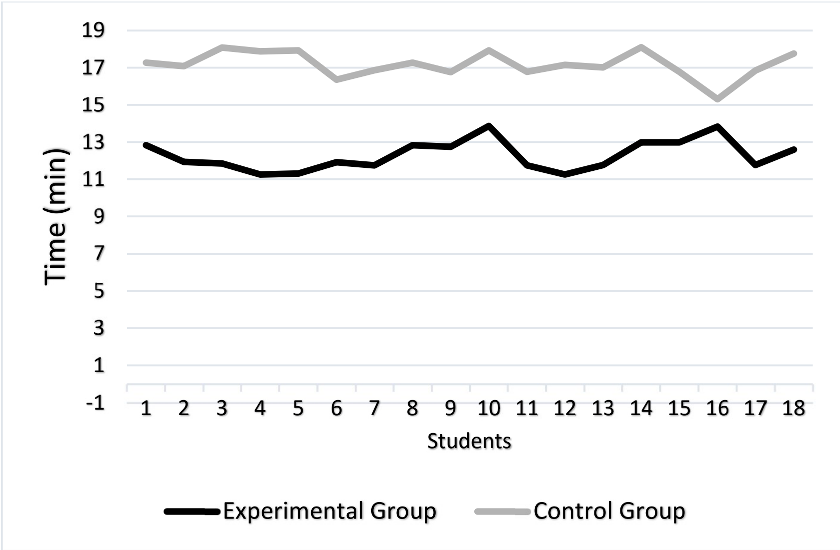

Figure 7. Time of each participant of the GR-2 to solve the questionnaire.

During the evaluation, the time taken by each student to answer the questions was taken into consideration. In Group EG_1 the average time to complete the questionnaire was 13.13 min, while for Group CG_1 it was 15.28 min. The time taken by each participant to complete the questionnaire can be seen in Figure 6. In Group EG_2, the average time was 12.29 min, while in Group CG_2, the average was 17.17 min. This can be seen in Figure 7.

6. Discussion

Due to the mandatory quarantine caused by the COVID-19 pandemic and the closure of educational institutions, most of them sought new means based on technology to maintain access to education [39]. This new modality of teaching shows that the adoption of technology will gradually become a new modality of access to education. The potential of digital technology in education has been repeatedly proven [6,40–42]. This research presents encouraging results for the benefit of students, by using an educational model supported by mobile technology.

Although there are various digital technologies for education, e-learning and m-learning have been the main tools adopted by most institutions to improve teaching and learning [43,44]. However, despite the multiple benefits, there are challenges to face for the correct deployment of digital technologies. This includes affordability of devices and Internet access for all students. In addition, most teachers lack technical support and need training for the proper use of these technologies [6].

A mixed methodology was used for this research. The experimental part consisted of the design and construction of a customized mobile application. This was created to motivate learning with topics that were defined by the students of the last levels of education. These topics were the most complicated to learn in their academic training. The topics to be included in the application were IPv4, IPv6 and numbering systems. The designed application was intuitive, since the students of the experimental group were able to use it without any problem, which indicates that its use is simple, friendly and the application motivates learning. Although several of the students had no experience in the use of educational apps, they had no problem using the application after a brief explanation in the classroom. In addition, its design allows users not to get bored with the theory, they can solve quizzes and get feedback for each learning topic. Statistical analysis was performed with the control and experimental groups using a questionnaire as an instrument to validate academic performance. At the end of the use of mobile devices and regular teaching, students completed the questionnaire designed to show the influence of mobile devices on knowledge retention. The results of the comparison of the two groups showed statistically positive results, since the students who used the application understood the topics better and retained the information learned better. These data obtained are consistent with other initiatives that used mobile applications to encourage learning in various subjects [2,39,45]. This is evidenced in the resolution of the questionnaire, the students who used the teaching method with IP LEARN obtained better grades and a shorter resolution time. For this reason, it can be indicated that the mobile application used as support in the educational model can improve learning and knowledge retention in students.

The use of mobile devices, compared to textbooks, has several advantages. For example, it makes it easier to study anywhere, avoids having to carry physical material, books, magazines, etc. There are books that can be downloaded to mobile devices or others that are available online, but the differential advantage of mobile applications is interaction. Users receive feedback while learning which is not possible in books.

In a traditional scenario of the educational model, the main figure is the teacher, the student becomes a passive entity, but if we add technology in the classroom, the student becomes directly involved in the educational process. It has been proven that the use of mobile technologies as a support in the classroom generates motivation and improves learning results [2,26]. In addition, contrary to traditional education, mobile learning provides flexibility in learning because communication is bidirectional, interactive, and can be personalized. In this work, it was possible to observe the benefit that personalized learning generates in students when using a mobile application de-signed and built specifically to address IP addressing issues.

The literature review showed that many of the learning initiatives with mobile devices were empirical, so this research shows the results of learning with a mobile application in a real scenario and with groups of students. Therefore, the use of digital technologies, properly used, can contribute positively to develop an innovative educational model, which contrasts with the fourth goal of the Sustainable Development Goals of the United Nations. This goal states "ensure equitable, inclusive, and quality education and promote lifelong learning opportunities for all by 2030". However, the crisis caused by COVID-19 delayed this goal and all that had been achieved until 2019. On the other hand, this crisis also accelerated the digital transformation, which made it possible to include technology and Internet access to continue with a fully online educational model. Emerging technologies, such as mobile learning, were used to continue education worldwide, opening new possibilities for education open to all and much easier and centralized access to educational material [8,46].

7. Conclusions

By means of an online survey, it was possible to validate that the mobile application was well received by the students, due to the quality of the visual content and its graphic distribution on the screen, generating visual attraction with an intuitive and functional flow of use.

In this research, it can be observed that, by using a mobile application in support of the traditional method of education, it is possible to positively influence the understanding of one or more topics, and thus demonstrate that digital technology is a potential tool in education. These results show that mobile devices can innovate educational methodologies and transform education as we know it. Although in the Google Play Store, there are several applications with the theory of addressing Ipv4, IPv6 and numbering systems, none of them brings together the theory with exercises and appropriate feedback. This is an important feature of creating customized mobile applications, as it is possible to identify gaps in learning and reinforce them with the help of digital technologies. In addition, the feedback provided by the mobile application allows users to reinforce knowledge and learn from mistakes made.

The use of an agile methodology for the design of IP LEARN contributed to the rapid organization of the participants, and thus to the orderly and equitable distribution of the functional requirements necessary to achieve the development of the application in the planned time (three months).

One of the characteristics of the use of mobile learning is the affordability and high penetration of this technology in many countries [6]. In this research, we were able to observe that there is a clear relationship between the device and the economic level of the students. When a student has more economic possibilities, he or she is more likely to have an excellent mobile device for use. However, the need to own the latest version of a mobile device in order to execute some mobile applications can be a barrier for students with low resources.

It is important to recognize which are the indicators that motivate the use of digital technologies in the students of this new generation. This could be the beginning of a new era in the teaching and learning process, which would allow students to be the main beneficiaries of the potential that technology and mobile applications have in education innovation.

8. Future Work

To improve the IP LEARN application, it is considered to increase the information on number systems, IPv4, IPv6, and to add other modules on the division into subnets with fixed mask and variable mask. In addition, it would be interesting to add a gamification allowing much more interaction with the user. On the other hand, accessibility issues should be included so that the application can be used even by people with disabilities.

A future work can be the development of the application for the iOS operating system, natively or through a framework to then publish it in the App Store so that there are more users who can benefit from it.

Education and learning can benefit from mobile applications developed for personalized learning or from free web-hosted applications. It is encouraged to use either of these two options to analyze educational performance, and to define a framework for the use of mobile applications that positively influence academic performance.

In addition, it is recommended to repeat the validation tests over several semesters and in different parallels, it may also be useful to carry out the research involving other universities. This extended analysis can counteract the results obtained in this research and improve the results presented.

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Appendix A. Dichotomous Test Responses for the Experimental and Control Groups

Table A1. Test one for groups EG_1 y CG_1.

TEST_1	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
EG_1	1	1	1	1	1	1	1	1	0	1	9
EG_1	1	1	1	0	1	1	1	1	1	1	9
EG_1	1	0	1	1	1	0	1	1	1	1	8
EG_1	1	1	1	1	1	1	1	1	0	0	8
EG_1	1	1	1	1	1	1	1	1	1	1	10
EG_1	1	0	0	1	0	1	0	1	1	1	6
EG_1	1	1	1	1	1	0	1	1	1	1	9

Table A1. *Cont.*

TEST_1	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
EG_1	1	1	1	1	1	1	1	1	1	1	10
EG_1	1	1	1	1	0	1	1	1	1	1	9
EG_1	1	1	1	1	1	1	1	1	0	1	9
EG_1	1	1	1	1	1	1	1	0	1	1	9
EG_1	1	1	0	1	1	1	1	1	1	1	9
EG_1	1	1	1	1	1	1	1	1	1	1	10
EG_1	1	1	1	1	0	1	1	1	1	1	9
EG_1	1	1	1	1	1	1	1	1	1	1	10
EG_1	1	0	1	1	1	1	0	0	1	1	7
EG_1	1	1	1	1	1	1	1	1	1	0	9
EG_1	1	1	1	1	1	1	1	1	1	1	10
CG_1	1	1	1	1	0	0	0	1	1	0	6
CG_1	0	0	0	0	1	1	0	1	0	1	4
CG_1	1	1	1	1	0	1	0	0	1	0	6
CG_1	1	1	1	1	0	1	0	1	1	1	8
CG_1	1	1	1	1	1	0	1	1	1	1	9
CG_1	0	0	0	1	0	1	0	1	1	0	4
CG_1	1	0	1	0	1	1	0	0	0	1	5
CG_1	1	1	1	1	0	0	0	1	1	0	6
CG_1	1	0	1	1	1	1	1	1	1	1	9
CG_1	1	1	1	1	0	0	0	1	0	0	5
CG_1	1	0	1	1	0	1	1	1	0	1	7
CG_1	1	0	1	1	1	0	1	1	0	0	6
CG_1	1	1	0	1	1	0	0	0	1	0	5
CG_1	1	0	1	1	1	1	1	1	1	1	9
CG_1	1	0	1	0	1	1	1	1	1	0	7
CG_1	1	1	0	1	1	0	1	1	1	1	8
CG_1	1	0	1	0	0	1	1	0	1	0	5
CG_1	1	1	0	0	0	1	1	0	1	0	5

Table A2. Test two for groups EG_2 and CG_2.

TEST_2	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
EG_2	1	1	1	0	1	1	1	1	0	1	8
EG_2	1	1	1	1	1	1	1	1	1	1	10
EG_2	1	1	1	1	1	0	1	1	1	1	9
EG_2	1	1	0	1	1	1	1	1	1	1	9
EG_2	1	1	1	1	1	1	1	0	1	1	9
EG_2	0	1	1	1	1	1	1	1	1	0	8
EG_2	1	1	1	1	1	1	1	1	1	1	10
EG_2	1	1	1	1	1	1	0	0	1	1	8
EG_2	1	1	1	1	1	1	1	1	1	1	10
EG_2	1	1	1	1	0	1	1	1	1	1	9
EG_2	0	1	1	1	1	1	1	1	1	1	9
EG_2	1	1	1	1	1	1	1	1	1	1	10
EG_2	0	1	1	1	0	1	1	1	1	1	8
EG_2	1	0	1	1	1	1	1	1	1	1	9
EG_2	1	1	1	1	1	1	1	1	1	1	10
EG_2	1	0	0	1	0	1	1	1	1	0	6
EG_2	1	1	1	1	1	1	1	1	0	1	9
EG_2	0	1	1	1	1	1	1	1	1	1	9
CG_2	1	1	1	0	1	0	0	0	0	0	4
CG_2	0	0	0	0	1	1	1	1	0	0	4
CG_2	1	1	1	1	0	0	0	1	0	1	6
CG_2	1	1	1	1	0	1	1	0	1	1	8
CG_2	0	1	0	1	0	1	1	1	0	1	6

Table A2. *Cont.*

TEST_2	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
CG_2	0	1	1	1	1	1	1	1	0	0	7
CG_2	1	1	0	0	0	0	0	1	0	1	4
CG_2	1	0	1	0	1	0	1	1	1	1	7
CG_2	1	1	1	1	1	0	1	0	1	0	7
CG_2	1	1	1	1	0	0	0	1	1	1	7
CG_2	0	1	0	0	1	0	1	0	0	1	4
CG_2	1	0	1	1	1	0	1	1	1	1	8
CG_2	0	1	0	1	1	1	0	1	0	0	5
CG_2	1	0	0	1	0	1	0	1	0	1	5
CG_2	0	1	1	1	0	0	0	0	0	1	4
CG_2	1	1	1	1	1	0	0	0	1	0	6
CG_2	1	1	1	0	1	0	1	0	0	1	6
CG_2	0	1	0	0	1	0	0	1	0	1	4

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