Available online at www.ijournalse.org

Emerging Science Journal

(ISSN: 2610-9182)

Vol. 9, No. 2, April, 2025

Usability Evaluation of a Mobile Augmented Reality App for PC Hardware Training: A Comparative Study in Three Countries

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Abstract

The proliferation of mobile applications for educational purposes has highlighted the need to evaluate their usability, especially in diverse international contexts. This study addresses the problem of insufficient engagement and effectiveness of educational tools related to PC hardware training, a problem exacerbated by cultural and contextual differences between regions. Understanding the importance of this issue is crucial, as effective educational tools can improve learning outcomes on a global scale. Previous research has explored various educational technologies but often failed to comprehensively address usability across different cultural contexts, limiting the generalization and impact of the results. This gap underscores the need for robust evaluation of educational applications in diverse populations. In this context, our research proposes the analysis of Build_PC, a mobile augmented reality (MAR) application designed to teach PC hardware, using the IBM Computer System Usability Questionnaire (CSUQ) to assess user satisfaction. This study was conducted in three universities from three countries—Ecuador, Indonesia, and Lebanon—covering a variety of cultural and educational settings. The results indicate remarkably high levels of user satisfaction with the augmented reality (AR) application across the three participating universities. Positive feedback suggests that the application effectively engages students and improves their understanding of PC hardware training, regardless of regional differences. The implications of these findings are significant, as they suggest that augmented reality applications may be a viable solution for overcoming educational barriers related to PC hardware training on an international scale. This study highlights the potential of such technology to enhance educational outcomes and provides a framework for future research in the global deployment of educational technologies.

Keywords:

Mobile Augmented Reality;
PC Hardware Training;
Usability Evaluation;
IBM CSUQ;
Comparative Study;
User Satisfaction.

Article History:

Received:	01	November	2024
Revised:	02	March	2025
Accepted:	11	March	2025
Published:	01	April	2025

1- Introduction

The rapid advancement of technology has significantly transformed teaching and learning methods across various fields, including technical and scientific education [1, 2]. In this context, PC hardware education faces unique challenges, as students often find it difficult to grasp complex concepts related to components and assembly, particularly when lacking a strong technical background [3, 4]. Traditional teaching methods, such as lectures and printed manuals, often

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DOI: http://dx.doi.org/10.28991/ESJ-2025-09-02-024

fail to provide a practical and comprehensive learning experience [5, 6]. Despite their potential, it is crucial to evaluate the effectiveness and usability of these tools in different cultural and educational contexts to ensure their global applicability [7, 8].

In response to these challenges, mobile augmented reality (MAR) has emerged as a promising tool that overlays digital information onto the physical environment, facilitating the understanding of complex concepts [9]. Previous studies have shown that MAR can enhance motivation and knowledge retention by providing interactive and visually engaging learning experiences [10]. However, these studies often focus on specific educational contexts, without exploring how cultural and technological factors may influence the effectiveness and acceptance of these applications [10]. The lack of studies that comparatively analyze the usability and perception of MAR-based educational tools across different geographic and cultural contexts represents a significant gap in the literature. Recent research highlights that the effectiveness of these technologies depends not only on their design but also on their ability to adapt to users' expectations and needs in diverse regions. Differences in technology access, learning styles, and familiarity with digital tools can significantly influence their acceptance and success [11, 12].

This study seeks to address these limitations by conducting a comparative evaluation of the Build_PC application, specifically designed for PC hardware education, in three distinct cultural contexts: Ecuador, Indonesia, and Lebanon. The main objectives of this research are:

Objective 1: To evaluate the usability of Build_PC using the IBM Computer System Usability Questionnaire (IBM-CSUQ) [13].

Objective 2: To analyze the perceived usefulness and recommendation intention of Build_PC as a support tool in higher education, utilizing a customized questionnaire based on previous research.

These countries were selected to provide a diverse sample in terms of culture and educational systems, allowing for an exploration of Build_PC global applicability and contributing to the design of more inclusive and effective educational tools. The primary contribution of this work lies in offering a comparative analysis across three distinct cultural contexts, thereby expanding the scope of previous research and providing a solid foundation for the future development of MAR-based educational applications. Furthermore, the findings can guide designers and educators in creating more adaptable and culturally relevant tools for technical education.

This section presents an overview of the use of MAR technology in education. Section 2 presents a review of the existing literature on the topic. Section 3 outlines the methodology used to achieve the proposed objectives. Section 4 presents the findings of the study. Section 5 shows the discussion. Finally, Section 6 presents the conclusions, and Section 7 outlines possible avenues for future research.

2- Literature Review

MAR has emerged as a transformative technology across various sectors, and its impact on higher education is particularly promising [14, 15]. MAR technology overlays digital information onto the real world through devices such as smartphones and tablets, offering new possibilities for interactive learning and the visualization of complex concepts [13, 16]. The use of this technology in education has expanded significantly in recent years [17-19]. MAR allows students to interact with digital content while remaining immersed in the physical environment, facilitating a deeper understanding of abstract concepts [20, 21]. Moreover, this technology enhances the educational experience and encourages active student participation [13, 22]. MAR offers innovative tools to visualize complex scientific processes, explore 3D models of architectural structures, or perform simulations of mathematical, physical, chemical, and other procedures [19, 23-25].

A crucial aspect of using MAR in higher education is its ability to enhance active learning by enabling students to interact with educational content in a more immersive way than traditional methods [14, 26]. For example, in disciplines such as engineering and medicine, students can use augmented reality (AR) to visualize and manipulate 3D models of complex systems or anatomy, facilitating a better understanding of concepts that are difficult to represent in a two-dimensional environment [27-29]. The use of MAR has also proven effective in improving motivation and collaborative work [30, 31]. Research shows that students demonstrate greater motivation and engagement in the learning process when using MAR as a support in their education [32-34]. This improvement is attributed to AR's ability to provide more dynamic and contextual learning experiences [34, 35].

MAR enables the integration of game elements into the educational process [36]. Students can participate in games that incorporate challenges and missions related to course content, making learning more engaging [37, 38]. On the other hand, teachers can use MAR to create interactive instructional materials, such as presentations that incorporate animations, allowing students to experience content in a more dynamic and immersive way [19]. This technology can also replicate laboratory experiences in a virtual environment, allowing students to practice procedures and techniques without the need for physical equipment [39]. This is particularly useful in fields such as biology or chemistry, where equipment can be expensive and practicing certain procedures may be hazardous [11, 39-41].

However, several obstacles hinder the proper deployment of this technology, including technical issues related to device compatibility, the quality of AR applications, and the need for adequate infrastructure to support these technologies [42-46]. Furthermore, students and teachers must be adequately trained to use AR technologies effectively. Without a clear understanding of how to use AR tools, the potential benefits may not be fully realized [47-50].

Despite these challenges, current trends in the development of MAR in higher education are encouraging [51]. The continuous evolution of AR technology and the growing availability of high-quality mobile devices are facilitating the creation of more sophisticated, accessible, immersive, and personalized applications that can adapt to the individual needs of students [13, 52, 53].

3- Research Methodology

Unlike other similar initiatives in the current literature, this research did not focus solely on the design aspects and outcomes of using Build_PC. Instead, this study aims to evaluate the usability of Build_PC and compare it among students from Ecuador, Indonesia, and Lebanon. The IBM-CSUQ was used for this purpose, which measures user satisfaction regarding the use of Build_PC. This is a well-established tool for evaluating the quality and effectiveness of interactive systems from the user's perspective. Its application in this study provides a detailed insight into how users in each country perceive the usability, ease of use, and usefulness of the application.

3-1- Mobile Augmented Reality Application Design

3-1-1- Design Process

The design process is fundamental to the development of effective educational applications, especially with the use of AR. In this context, several stages were addressed that guarantee an intuitive and functional user experience. Below is a detail of how the key components were identified to facilitate interaction and learning through AR technology:

- Identification. Initially, the main components of a desktop computer and their respective functions were identified. Subsequently, the capabilities of mobile devices with the Android Operating System (OS) were investigated to determine the tools and Software Development Kits (SDKs) suitable for developing educational applications. Finally, frameworks and libraries used in Unity for developing MAR applications were classified. These libraries are needed to facilitate the tracking of a 2D physical model and map the desktop computer model to the real world through the mobile device's camera. The chosen framework was Vuforia, a licensed system that provides AR capabilities without consuming excessive resources.
- Optimization. For the computer model, a free asset downloaded from the internet was used, which was later optimized for seamless use on mobile devices. The open-source tool Blender was utilized for this purpose.
- Interface Design. The number of interfaces to be displayed to users was defined, including the settings menu and the information window for the desktop computer components. Subsequently, the positioning and style of elements in each interface were designed, including text placement, color, size, and font type.
- User Interaction Design. Several interaction possibilities were defined, such as using cursors, interacting through the camera with hand gestures, among others. Ultimately, a recasting system was chosen to allow users to tap on a component on the screen, with the application responsible for mapping that point and component to the exact location within the computer case.

3-1-2- Design Elements

The development of the marker-based AR application called Build_PC was carried out using Unity 2022.3.17f1 LTS together with Visual Studio 2022 Community Edition. These are commonly used tools in the development of augmented reality video games. The features of these platforms are explained in Table 1. The following libraries were used for the application development:

- Unity: UnityEngine / UnityEngine.UI: for connecting and using Unity engine's internal functions.
- UnityEngine.InputSystem: for user interaction with the application and UI.
- Vuforia: to use the phone's camera and have a model to track the PC.

Table 1. Development Platforms Used

Development platforms	Features
Unity	Unity is a video game development platform that has different versions of long-term support (LTS). Also, it can be defined as a game engine that provides a complete environment for the development of 2D and 3D video games, as well as mixed reality (XR). The developed games can be exported for use in different devices such as, desktop computer, laptop, console, smartphone, tablet, Oculus, among others.
Visual Studio 2022	Visual Studio is an integrated development environment (IDE) produced by Microsoft. This software is used to write, debug, and compile programming code. It includes a package that can be installed to connect to Unity and debug code while running the application.

In the development of an application, which is going to be used as support in education, it is essential to clearly and precisely establish the requirements and needs that are intended to be addressed [2, 54]. These elements will guide the creative process, ensuring that the application is effective in meeting its educational objectives [54]. Likewise, the design must ensure that the application motivates users and encourages them to use it [55, 56]. Therefore, it should have a user-friendly interface, be simple, coherent, and intuitive, avoiding redundancy and offering interactive navigation [2, 54, 57, 58].

In this case, the requirements were identified in a previous study by Criollo-C et al. [59], Rivera Alvarado et al. [60], and are listed in Table 2.

Additionally, due to the specific design and usability, Build_PC has the following functionalities:

- Component Interaction: The user should be able to interact with the PC components and interface freely, easily, and intuitively.
- Component Information: The user should be able to obtain information about each component and its function.
- Component Order Verification: The user should receive feedback when making an error.
- Visualization: The user should be able to see the PC components clearly and without confusion both inside and outside the case.
- Friendly Environment: The user should perceive an environment where they can work and complete the proposed exercises without problems.

Table 2. General Requirements for the design of MAR applications [59, 60]

Requirements	Features
Simple and easy to use	Provide ease of use of the application, the user should use the application without any major difficulties.
Consistent interfaces	Use known functionalities that resemble computer menus.
Nice design	Generate satisfaction, enthusiasm, and fun by using the different controls in the activities carried out by the application.
Feedback	Provide an understanding of mistakes made to improve task interpretation.
Multimedia content	Generate use intent by creating multimedia interfaces that attract the user's attention.
Intuition	Avoid user disorientation due to total number of interactions.
Motivation	Motivate the user with kind messages while progressing through the game.
Navigability	Follow the user interface design principles established by the platform on which the mobile application was developed.
Lightweight	The application must allow its execution on devices with limited processing and storage capacity, although this results in loss of performance.
Extensibility	The sensors of a device are different depending on the hardware used by the manufacturers. With the wide variety of methods for obtaining information, the designed application must be open to new ways of accessing the sensors.
Ease of testing and maintenance	Consistency in components should facilitate the development of unit tests and maintenance of the application.

The configuration of these activities was carried out within a set timeframe defined in Table 3. If problems arose, the team would briefly meet to resolve doubts and continue with the project. The priority of each cycle was determined by the project's final objectives. At the end of each cycle, the work done was reviewed, demonstrated, and adapted in a team meeting to finalize Build_PC development. The following are images of the designed application's use. Figure 1 shows how Build_PC places PC elements 3D on the mobile device. Figure 2 shows a student using the Build_PC application. These two figures illustrate how the Build_PC application displays computer parts in a 3D format and how users can interact with it.

Table 3. Iterations Required for the Construction of the MAR Application

Iteration number	Definition	Priority (1 -10)	Iteration duration (Weeks)
1	Create components.	10	1
2	Create interaction.	10	1
3	Optimize models.	6	2
4	Create tracking model.	9	1
5	Create UI elements.	8	1
6	Create block order verification.	6	1
7	Create option not to use tracking.	9	2
8	Add component information.	9	1
9	Create saving system.	7	2
10	Create object thumbnails for the information screen	5	1
Total duration of mobile application development			**13 weeks**

Figure 1. **Build_PC environment**

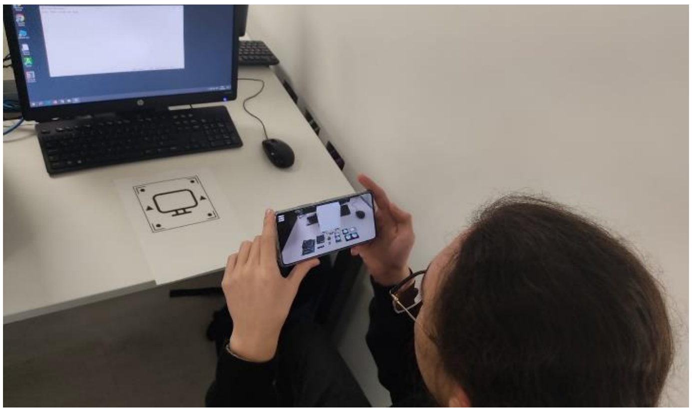

Figure 2. **Student using Build_PC**

3-1-3- Build_PC Operation

The Build_PC design incorporates a language-switching feature. Users can choose to view interface information in Spanish, English, Indonesian, or Arabic. This multilingual capability enables Build_PC to cater to a diverse audience, accommodating various linguistic preferences. By supporting multiple languages, the application enhances accessibility and inclusion, thereby broadening its educational reach and impact. This feature ensures that users from different linguistic backgrounds can effectively engage with the application, further supporting its goal of providing a comprehensive and user-centric educational tool. Moreover, the inclusion of a language-switching feature demonstrates a commitment to global usability and user satisfaction, contributing to a more inclusive educational experience. The design approach not only addresses immediate user needs but also anticipates future demands for expanded language support, thus aligning with best practices in educational technology development.

3-2- Participants

This research involved the participation of 150 students from higher education institutions, distributed equally among Ecuador, Indonesia, and Lebanon, with 50 participants from each country. All students provided informed consent through a web form. Participants were selected through convenience sampling. Of the 150 participants, 64 (42.7%) were women, and 86 (57.3%) were men. Notably, Indonesia contributed the highest proportion of women in this study, with 62% compared to 38% men. In Lebanon, 22 women (44%) and 28 men (56%) participated. In Ecuador, the proportion of women was the lowest, with 11 women (22%) compared to 39 men (78%).

3-3- Experimental Protocol

Each participant provided informed consent via a web form. The experiment began with an introduction to the use of the Build_PC application, using a Build_PC usage diagram detailed in Figure 3. Participants were given the opportunity to ask questions and provide feedback on the designed application. Subsequently, they proceeded to use the Build_PC application, as shown in Figure 2, which lasted approximately 20 minutes per student. After using the application, each participant completed two questionnaires. The information gathered allowed for the evaluation of the application's usability and the perceived usefulness of using AR technology as support in higher education. These data can be valuable for educators and educational institutions looking to incorporate AR to innovate traditional methodologies and adequately address current challenges in the learning process.

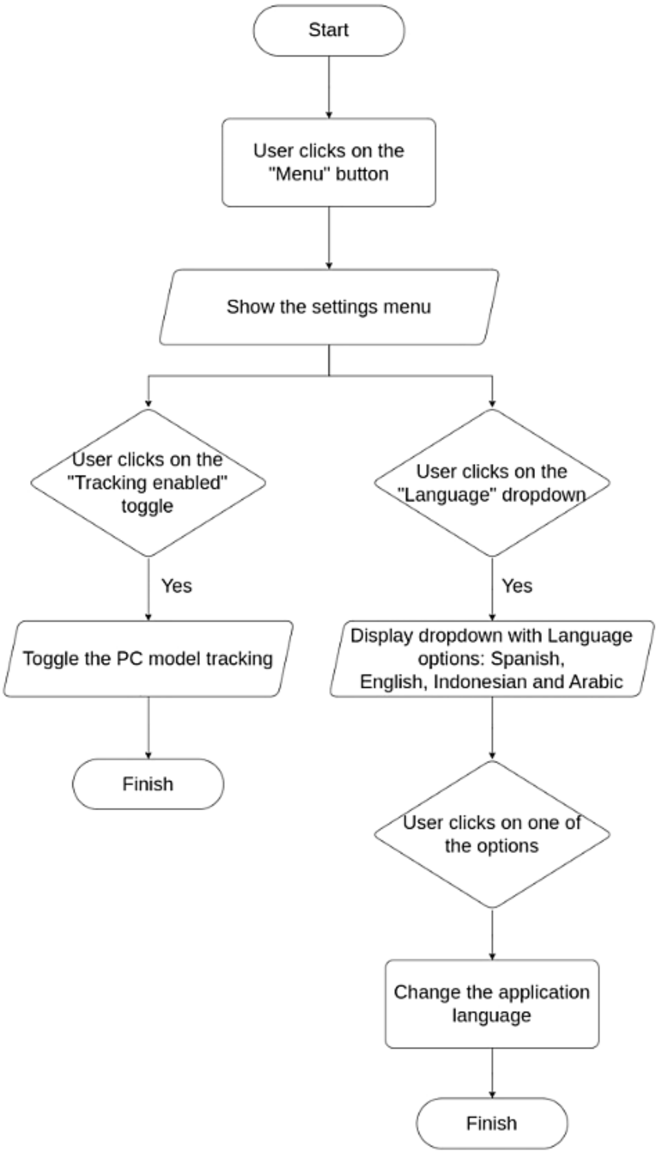

Figure 3. Build_PC Usage Function Diagram

3-4- Usability Analysis

To evaluate the usability of Build_PC, a survey based on the IBM-CSUQ tool was used, which employs a 7-point Likert scale, where 1 indicates strong disagreement or very unlikely, and 7 indicates strong agreement or very likely. [61, 62]. This questionnaire consists of 19 questions designed to measure user satisfaction with the developed application [61]. The survey aims to gather data on various aspects, such as the ease of use of the system (SYSUSE), the quality of the information provided (INFOQUIAL), the quality of the interfaces (INTERQUIAL), and an overall evaluation of the application and its ease of use (OVERALL). Below are the questions from the questionnaire:

3-4-1- Questions SYSUSE (QSY)

Q1. Overall, I am satisfied with how easy it is to use this system.

Q2. It is simple to use this system.

Q3. I can effectively complete my work using this system.

Q4. I am able to complete my work quickly using this system.

Q5. I am able to efficiently complete my work using this system.

Q6. I feel comfortable using this system.

Q7. It was easy to learn to use this system.

Q8. I believe I became productive quickly using this system.

3-4-2- Questions INFOQUIAL (QIF)

Q9. The system gives error messages that clearly tell me how to fix problems.

Q10. Whenever I make a mistake using the system, I recover easily and quickly.

Q11. The information (on-screen messages and guidance or other documentation) provided with this system is clear.

Q12. It is easy to find the information I need.

Q13. The information provided with the system is easy to understand.

Q14. The information is effective in helping me complete my work.

Q15. The organization of information on the system screens is clear.

3-4-3- Questions INTERQUIAL (QIT)

Q.16 The interface of this system is pleasant.

Q17. I like using the interface of this system.

Q18. This system has all the functions and capabilities I expect it to have.

3-4-4- Question OVERALL (QOV)

Q19. Overall, I am satisfied with this system

3-5- Perceived Usefulness Analysis

When designing an educational application, it is not only crucial that it functions effectively, but also that users consider it potentially useful as support in their educational process. For this reason, a survey was used to measure the perceived usefulness of Build_PC as a complementary tool in PC hardware training. The questions used in the survey, based on our previous research Jang et al. [13], are as follows:

QA. Do you think this application is applicable in classrooms to motivate learning about PC hardware?

QB. Do you think this application gives students an interesting insight into the parts of a PC?

QC. Would you use this app in your classroom?

QD. Do you think that using this application improves your learning?

QE. Do you consider this application as an effective tool for guided learning in class?

QF. Would you recommend this application as an educational tool in the classroom?

This survey also includes a multiple-choice question. After using the application, participants are asked to choose a word that best describes their perception of its use from the following options: useful, entertaining, easy to use, user-friendly, motivating, intuitive, or prefer not to answer.

4- Results

4-1- Usability Analysis

The analysis of the results for the countries of Ecuador, Indonesia, and Lebanon focuses on evaluating the usability of the Build_PC application through the IBM-CSUQ questionnaire. In each country, the average, standard deviation, and median values for the four categories of the questionnaire are presented, along with the maximum, average, and minimum values. Differences between men and women in terms of their perception of the application's usability are graphed, allowing for the identification of potential significant variations between both genders. In this context, Table 4 present the results for the average, standard deviation, and median for the four categories of the IBM-CSUQ tool. Table 5 show the maximum, average, and minimum values associated with the tool used for the usability analysis.

Table 4. Average (μ), Standard Deviation (σ), and Median (M) of the IBM-CSUQ Survey

IBM-CSUQ	Question	Ecuador			Indonesia			Lebanon		
		μ	σ	M	μ	σ	M	μ	σ	M
SYSUSE (QSY)	Q1	6.02	0.71	6	6.02	0.71	6	6.02	0.71	6
	Q2	5.90	0.86	6	5.90	0.86	6	5.90	0.86	6
	Q3	6.04	0.70	6	6.04	0.70	6	6.02	0.71	6
	Q4	5.78	0.76	6	5.84	0.68	6	5.78	0.76	6
	Q5	5,62	0.97	6	5.80	0.78	6	5.68	0.89	6
	Q6	5.72	0.67	6	6.12	0.77	6	6.14	0.76	6
	Q7	6.00	0.95	6	6.04	0.90	6	6.04	0.88	6
	Q8	5.62	0.73	6	5.64	0.69	6	5.66	0.69	6
INFOQUIAL (QIF)	Q9	5.50	1.04	6	5.82	0.63	6	5.46	0.93	6
	Q10	5.70	1.04	6	5.86	0.83	6	5.60	1.09	6
	Q11	5.50	1.37	6	5.80	0.97	6	5.44	1.26	6
	Q12	5.90	0.89	6	6.04	0.67	6	5.82	0.85	6
	Q13	5.54	1.15	6	5.80	0.83	6	5.52	1.05	6
	Q14	5.42	1.16	6	5.74	0.80	6	5.40	1.11	5.5
	Q15	5.80	0.93	6	5.90	0.74	6	5.72	0.70	6
INTERQUIAL (QIT)	Q16	6.08	0.72	6	6.02	0.62	6	6.04	0.73	6
	Q17	6.02	0.91	6	5.80	0.86	6	5.94	0.91	6
	Q18	5.86	0.76	6	5.84	0.68	6	5.82	0.72	6
OVERALL (QOV)	Q19	6.24	0.77	6	6.52	0.50	7	6.38	0.57	6

Table 5. General Results of the IBM-CSUQ Survey

	Ecuador				Indonesia				Lebanon			
	QSY	QIF	QIT	QOV	QSY	QIF	QIT	QOV	QSY	QIF	QIT	QOV
Top	6.16	6.22	6.53	7.07	6.25	6.23	6.38	7.02	6.22	6.17	6.47	6.95
Average	5.84	5.62	5.99	6.46	5.93	5.85	5.89	6.52	5.91	5.57	5.93	6.38
Bottom	5.51	5.02	5.44	5.85	5.60	5.47	5.39	6.02	5.59	4.96	5.40	5.81
Median	5.88	5.71	6.00	7.00	5.94	5.86	6.00	7.00	5.94	5.64	6.00	6.00
Standard Deviation	0.32	0.60	0.54	0.61	0.32	0.38	0.50	0.50	0.31	0.60	0.53	0.57

Figure 4 graphically illustrate these results for each country: Ecuador, Indonesia, and Lebanon, respectively. Additionally, Figures 5 and 6 graphically represent the responses of the 50 participants, grouped by male and female gender, for all three countries. These data allow for an analysis of how each group experiences the usability of Build_PC. The graphs help identify potential significant differences between men and women regarding the usability of the application as an educational support tool. Understanding these differences may be crucial for fully interpreting the results. In Ecuador there is minor differences can be observed between men and women, with a homogeneous trend in category scores, particularly in INTERQUIAL and OVERALL. In Indonesia there is allow for a comparative analysis between genders, highlighting a positive perception in both groups with slight variations in specific categories. In Lebanon there is an overall positive perception of the application, with minor gender differences, particularly in the clarity of the information presented.

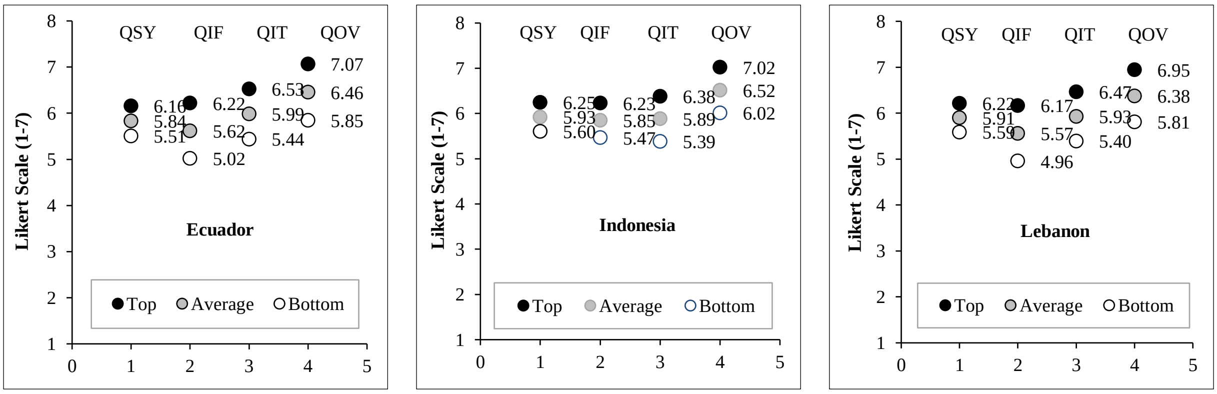

Figure 4. General results of the IBM-CSUQ survey

Figures 5 and 6 reveal specific trends in the usability of Build_PC based on the country and participants' gender. These differences are crucial for identifying areas of improvement in the application's design to ensure an inclusive user experience. For instance, the variations in INFOQUIAL between men and women in Indonesia and Lebanon suggest the need to optimize information presentation for more uniform comprehension. Overall, these visualizations complement the tabular data, providing a clear representation of how different groups perceive the usability of the application. This analysis contributes to improving the educational experience and adapting the technology to the specific needs of its users.

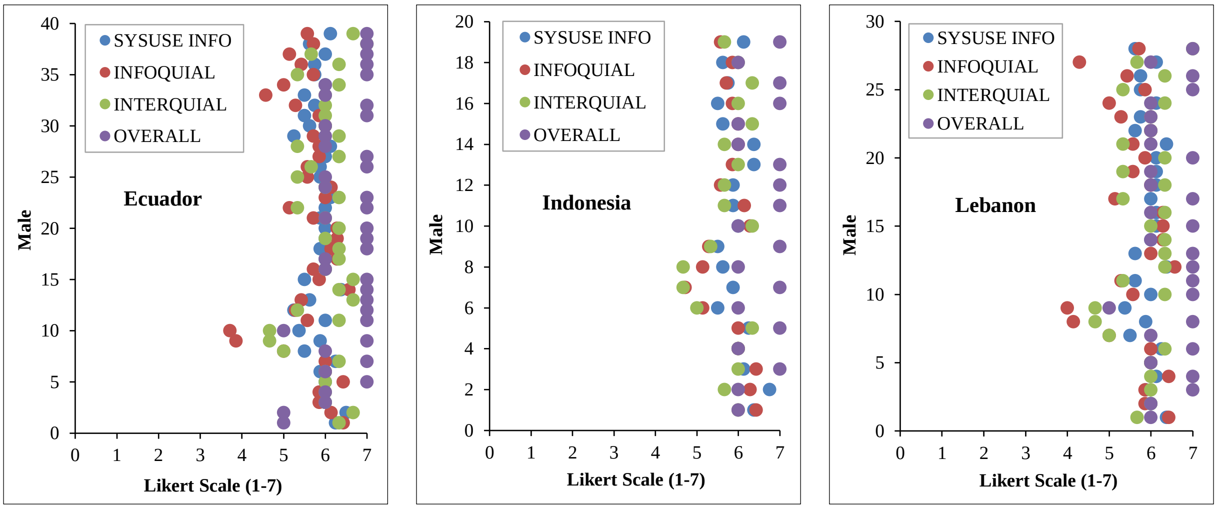

Figure 5. Response of participants in the IBM-CSUQ survey (Male)

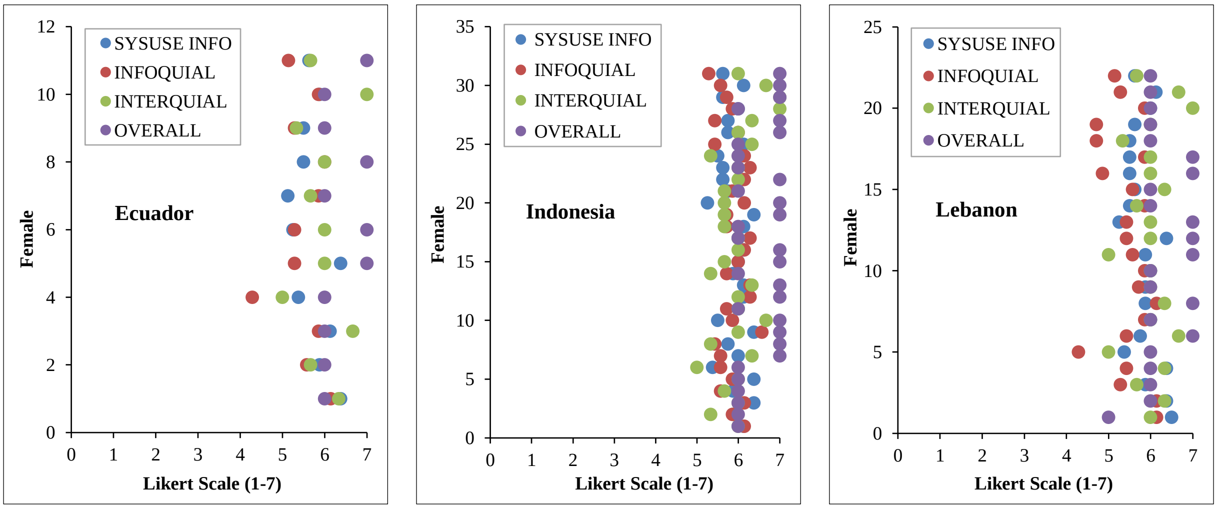

Figure 6. Response of participants in the IBM-CSUQ survey (Female)

4-2- Perceived Usefulness Analysis

For Ecuador, the results indicate that the perception of participants, both men and women, is highly positive regarding the use of Build_PC as an educational tool. The answers to questions QA, QB, QC, QD, QE, and QF, in Figure 7, reveal that the majority of participants "totally agree" or "agree" with the usefulness of the application to motivate learning, offer an interesting view of PC hardware, and recommend its use in the classroom. Furthermore, in Figure 8, the words most selected by students to describe the application are "entertaining" and "useful", highlighting a favorable perception of its functionality. These results show that Build_PC not only facilitates guided learning but also generates an engaging and motivating experience.

In the case of Indonesia, the results reflect that the Build_PC application is perceived as a useful and easy-to-use tool. The responses show that a large proportion of participants "strongly agree" or "agree" with the questions related to the enhancement of learning and the effectiveness of the tool in the classroom. Figure 8 highlights the keywords selected by students, where the perception that the application is "useful" and "easy to use" predominates. This suggests that Build_PC has a user-friendly interface that facilitates user interaction and the learning of complex concepts.

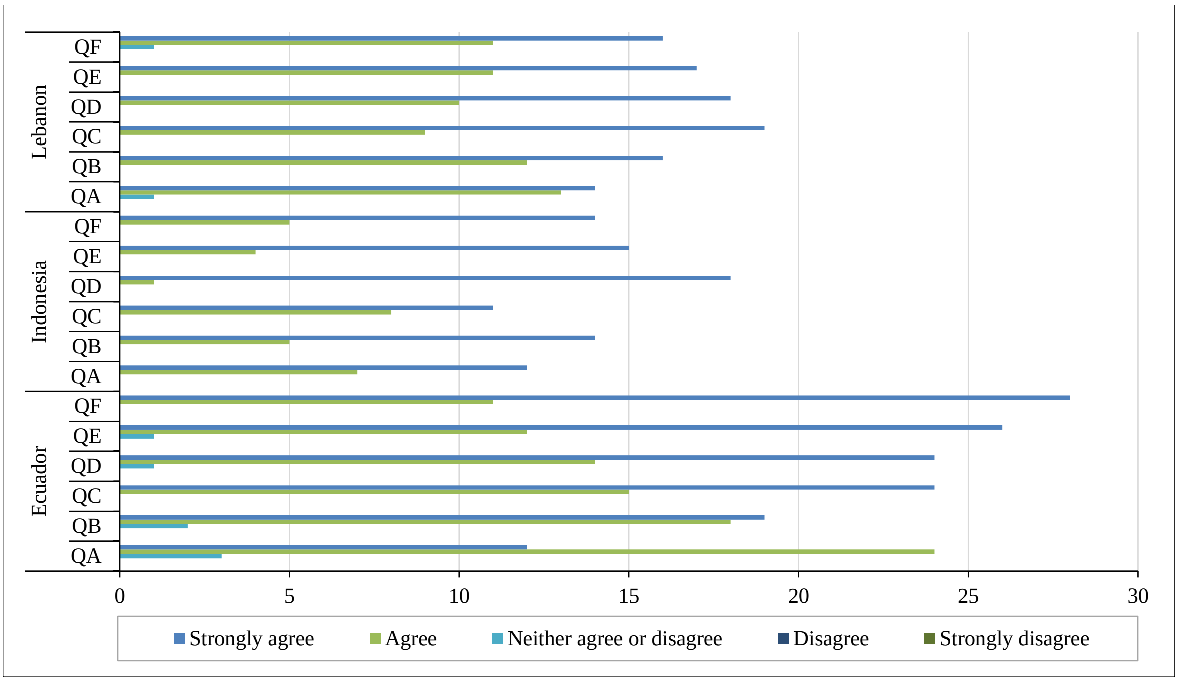

Figure 7. **Answer to questions QA, QB, QC, QD, QE, and QF**

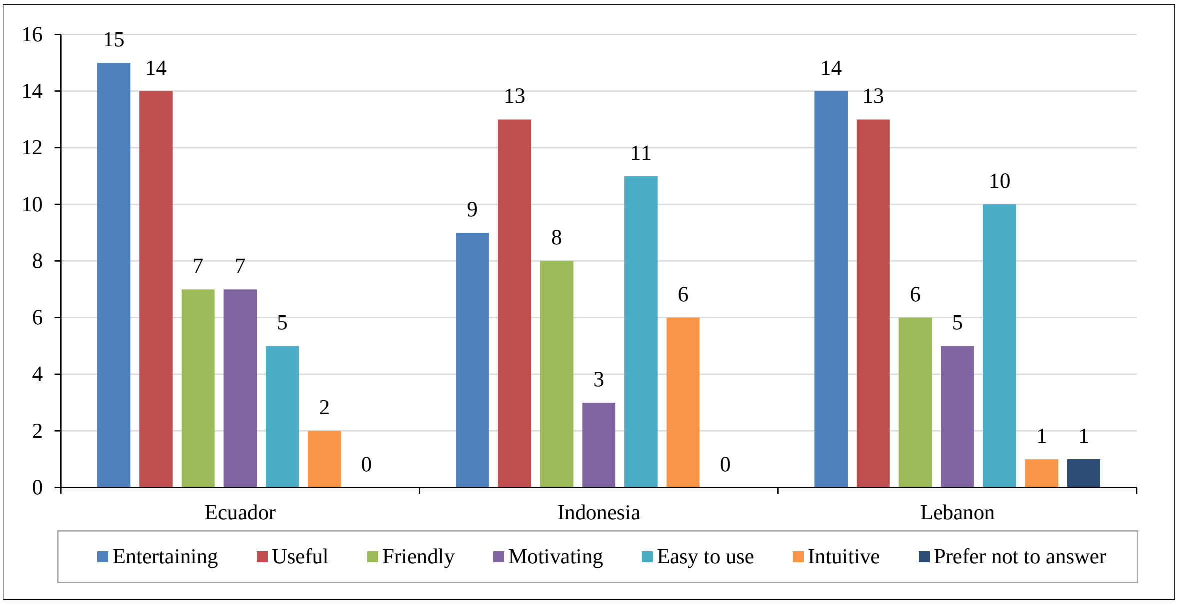

Figure 8. **Using words to describe the application**

In Lebanon, the results are consistent with those observed in the other countries. The majority of participants consider the application to be "useful" and "entertaining", as indicated by the responses to questions QA, QB, QC, QD, QE and QF, and the words selected in Figure 8. This reflects that the application succeeds in capturing students' interest by offering an innovative and effective learning experience. Similar to the other countries, participants positively valued the impact of the tool on their learning, as well as its ease of integration in the classroom and its ability to offer a guided experience.

5- Discussion

5-1- Objective 1

The IBM-CSUQ tool is widely used and recognized in the field of usability, it also guarantees in this research, effectiveness, ease of use, wide coverage, standardization, and adaptability [61].

5-1-1- Usability in Ecuador

The usability study revealed a positive outcome among the students. In the survey, most of them responded "agree" and "strongly agree" to the questions posed. This can be observed in Tables 4 and 5, Figures 5 and 6. The data presented show that the quality of the interfaces (INTERQUIAL: Q16 - Q18) has a positive trend, higher than usability (SYSUSE) and the information presented (INFOQUIAL), both in the maximum value (6.53) and in the average of the results (5.99). These values indicate that, when using Build_PC, students perceive a high quality in the application's interfaces. On the other hand, the quality of the information presented in Build_PC (INFOQUIAL: Q9 - Q15) obtained the second-best result, both in the maximum value (6.22) and in the average (5.62). This suggests that Build_PC is designed in such a way that students can interact with it intuitively and without difficulties. If the application presents useful and engaging information, it is highly likely that students will adopt and want to use it for their learning.

The system's usability (SYSUSE: Q1 - Q8) showed the lowest value among the four categories (SYSUSE, INTERQUIAL, INFOQUIAL, and OVERALL), both in the maximum value (6.16) and in the average (5.84). The lower usability experienced when using Build_PC may negatively affect the user experience and reduce users' confidence in the application. This result suggests that the application's design can and should be improved in terms of usability and ease of use to enhance students' perception. To sum up, the overall satisfaction data (OVERALL: Q19) show that Build_PC was perceived adequately by the students, with scores ranging from 5.85 to 7.07, with most scores close to the average of 6.46, with a standard deviation of 0.61, indicating some variability in the students' responses.

In this context, Table 4 Question Q14, "The information (on-screen messages and guidance or other documentation) provided helps me complete my work," received the lowest score (μ = 5.42). The low score on Q14 indicates that users found the information provided by Build_PC whether in the form of on-screen messages, guidance, or additional documentation—was not entirely useful in helping them complete their tasks. The low score on this question highlights a significant deficiency in the help provided to users. Addressing this issue by improving the quality, visibility, and relevance of the information, as well as personalizing the assistance, will be crucial to optimizing user experience and learning effectiveness. Question Q16, "The interface of this system is pleasant," received the highest rating (μ = 6.08). The high rating on Q16 suggests that users found the Build_PC interface particularly appealing and pleasant. The high score on this question underscores the success of the Build_PC interface in providing a visually attractive and enjoyable experience for users. This positive aspect of usability not only enhances overall satisfaction but can also positively influence user engagement and learning effectiveness.

5-1-2- Usability in Indonesia

The usability study revealed a positive outcome among the students. In the survey, most of them responded "agree" and "strongly agree" to the questions posed. This can be observed in Tables 4 and 5, and Figures 5 and 6. The data presented show that the quality of the interfaces (INTERQUIAL: Q16 - Q18) has a positive trend, higher than system usability (SYSUSE) and the information provided (INFOQUIAL), both in the maximum value (6.38) and the average of the results (5.89). These values indicate that, when using Build_PC, students perceive a high quality in the application's interfaces. On the other hand, system usability (SYSUSE: Q1 - Q8) achieved the second-best result, both in the maximum value (6.25) and the average (5.93). This suggests that Build_PC is designed in such a way that students can interact with it intuitively and without difficulties. If the application has adequate usability, it is very likely that students will adopt and want to use it for their learning.

The quality of the information provided in Build_PC (INFOQUIAL: Q9 - Q15) showed the lowest value among the four categories (SYSUSE, INTERQUIAL, INFOQUIAL, and OVERALL), both in the maximum value (6.23) and the average (5.85). The low quality of the information presented in Build_PC may negatively impact the user experience. This result suggests that the design of the application can and should improve how information is presented within Build_PC to enhance students' perception. Finally, the overall satisfaction data (OVERALL: Q19) show that Build_PC was perceived positively by the students, with scores ranging from 6.02 to 7.02, with most scores close to the average of 6.46 and a standard deviation of 0.61. This rating suggests that, in general, students found that Build_PC met their expectations and needs. The proximity of most scores to this average also suggests that user experiences were largely consistent, with no major discrepancies in the overall perception of the system. The relatively low standard deviation of 0.61 reinforces this impression of consistency, indicating that individual scores did not deviate significantly from the average. This is a positive sign, as a low standard deviation suggests uniformity in the user experience, which may indicate an effective implementation of the system that provides a homogeneous experience for the majority of users.

In this context, Table 4 shows Question Q8, "I believe I became productive quickly using this system," received the lowest score (μ = 5.64). This result suggests that there are specific areas where the mobile application may need improvements to enhance students' perception of its usability. On the other hand, question Q6, "I feel comfortable using this system," received the highest rating (μ = 6.12). This high value indicates that users found the system comfortable and easy to use, which is a positive indication of its design and functionality. The high rating in this question highlights the system's effectiveness in providing a satisfactory user experience.

Comfort in using a system is crucial, as it can significantly influence overall user satisfaction and their willingness to continue using the system in the long term. In this regard, the intuitive design, ease of navigation, and efficient responsiveness to users' needs appear to have played a crucial role in the positive perception reported. Moreover, this perception of comfort may have important implications for user retention and system promotion. Users who feel comfortable with a platform are more likely to continue using it and recommend it to others, which can lead to increased adoption and dissemination of the system within their environment.

5-1-3- Usability in Lebanon

The usability study revealed a positive outcome. In the survey, most participants responded "agree" and "strongly agree" to the questions posed. This can be observed in Tables 4 and 5, and Figures 5 and 6. The data show that the quality of the interfaces (INTERQUIAL: Q16 - Q18) has a positive trend, higher than system usability (SYSUSE) and the information provided (INFOQUIAL), both in the maximum value (6.47) and in the average of the results (5.93). These values indicate that, when using Build_PC, students perceive a high quality in the application's interfaces. On the other hand, system usability (SYSUSE: Q1 - Q8) achieved the second-best result, both in the maximum value (6.22) and in the average (5.91). This suggests that Build_PC is designed in such a way that students can interact with the application intuitively and without difficulties.

The quality of the information provided in Build_PC (INFOQUIAL: Q9 - Q15) showed the lowest value among the four categories (SYSUSE, INTERQUIAL, INFOQUIAL, and OVERALL), both in the maximum value (6.17) and in the average (5.57). The low quality of the information provided in Build_PC may negatively impact the user experience. This result suggests that the design of the application can and should improve how information is presented within Build_PC to enhance students' perception.

Eventually, the overall satisfaction data (OVERALL: Q19) show that Build_PC was perceived positively by the students, with scores ranging from 5.81 to 6.95, with most scores close to the average of 6.38 and a standard deviation of 0.57. This rating suggests that, in general, students found that Build_PC met their expectations and needs. The standard deviation of 0.57 indicates that individual scores did not deviate significantly from the average, suggesting uniformity in the user experience. This could indicate the potential for effective system implementation, as it offers a homogeneous experience to most users.

In this context, Table 4 shows Question Q14, "The information is effective in helping me complete my work," received the lowest score ($\mu = 5.40$). This result highlights a weakness in the effectiveness of the information provided by the app to help users complete their tasks. Addressing this area could significantly improve the app's usability and increase user satisfaction. On the other hand, question Q6, "I feel comfortable using this system," received the highest rating ($\mu = 6.12$). This high score suggests that users found the system comfortable and easy to use, which is a positive indicator of its design and functionality. This score reflects a positive user experience in terms of comfort when using Build_PC. It is a good indication that the application is accessible and enjoyable to use, which is crucial for the tool's acceptance and success. However, it is important to balance this strength with improvements in areas where Build_PC may be lacking, such as the effectiveness of the information provided. Combining a comfortable experience with highly effective information and support is key to achieving optimal usability.

5-1-4- Comparison of the Three Countries

In terms of overall usability, the three countries present similar results, with an average score indicating a positive perception of the application. The median in all cases is 6, reflecting a predominantly favorable opinion regarding the system's usability. However, it is important to note that, although the scores are consistent, some users may have experienced minor challenges in terms of ease of use or task efficiency. Regarding the quality of the information provided, Indonesia scored the highest, indicating that users found the information clearer and more accessible in that region. The lower standard deviation in Indonesia suggests that users have a more uniform experience in this aspect. In Ecuador and Lebanon, although the averages are positive, the higher standard deviations indicate greater variability in responses, suggesting that some users may have found the information provided by the application confusing or insufficient.

Regarding the quality of the information provided, Indonesia scored the highest, indicating that users found the information clearer and more accessible in that region. In Ecuador and Lebanon, although the averages are positive, the higher standard deviations indicate greater variability in responses, suggesting that some users may have found the information provided by the application confusing or insufficient.

In terms of interface quality, all evaluated countries show positive and similar scores, with averages indicating that users find the interface pleasant. The lower standard deviation in Indonesia reinforces the perception that users in that country have a more uniform and consistent experience with the interface. However, the higher standard deviation in Ecuador and Lebanon suggests that some users may have found aspects of the interface less satisfactory, possibly related to aesthetics or usability.

Indonesia clearly stands out in terms of overall acceptance, with an average score higher than that of the other two countries and a median of 7. This indicates a widespread perception of high satisfaction among Indonesian users, accompanied by a relatively low standard deviation, suggesting that most users are very satisfied with the application. Lebanon also shows high acceptance, with an average score above 6, while Ecuador, although showing good overall acceptance, presents a higher standard deviation, indicating a wider spread of responses, possibly due to varied experiences with the application.

5-2- Objective 2

5-2-1- Perceived Usefulness-Students in Ecuador

Both men and women agree in their perception of the application's ability to motivate learning about PC hardware. Women perceive a higher level of motivation or find the application more attractive in terms of encouraging learning, while some men might have higher expectations or see areas for improvement in terms of motivation. Both groups agree that the application provides an interesting perspective on the parts of a PC, although women seem to have a slightly more positive perception. This suggests that women may feel more comfortable with the presentation of information or perceive that the application offers a better overview of PC components.

The responses from both genders are mostly positive regarding whether they would use the application in the classroom. While women find the application more useful in a class context, both groups believe that the application enhances their learning. This pattern suggests that women may feel more benefited by the tool in terms of improving learning, whereas some men may have a more varied or less consistent experience regarding its effectiveness in enhancing their understanding.

As for the effectiveness of the application as a guided learning tool, women rate the application more positively and uniformly. This could indicate that women find the structure of the application more suitable for guided learning, while some men might feel that the application needs adjustments to be more effective in this regard. Both groups would recommend the application as an educational tool. Men, though also inclined to recommend the application, show more variability in their responses. This could reflect a difference in expectations between the two genders regarding the tool's implementation in educational settings.

5-2-2- Perceived Usefulness-Students in Indonesia

Both men and women perceive Build_PC as a useful tool for motivating learning in an educational environment. Although some students see room for improvement in this area, most agree on its motivational effectiveness. Both men and women perceive Build_PC as effective in enhancing their understanding of the internal components of a computer. This finding reinforces the idea that the application not only motivates learning but also provides an enriching experience for understanding the structure and functioning of a PC.

Both genders see the potential for using the application in the classroom, suggesting a high likelihood of adoption in educational settings. However, not all female students are fully convinced of its direct integration into the classroom, which may be linked to the specific needs of each course or a preference for different learning methods. On the other hand, both men and women consider that the application enhances their learning, indicating that the Build_PC tool has a positive impact on content comprehension, although some students believe there is room to further optimize its ability to improve learning.

Both groups of students consider the application to be an effective tool for guided learning in the classroom. The results reinforce the perception that Build_PC can be used as an effective pedagogical tool to support classroom learning, particularly in courses related to PC hardware. Both men and women would recommend the application as an educational tool, though men seem slightly more inclined to do so without reservations. This suggests a high level of satisfaction with the tool and its perception as a valuable addition to the educational environment.

Both genders appreciate the ease of use and utility of the application, but women emphasize more that the application is user-friendly, which could imply a greater focus on the user experience. These characteristics are essential for any educational tool, as they contribute to student adoption and engagement.

5-2-3- Perceived Usefulness-Students in Lebanon

Overall, the survey results show that both men and women have a positive perception of the Build_PC application as an educational tool for learning about PC hardware. Although both genders consider the application effective and motivating, men seem more optimistic about its immediate application in the classroom and its potential to improve learning. Women, on the other hand, present a more critical perspective, suggesting they may be looking for more depth or interactivity in the content. This indicates that the application succeeds in being engaging and useful for both genders, but also highlights the importance of continuing to refine and personalize the experience to meet specific expectations and preferences, particularly in areas related to motivation and educational effectiveness. This could imply improvements in the interface, more interactivity options, or additional learning customization tools.

5-2-4- Comparison of the Three Countries

From the analysis, Indonesia appears to have a slightly more positive perception of the application's ability to motivate learning, while Ecuador and Lebanon show greater variability in responses, which could indicate differences in the educational context. The perception of the application's usefulness for understanding the parts of a PC is similar in all three countries, with a slight advantage for Indonesia in terms of consistency in responses. In all countries, there is a high willingness to use the application in the classroom. Ecuador seems to have the highest willingness, with more homogeneous responses around the maximum score. The perception of the impact on learning is positive in all three countries, but it seems to be slightly stronger in Ecuador and Indonesia than in Lebanon. Ecuador and Indonesia have a higher rate of recommending the application compared to Lebanon, where there is a bit more variability in the responses. The general perception of the application is positive in all three countries, with similarities in terms of usefulness and ease of use. However, in Lebanon, some students seem to have had a more varied experience.

6- Conclusion

The analysis of the four key factors (SYSUSE, INFOQUIAL, INTERQUIAL OVERALL) for the Build_PC application reveals positive acceptance in the three countries evaluated. However, Indonesia stands out as the country with the best perception in terms of usability, quality of information, and overall system acceptance. The results in Ecuador and Lebanon are also positive, although they show more variability in some areas, such as the quality of information and the aesthetics of the interface.

This analysis suggests that the application is well received across various cultural contexts, but also identifies areas where the user experience could be improved, particularly in terms of clarifying information and ensuring interface consistency. Improvements in these aspects could help reduce variability in user experiences and further increase overall acceptance of the application globally.

The Build_PC application is well received in all three countries, with similar perceptions regarding its usefulness, motivation to learn about hardware, and willingness to use it in the classroom. However, Indonesia appears to have a slightly more positive and consistent perception compared to Ecuador and Lebanon, where greater variations are observed in some aspects, such as the impact on learning and recommendation as an educational tool. The results suggest that the application could be equally effective in different contexts, although it would be helpful to adapt certain elements to improve the user experience in countries where responses are more varied.

One of the key advantages of using the IBM-CSUQ was its ease of implementation, as it allowed for the rapid and systematic collection of quantitative data. Additionally, the tool facilitated the analysis of results, providing a clear 1 to 7 scale for each item, which enabled a detailed analysis of standard deviation and averages in each country. This resulted in solid data that support the conclusions on the system's usability and acceptance.

The IBM-CSUQ was an invaluable tool for this research, allowing for a comprehensive evaluation of the usability, quality of information, and interface of the Build_PC application in different cultural and educational contexts. Its ability to generate comparable and detailed results across regions provides a solid foundation for future improvements in the system's design and implementation in international educational settings. Through the use of this questionnaire, the applicability of the tool to evaluate educational technologies was validated, and critical areas were identified to optimize the user experience.

6-1- Future Work

Future work could explore the long-term impact of using Build_PC on knowledge retention and skill transfer to real-world scenarios. This could involve conducting longitudinal studies to evaluate whether students who learn about PC hardware using the application retain knowledge better over time compared to those who use traditional methods. Additionally, it would be valuable to analyze how effectively students can apply the concepts learned to practical tasks, such as assembling PCs independently, after using Build_PC.

Furthermore, research could investigate how Build_PC can be optimized for students with disabilities, such as visual, auditory, or motor impairments. This could include designing accessible interfaces, integrating voice assistants, or making adjustments to ensure an inclusive experience. A comparative analysis could also be conducted between Build_PC and other emerging educational technologies such as virtual reality (VR), artificial intelligence (AI), and mobile learning platforms. This would help identify which technology is best suited for different educational contexts and learning objectives.

Additionally, the use of Build_PC could be extended, or similar applications could be developed to teach complex concepts in other fields, such as engineering, medicine, or architecture, evaluating their effectiveness in these contexts. Moreover, elements of gamification, such as rewards, levels, and challenges, should be integrated to analyze whether these features can enhance student motivation and engagement while using the application.

7- Declarations

7-1- Author Contributions

Conceptualization, S.C.-C., A.G.-A., and A.J-A.; methodology, S.C.-C. and A.G.-A.; software, S.C.-C.; validation, S.C.-C., S.L.-M., Y.M.A., and A.F.; investigation, S.C.-C. and A.G.-A.; resources, S.C.-C. and A.G.-A.; data curation, S.C.-C., A.G.-A., Y.M.A., and A.F.; writing—original draft preparation, S.C.-C. and A.G.-A.; writing—review and editing, S.C.-C., A.G.-A., and S.L.-M.; visualization, S.C.-C. and A.G.-A.; supervision, S.C.-C., A.G.-A., and S.L.-M.; project administration, S.C.-C. and A.G.-A.; funding acquisition, S.C.-C. All authors have read and agreed to the published version of the manuscript.

7-2- Data Availability Statement

Publicly available datasets were analyzed in this study. This data can be found here: *https://udlaec-my.sharepoint.com/:f:/g/personal/luis_criollo_udla_edu_ec/Ei8IzZ5-ad9Ep_d_NAH-uwABpWq5etkaeDNwimFVYwhy 2g ?e= rqDOBq/DataJournal*.

7-3- Funding

Universidad de Las Américas-Ecuador funded this research as part of internal project 507.A.XIV.24 and TIC.LCC.23.01.

7-4- Institutional Review Board Statement

Not applicable.

7-5- Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

7-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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