

Implementation of a Visual Augmented Reality Method in a Carpentry Course: A Case Study

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<https://doi.org/10.34190/ejel.22.3.3065>

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Abstract: In this study, an m-Learning environment that uses Augmented Reality (AR) as a central tool was successfully implemented to support the development of job skills in a basic carpentry course. The app, designed with visual reinforcements in the form of images, gifs and videos, allowed learners to interact with 3D models of the tool and materials inventory, using augmented reality glasses to enhance the learning experience. The results of the data analysis and discussion revealed several fundamental conclusions: firstly, the AR-assisted visual technique on mobile devices proved to be a highly effective complementary learning tool, highlighting its potential to significantly improve the educational process. Second, the AR tool showed greater effectiveness in low-performing learners, suggesting that this technology may be especially beneficial for those who face challenges in conventional learning. Furthermore, learners' positive attitudes toward the app supported the overall acceptance of the technology, and the positive activation between app evaluation and learning attitudes underscores the importance of the AR-enriched educational experience. This study not only presents conclusive results on the effectiveness of AR in skill training, but also highlights its potential to address specific challenges in indigenous communities, thus establishing a solid foundation for future applications and developments in the field of education and the training.

Keywords: Augmented reality, Job skills, Carpentry learning

1. Introduction

Considering the existence of indigenous communities that lack access to basic job training for the development of skills trade, the prevailing need arises to create a learning environment conducive to the development of skills and abilities in the basic carpentry trade. This approach is based on a detailed understanding of the tool inventory and its functions, as well as the materials inventory and its uses.

The challenge lies in the lack of modern teaching tools that can effectively address this gap in remote communities. It is in this context that augmented reality (AR) emerges as a viable solution. AR offers a unique interface for users by combining the real world with the virtual world. Unlike traditional virtual reality, AR allows fluid interaction with virtual objects that are integrated into the user's real environment, providing an authentic and natural experience in human-device interaction. The research question focuses on exploring how specific aspects of Wayuu culture, such as matrilineal family structure and social dynamics, could influence the way educational programs are designed and implemented, especially those that seek to improve skills and competencies in specialized trades. Then the research question is "How does the complex matrilineal family structure and the unique sociocultural dynamics of the Wayuu population impact the implementation and effectiveness of educational programs, especially in indigenous communities, with a focus on the development of skills and knowledge in trades specialized, like basic carpentry?"

The implementation of AR in this context is simplified by requiring only a mobile device with a camera. By considering previous work carried out in indigenous communities, such as those of Maigua (2012) and Martínez (2017), where AR with markers was used to teach specific trades, a solid conceptual foundation is established. Maigua (2012) explored the process of observing images in a "Magic Book" to teach the craft of a graphic editor, while Martínez (2017) used a camera and an AR application to teach photography. In both cases, the effectiveness of the application of the visual technique in these communities was evident.

The structuring of the carpentry course is based on a systematic methodology that encompasses various sessions, each designed with specific objectives to cultivate specialized skills trades among apprentices. The conception of the course is closely aligned with the implementation of the Augmented Reality (AR) application, seeking to maximize the effectiveness of the learning process. Below are the crucial elements of course planning and how they integrate harmoniously with the AR application:

Initial Session - Tool Recognition and Handling, its objective is to familiarize participants with basic carpentry tools and promote a comprehensive understanding of their proper use. AR Integration is the AR application that

becomes a pedagogical tool by presenting three-dimensional models of the tools, allowing learners to virtually explore each instrument and understand its functionality accurately. In the second session, the types of wood and materials are identified, the objective is to instruct students in the identification of various woods and materials essential for the exercise of carpentry, its integration with AR is the application and display of augmented images to illustrate types of wood and materials, providing a visual and contextual experience that facilitates the assimilation of information. A third session presents the techniques of cutting and assembling wooden pieces, its objective is to cultivate practical skills in cutting and joining wooden components, its integration with AR is the application of a virtual simulator, demonstrating cutting and assembly techniques through interactive 3D models, allowing learners to practice virtually before applying their skills trade in the physical environment. The fourth session has to do with the complex assembly of a wooden chair, its objective is to apply previous knowledge in the assembly of more complex structures, the Integration with AR is that the application guides participants through the assembly process using models 3D, offering real-time virtual feedback to optimize skill acquisition. And finally we find the fifth session, which is the comprehensive evaluation of competencies, its objective is to evaluate the assimilation of skills and knowledge throughout the course. The integration with AR is that the AR application is used for assessment, presenting virtual scenarios that challenge learners to apply their skills and respond to practical situations, providing a comprehensive assessment of their competencies.

The research is aimed at effectively implementing the visual AR technique as a learning tool in the carpentry course. The methodological strategy encompasses the definition of specific learning objectives, the efficient integration of AR to offer rich interactive experiences, the continuous collection of feedback to refine the educational experience, competency assessment using AR and practical projects, and data analysis to support conclusions and recommendations. This comprehensive methodology aims to provide students with robust and advanced training in carpentry, taking advantage of the capabilities of augmented reality to significantly enhance the acquisition of skills and knowledge in this specific field in a carpentry course intended for an indigenous community that needs improve your family income. The main objective is to evaluate the impact of this technique on the cognitive performance of learners, compare its effects between high- and low-achieving students, and analyze learners' attitudes towards the application. The transition towards the introduction of AR as an effective solution in this context highlights its potential to address the existing gap in carpentry training in underserved communities.

2. Literature Review

2.1 Evolution of Augmented Reality.

The concept of "Augmented Reality" was coined by researcher Caudell (1992), he used the concept to describe a system that would help workers assemble and install electrical wires in airplanes (Caudell & Mizell, 1992). Rosenberg & Feiner (1993) also developed an AR feature for aircraft maintenance, which improved operator performance by adding virtual information about the feature to be repaired. Furthermore, Loomis and colleagues (1993) made a GPS (Global Position System) AR-based system to aid the blind in assisted navigation by adding spatial audio information. Soon after, the first mobile AR system (MARS) capable of adding virtual information about tourist buildings was developed (Feiner et al., 1997).

In the following years, AR technologies have been developed mainly by research laboratories and higher education institutions around the world (Azuma 1997; Milgram & Kishino, 1994; Billinghurst, Kato, & Poupyrev, 2001). Washington University created the Magic Book, which superimposes 3D virtual images on actual books. Shelton & Hedley (2002) also used AR to teach higher education geography novices how to establish relationships between the Earth and the Sun. Kauffman (2003) from the University of Vienna, in addition, created a tool for geometry novices referred to as Construct 3D. In the same vein, Li (2010) from Universidad de Nuevo México used AR in an interactive narrative in a physical environment referred to as ARIS.

Over the past few years, technology has begun to slowly migrate from the research labs to the marketplace via applications ranging from marketing to entertainment, advanced visualization, maintenance, design, medicine, and publishing. Since then, several applications have been developed: Thomas et al. (2000) created ARQuake, a mobile AR video game; in 2008, Wikitude allowed compiling information about user surroundings through a mobile camera, the Internet, and GPS (Perry, 2008). In 2009, other AR applications, such as AR Toolkit and SiteLens, have been developed to add virtual information to the physical user's surroundings. In 2011, Total Immersion developed the D'Fusion and AR system for project design (Maurugeon, 2011).

In conclusion, AR offers the possibility to learn to visualize and act with phenomena that traditionally novices study theoretically, without the possibility to see and test in the real world (Chien, 2010). In recent years, applications have been developed that show the positive effects of this technology as a learning aid on greater content comprehension and memory retention, as well as on learning motivation and performance accuracy (Radu, 2014), academic success and motivation (Di Serio et al., 2013).

2.2 Augmented Reality – AR

During the last decades, Augmented Reality (AR) has broadly been defined and discussed. For example, Azuma (1997) mentions that AR is a variation of virtual environments (VE), or Virtual Reality, as it is more commonly referred to. VE technologies completely immerse the user in an artificial environment; while immersed, the user cannot see the real world around them. Kaufmann (2004) also argues that AR allows the user to see the real world, with virtual objects superimposed onto or composed of the real world. On the other hand, Goldiez (2001) describes AR as a field of technology in which the real world is superimposed with additional information from a computer-generated sensory display. For Perey (2011), the expression “Augmented Reality”, refers to the emerging technology that allows the real-time blending of processed digital information with information coming from the real world by means of appropriate interfaces.

Other definitions, such as Kesima & Ozarslan (2012) assert that AR is a new medium that combines aspects of ubiquitous computing, tangible computing, and social computing. It offers unique possibilities, combining physical and virtual worlds, with continuous and implicit user control from the point of view of interactivity. Martins & Santos da Rosa (2016) also define AR as the enhancement of an individual’s visual experience with the real world by integrating digital visual elements. It is characterized by a combination of the real and virtual worlds. Therefore, an augmented reality environment allows the user to view the real world with computer-generated virtual objects, in other words, real objects superimposed or merged.

Augmented Reality allows users to access information directly by superimposing digital information onto physical space by means of markers. Siltanen (2012) defines a marker as a sign or image that a computer system detects from a screen using image processing, pattern recognition, and computer vision techniques.

Feng & Kamat (2014) also refer to a marker as an image or corresponding descriptors with key features and points. Usually, an AR marker is easily recognized and tracked as it is a black and white image or a QR code. According to Thanabornvorwiwat & Patanukhom (2018), a marker is a special four-cornered pattern preferably with gray shades and symbols to estimate homographs. On the other hand, researchers such as Chen et al. (2016) state that a marker is based on geometric features considered for estimating a 3D object, which are often segments, well-marked straight lines, contours or points in cylindrical objects or a different combination of these features.

2.3 Overview of the Wayuu Community

The Wayuu population is made up of 278,212 indigenous individuals, as reported by DANE in 2015. Within this population, an overwhelming 97% speak the Wayuunaiki language. Wayuu society exhibits a distinctive and intricate matrilineal family structure, organized into 30 different clans, each of which has its own territory and totem animal.

Central to Wayuu society is the fundamental role of the “putchipu” or “palabrero”, who serves as a bearer of the word and mediator in resolving conflicts between clans. The highest family authority rests with the maternal uncle, who actively participates in all family and domestic affairs.

In nuclear family dynamics, children are guided by the maternal uncle, diverging from the conventional role of the biological father. Women assume leadership and organizational responsibilities within the clan, participating actively and independently in political affairs. The Wayuu community is dedicated to various activities, including livestock, fishing, agriculture and salt extraction carried out by men. At the same time, women dedicate an important part of their time to making backpacks, nets, hammocks and managing domestic tasks, as noted by the Ministry of Culture of the Republic of Colombia in 2010.

2.4 Augmented Reality in Indigenous Populations

This section mentions research on the implementation of Augmented Reality in indigenous populations. Two studies that highlight the use of markers for content generation in AR are Maigua (2012) and Martinez (2017).

In the study of Maigua (2012), AR was implemented to develop a magazine on the indigenous history of Ecuador. It was done through a “Magic Book”, which is an open book that contains markers to generate augmented reality

content with the use of a smartphone in the school for indigenous girls in Saquisilí. The teacher taught the process of observing the images obtained from the "Magic Book" to teach graphic editing skills. Finally novices manipulated the markers to observe the images in AR, to then modify, retouch, optimize and place them definitively in the "Magic Book". Similarly, in an indigenous community of Cauca (Colombia), a group of indigenous people was trained in photography, Martínez (2017) used a camera, a Smartphone, and an AR application, several photographs of local birds were taken and stored in the Smartphone's memory, then the impressions of the markers were taken for each bird and with the application (app) they were observed in AR. Finally, novices observed the 3D images and chose those with the best quality to publish them to observers around the world. In the study by Zapata et al., (2023), the preservation of the Quechua language as the mother tongue in a Peruvian Amazon indigenous group was taken into account, where kindergarten children reinforce words with the help of augmented reality. According to Camacho et al., (2019), this article evaluated the level of influence that the use of a mobile application with augmented reality had on indigenous primary school students for learning the Quechua language, a quasi-experimental design was used and the sample it was made up of sixty students divided into two classrooms of thirty students respectively. On the other hand, in the document by Cabanillas M., Canchaya A. & Gómez R., 2020, it shows the development of an AR application following the mobile d methodology, for the creation of 3D models referring to pre-Inca cultures and determines the influence it would have on learning. of primary level students.

González, et al. (2015) highlight the importance of this holistic approach to preserve the ancestral knowledge of carpentry, strengthen the cultural identity of indigenous communities, and promote sustainable development.

In conclusion, AR can be implemented in indigenous communities for the training of skilled trades with the use of markers and mobile devices. The proposal is consistent with studies conducted in the state-of-the-art that show the effectiveness of this software when implemented in said communities.

3. Research Methods

3.1 Research Topic

This study involved 12 indigenous men from the Wayuu indigenous community. The software impact experiment was conducted in a rural division called Torcoromaná, La Guajira (Colombia), lasted three months and was developed in three stages: (1) Reconnaissance, whose objective was to identify the Wayuu indigenous community through an indigenous leader, who contacted the Torcoromaná *ranchería*, where activities were carried out in a small school without electricity or internet; (2) Training, five in-person meetings were held between the indigenous people and the researchers that focused on the knowledge of the course developed in A; and (3) Job competency assessment, the indigenous people in the sixth session had the task of assembling a chair, they were recorded in order to identify the job competencies in the carpentry trade.

3.2 Research Justification and Preparation of Experiments

In this section, the study focuses mainly on the supplementary learning effect of AR-based learning tools on a carpentry course. The group of novices in the test class were taught the content of "Inventory of tools and materials; assembly and fitting of parts". The master carpenter was interviewed prior to the design and development of this AR tool, and he noted that in his previous experiences, he had taught formal novices and not indigenous people from the region. However, he expressed his desire to review the content using an AR tool to guide a teaching process with good outcomes in learning the content involving "Inventory of tools and materials; assembly and fitting of parts". To carry out this experiment, a leader of the Wayú ethnic group was contacted to invite a group of 10 indigenous individuals residing in the Mano de Dios ranch, who have no knowledge of the Spanish language or the carpentry trade. These participants, aged between 18 and 25, were previously instructed by a master carpenter using a specific guide. Their task was to assemble a chair made up of 10 pieces, without using the visual method of Augmented Reality. This group of individuals formed the control group in the study.

The most significant limitations to carry out this research and involve indigenous groups from various *rancherías* lie in their residence in a remote and hostile area, specifically in the northern part of Colombia, characterized by being completely desert and extremely difficult to access. The nomadic nature of these groups makes contact even more difficult, since they do not permanently settle in the same place. This results in a shortage of indigenous participants for the study. Additionally, the language barrier, called Wayuunaiki, presents an additional challenge in communicating with this ancient tribe. On some occasions, indigenous communities live in risk areas, which further complicates the possibility of visiting them for research.

In the first instance, the group of indigenous people from the Torcoromaná ranchería was subjected to the following corresponding sections as explained below:

The pre-test scores will represent the learning outcomes, the trainees will use a wooden chair assembly protocol and activity form, and the post-test scores will represent the learning outcomes after using an AR research-based learning tool. In this activity, using the inquiry method, responses of the novices in the test group had to be conclusions that they had to reach on their own when observing and exploring. In this case, the difference between pre-test and post-test scores will represent the learning effect. The questionnaire mainly assesses learning attitudes toward the AR learning tool.

To start the experiment, researchers pre-installed the AR software on each device. The experiment contains five sections, as shown in Table 1.

Table 1: Experiment design

Contents	Operability
Pre-test	Each student is required to complete an assignment and a questionnaire independently.
-Group training -Learning consultations using the activity form	- The class is randomly divided into four groups. - Each group is required to use the AR tool to learn as indicated on the activity form - Completing the form cooperatively without teacher guidance (AR toolkit contains AR-based software, bookmarks, and the activity form)
Post-test	Each student must independently complete the same test used in the pretest.
Survey	Each student is required to complete a questionnaire
Interview	Five learners are randomly chosen and interviewed about their feelings during the inquiry-based learning process.

3.3 Research Hypotheses

Performance Hypothesis:

Hypothesis 1: It is expected that the evaluation of the apprentices, when evaluated after using the Augmented Reality (AR) tool, will show a statistically significant improvement in their skills and knowledge in the carpentry trade.

Performance Difference Hypothesis:

Hypothesis 2: It is anticipated that influential corrections to the AR tool among learners, as well as differences in impact between high- and low-performing groups, will be evident and can be compared for the purpose of identifying specific patterns of improvement.

Motivation Hypothesis:

Hypothesis 3: The possibility is raised that the AR tool has a positive impact on the motivation of apprentices towards learning the carpentry trade. The aim is to explore whether the experience with the AR tool is meaningful and interesting for the apprentices, thus contributing to an increase in their motivation towards learning the trade.

3.3.1 Pre- and post-testing

The questionnaire was designed by a carpentry instructor from the National Learning Service (SENA), who also collaborated in the design of the contents of the e AR application and further assessed by three carpentry experts. The questionnaire includes 30 questions, associated with the learning content "Inventory of tools and materials; assembly and fitting of parts". Prior to the experiment, a pre-test was conducted with the whole class: "Tools and Materials Inventory Test". Subsequently, the researchers randomly divided the class into 4 groups. Then, each group used the AR tool proposed in this paper to complete an inquiry-based learning task. After learning with AR, a post-test was conducted using the same questionnaire: the "Tools and Materials Inventory

Test". The questionnaire assesses novices' understanding and memorization of several key knowledge points in this content. The questionnaire uses a fill-in-the-blank format ; the questions are general knowledge questions and are briefly summarized as follows: Which are the cutting tools? On what material is it used? What is the maintenance process of a cutting tool? How many striking tools do you know about? Which is most commonly used? How are the tools distributed on the workbench? What does the maintenance process of a striking tool consist of? Questions about materials include what type of material do you use in making a chair? How many types of material do you know about? Which one has the highest hardness?

3.3.2 Manner of instruction and activity

Based on inquiry, three groups were created without teacher instructions under a group learning scenario where the novices had to perform explorations with the use of the AR tool and conclude on their own events inherent to knowledge. The form of this activity was designed by the researchers in accordance with the application and does not limit the novices' operations with the markers; moreover, it was designed to aid the learning process in the operational steps and encourage them to ask introductory questions, think, and draw conclusions. Considering that this is the first time novices gain knowledge about AR technology and are placed under a self-exploration scenario without teacher guidance, then, the activity form aims to show them how to use the markers to interact with the device and observe correctly. Novices are also encouraged to operate markers freely and intuitively to see what they may discover.

3.3.3 Post-questionnaire

According to previous studies where questionnaires were conducted using the constructs of learning attitude, software satisfaction, cognitive validity, and cognitive accessibility, a questionnaire was developed using a 6-point Likert scale: where 1 represents "strongly disagree" and 6 represents "strongly agree". In the paper by Hwang & Chang (2011), a review of items of the construct "learning attitude" was conducted where ten items were considered. Based on the research by Chu, Hwang & Tsai (2010), 11 items were adopted for the construct "satisfaction with the software", similarly for the construct "cognitive validity", six items were chosen and for the construct "cognitive accessibility", three items were taken from the work of Chu et al. (2010). In this activity, 12 copies of the questionnaire were distributed and 12 were received, all considered valid. For the reliability of the complete questionnaire and each construct a reliability analysis was performed, according to Cronbach's Alpha coefficient the questionnaire is (0.815), see Table 2. Each construct is considered to have a high internal consistency and reliability, according to Cronbach's Alpha coefficient, which for each construct should be higher than 0.70.

3.3.4 Interview protocol

The purpose of the interview is to further explore novices' learning experiences through the AR tool. The following questions were asked during the interview

- Do you think this AR tool facilitates your carpentry learning?
- Why do you think this tool is useful? In what areas does the tool help you?
- Do you want to use AR software to learn carpentry in the future? Why?
- For which content do you think AR tools are better?
- Do you think the AR software has any disadvantages? Which ones?
- Can you offer any tips to improve this AR learning tool?

Table 2: Cronbach's Alpha Coefficient

Variable	Number of items	Cronbach's alpha
Learning attitude	10	0,722
Satisfaction	11	0,863
Cognitive validity	6	0,865
Cognitive accessibility	3	0,811
In general	30	0.815

3.4 Introduction to the AR Toolkit

The AR toolkit developed during this study contains AR software, 20 markers, an assembly protocol, and an activity form. The software contains an application specific to tool and material inventory reconnaissance, (5) tool maintenance animation gifs, and (2) short videos on the assembly of wooden parts. The interaction tool used with this software is the marker. One set contains twelve printed markers from the tool inventory and another set of markers contains eight printed markers from the material inventory, each marker has printed on one of its sides the tool to be viewed that can be selectively applied. Once the software is installed on the devices, the novices can use different markers to view the 3D image on the device screen and perform inquiry-based learning as indicated in the activity form and generalize further concepts and conclusions.

3.4.1 Instructional design of the experiment

In contrast to previous AR studies, a learner-centered scenario was adopted, in which learners are divided into groups and learn in an AR environment on their own. They use markers to represent the inventory of tools and materials and intuitively appropriate knowledge from a simulation of natural movements. Novices are expected to explore and reach conclusions through group effort without benefiting from direct teacher instructions. In this case, the activity form shows the operational steps and poses questions corresponding to the required knowledge points, which encourage them to think and research. The following is a description of how activity 1, the "Tool Recognition" case, is developed. In this case, the first group of markers represents twelve different tools related to the carpentry trade. Activity 1 takes 10 to 15 minutes to complete, as does the second set of markers representing the eight materials to be used in the procedure. The activity form instructs the operating procedure for this activity and poses questions about what the novices observed in each 3D image. With the 3D models shown from different markers, novices are expected to master the reconnaissance of tools and their functions and the types of materials and their uses. With this hands-on activity, novices are expected to memorize, learn, and know the tools and type of wood to be used. We also positively predict that novices can better memorize the process with the 3D object viewing operation.

3.4.2 Design and development of the AR environment

In this research, an M-learning environment was designed on a mobile platform with an AR visual technique and with devices such as Smartphone and tablets, the application was made in a free software called Scope (version 0.5). The essence of the human-device interaction with this application is to detect and record the position of each marker in the camera view, since the application will activate different animations when the marker is in different positions. In other words, the interaction between users and devices is based on position.

Activity one was developed in two sessions. In the first session, novices were trained in the use of the AR-based application (Figure 1).

The developed environment contains two learning activities described below:

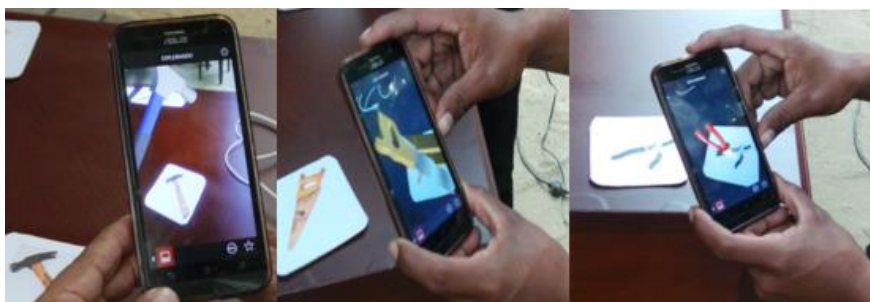


Figure 1: Novices using markers

The purpose of the second session was to introduce novices to basic carpentry tools, according to the activity form, such as: hammer, saw, screwdriver, wrench, tape measure, ruler, clamp, pencil, chisel, planer, file, and brace. During this session. Novices manipulated the markers to be able to see the AR effect on the mobile device, they thus got to know the tools virtually (Marcincina et al., 2013). (Figure 2).

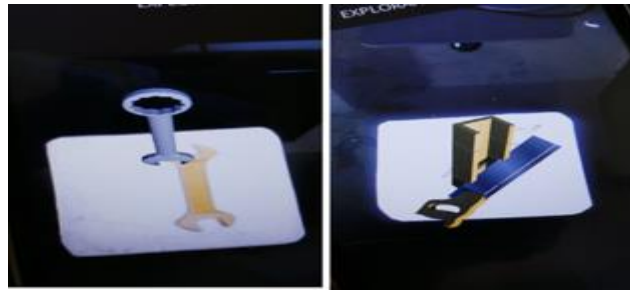


Figure 2: Viewing tools in AR

During this session, and according to the activity form, novices recognized the types of wood in the region suitable for carpentry work according to their physical properties such as density, hardness, and flexibility. Similarly, subsequently the AR application developed in Scope was opened, on the “Types of Woods” menu, and the types of trees were recognized using markers and it was possible to observe pine, snail, cedar, and oak in AR. In this session each novice had the possibility of manipulating the mobile device and observe the effect of AR on learning about the shape of the tree and the view of the wood after cutting (Figure 3).

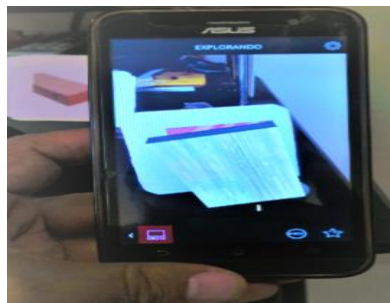


Figure 3: Wood cutting

With the help of the form in activity two, novices were shown video content on tool reconnaissance (Figure 4A), regarding uses and maintenance (Figure 4B), and also topics of measurement and wood cutting were also shown with an explanation of the techniques of cross-cutting and longitudinal cutting, and finally, the total assembly was shown including the verification of the joining of parts, polishing, and finishing.

In the development of the course, theoretical lessons on the application of augmented reality (AR) were cohesively integrated with physical carpentry practices. Each theoretical session on the recognition and handling of tools, identification of types of wood and materials, cutting and assembly techniques, complex assembly of a wooden chair, and the comprehensive evaluation of competencies, was complemented with practical applications in the physical environment. The participants, after acquiring theoretical knowledge through AR, had the opportunity to apply these teachings practically in the actual construction and assembly of carpentry structures. This integrated approach not only strengthened the theoretical foundations, but also allowed apprentices to consolidate their skills through practical experience, thus creating a meaningful connection between the application of technology and the physical execution of carpentry tasks.



Figure 4: Reconnaissance of tools (A) and use of tools (B)

3.5 Methods of Data Analysis

In this experiment, both the quantitative method was used to explore the change in novices scores and the qualitative method was used to delve into novices' feelings and experiences throughout the process.

3.5.1 Quantitative research methods

To analyze the data obtained from the test and the questionnaire, a paired t-test was performed on the pre- and post-test scores and an independent t-test on the scores of high- and low-performing novices to determine the differences between them. Descriptive statistics were calculated for each questionnaire item and each construct as a whole, including mean score, standard deviation, and maximum and minimum values. In addition, a Pearson correlation coefficient was calculated between learning attitude and the other three constructs.

3.5.2 Qualitative research methods

A 40-minute video was made and photographs were taken during the class. In addition, researchers obtained exceptional performance records from novices. After the class, five novices were interviewed, and the interviews were recorded. The video, images, and notes acquired from the case study were analyzed. Several scenes from the experiment are shown in Figure 5.



Figure 5: Scenes from the experiment

4. Data Analysis and Conclusions

The research used various tools to evaluate the impact of the Augmented Reality (AR) tool on indigenous participants. Initially, a test for paired samples was administered, aimed at evaluating the prior knowledge of the indigenous people before the intervention with the AR tool. The significant improvement in post-intervention scores suggests that the AR tool positively contributed to the cognitive performance of the participants. In addition, an independent test was carried out, classifying the participants into high and low performance groups. The significant differences between these groups indicate that the AR tool had a particularly positive impact on those with lower initial performance.

To understand the variability in indigenous responses, descriptive statistics are applied to the questionnaire responses, evaluating each item and construct. This methodology allowed us to identify specific patterns and areas of interest. Furthermore, Pearson's rating coefficient was calculated to measure the relationship between learning attitude and other constructs, providing insights into how indigenous people's disposition towards learning relates to their perception of the AR tool. In addition, observations and interviews were carried out to obtain qualitative information on indigenous people's attitudes and evaluations towards educational technology, offering a deeper understanding of their individual experiences. Together, these tools will provide a comprehensive assessment of the impact of the AR tool on Indigenous participants.

4.1 Overall Cognitive Performance

The experiment produced 12 * 2 test copies (12 for the pretest and 12 for the posttest), all of which were considered effective. A paired samples t-test was performed for the pre-test and post-test score variables. The variable tested is a posttest score minus the pretest score, which represents the difference obtained after using the AR tool for each student. The results are shown in Table 3.

Table 3: Paired samples t-test for pre- and post-test scores

	aver.	Dev. deviation	Dev. Deviation error	95% confidence interval of the difference		t	gl	Sig. (bilateral)
				Lower	Superior			
Par1 Begin. P. Afer	-.80000	,31909	,09211	-1,00274	-,59726	-8,685	11	,000

Table 3 shows that the p-value (two-tailed) of the mean is close to zero ($t = -8.685$), $p\text{-value} = 0.000$). When the significance level is 0.05, we should reject the null hypothesis, which suggests that novices' scores after using the AR research-based learning tool are significantly higher than those obtained before the learning activity.

4.2 Comparison of Learning Gains of High- and low-performing Novices

Ordering the pre-test scores of novices from highest to lowest, the first 33% are categorized as high-performing novices and the last 33% as low-performing novices. The average learning gains of both groups are calculated, as shown in Table 4. Then, an independent t-test is performed with the difference between learning gains of high-performing novices and learning gains of low-performing novices, as shown in Table 5.

Table 4: Mean scores for low- and high-performing groups.

Group	Pre-test average	Post-test average	Gain average
High-achieving	26	27.5	1.5
Low-achieving	11.3	17.5	6.2

For Levene's test for equality of variances shown above in Table 3, $F = 3.516$ $p = 0.090 > 0.05$, which suggests that we cannot reject the null hypothesis and must accept that the variance difference is not significant at the 0.05 significance level; we should refer to the "Equal variances assumed" row. In the top row, $t = 3.541$ and $p = 0.005 < 0.05$, suggesting that the difference in mean and learning gains between the low-performing group and the high-performing group are significant at the 0.05 level.

Table 5: Independent sample test

	Levene's test of equality of variances		t	gl	Sig. (bilateral)	T-test for equality of measures		95% confidence interval of the difference	
	F	Sig.				Measurement differences	Standard deviation differen	Lower	Superior
P. after: Equal variances are assumed	3,512	,090	3,541	10	,005	4,88889	1,38064	1,81263	7,96515
Equal variances are not assumed			5,854	9,897	,000	4,88889	,83518	3,02537	6,75241

4.3 Attitudes Toward the AR Tool with a Questionnaire Analysis

In the questionnaire analysis, we calculated the score for each construct by averaging all the corresponding items within each construct. The descriptive statistics obtained are shown in Table 6.

Table 6: Descriptive statistics for the four constructs of the questionnaire

	N	Min.	Max.	Average	Std. Deviation
Attitude	12	3,25	5,59	4,2150	,62769
Satisfaction	12	3,90	5,27	4,4733	,34254
Validity	12	3,21	5,78	4,3692	,93181
Accessibilitv	12	3,06	5,78	4,1925	,87922
	12				

In the above table, it is possible to observe that the construct “Cognitive Validity” has the highest mean value, suggesting that the assessed novices generally have positive learning attitudes. In contrast, the construct “Satisfaction” has the lowest mean value, suggesting that the usability of this AR-based learning tool is not as satisfactory as that of the other three constructs and needs to be further improved. Descriptive statistics of each item in the four constructs shown, respectively, in the tables below. The descriptive statistics for the items related to the construct “Learning Attitude” are shown in Table 7.

Table 7: Descriptive statistics for the construct “Learning attitude”

	N	Min.	Max.	Average	Std. Deviation
I find learning about "tool and function recognition" rewarding	12	3,23	5,56	3,6933	,68250
I find learning basic woodworking rewarding.	12	3,23	4,78	3,9725	,53350
I believe that learning and observation related to the contents of basic carpentry, in addition to books, are significant.	12	3,05	5,56	3,9225	
I think that learning and observing things related to carpentry is interesting	12	3,23	4,78	3,8042	,58232
I will actively look for information related to basic woodworking in books or guides.	12	3,23	4,56	3,7142	,53670
When I run into problems learning basic carpentry, I consult teachers, classmates, books, or guides for solutions.	12	3,23	5,56	3,8158	,86888
I believe that learning carpentry is important to the community.	12	3,23	4,56	3,6600	,56350
I think that doing the activities using AR is novel	12	3,23	4,56	3,6750	,51410
It is good to use new technology tools	12	3,23	4,56	3,7425	,51864
I find that learning carpentry with devices is interesting	12	3,05	5,56	4,0775	,76692
Valid N (per list)	12				

The statement “I find learning carpentry with devices interesting” has the highest value (Mean = 4.07), which has a close to full score of 6, suggesting that most novices consider learning carpentry with the help of devices important. Whereas the item “I think learning woodworking is important to the community” has the lowest score (Mean = 3.66), which means that although they find learning woodworking important, most novices only learn woodworking in class or in the workshop and do not actively seek to share the information. Table 8 shows the descriptive statistics for the items related to the construct “Satisfaction”.

Table 8: Descriptive statistics for the construct "Satisfaction"

	N	Min.	Max.	Average	Std. Desviation
AR-based learning app is more interesting than previously used learning methods	12	3,23	5,56	3,6933	,68250
This learning tool can help me discover new questions.	12	3,23	4,78	3,9725	,53350
Using the AR-based app allows me to see woodworking concepts like knowing tools in their basics in a different way.	12	3,00	5,56	3,9142	,93540
I like to learn basic carpentry using AR	12	3,23	4,25	3,5542	,38907
The design of this app is nice and genuine.	12	3,23	4,25	3,6308	,46647
I hope other skilled trades apply AR tools to learning as well.	12	3,23	5,89	3,8708	,91704
I hope to use similar AR tools to learn another skilled trade in the future if possible.	12	3,23	4,56	3,6600	,56350
I will recommend the AR learning tool to other classmates	12	3,23	5,96	3,7917	,80803
I'm interested in using AR-based learning tools.	12	3,23	4,56	3,8258	,50905
The content of this application is closely related to "the assembly of parts", which is an interesting topic for me.	12	3,05	5,87	3,9750	,91459
The AR-based learning tool allows me to learn not only on my own, but also with my friends and classmates.	12	3,23	5,56	3,4883	,66386
Valid N (per list)	12				

In this table, the item, "The content of this application is closely related to the assembly of parts, which is an interesting topic for me," has the highest score, 3.97, which suggests that novices enjoy the AR learning tool and that it poses new questions to solve. Although the statement "I enjoy learning basic carpentry using AR" has the lowest value, 3.55, suggesting that novices may find the AR tool interesting, there are still issues that discourage them from recommending the software to other classmates.

Descriptive statistics for the items related to the construct "Cognitive Validity" are shown in Table 9.

Table 9: Descriptive statistics for the construct "Cognitive validity"

	N	Min.	Max.	Average	Std. Desviation
Operating the AR application is not difficult	12	3,23	5,56	3,6933	,68250
Learning to use this AR tool doesn't cost me a lot of time and energy	12	3,23	4,78	3,9725	,53350
The content and procedures of this learning activity are clear and understandable to me.	12	3,00	5,56	3,9142	,93540
Valid N (per list)	12				

In this table, the item "Learning to use this AR tool does not imply much time or effort" has the highest score, 3.97, whereas the item "Operating the AR application is not difficult", has the lowest score, 3.69. These results suggest that, although novices think they can master how to operate the application very quickly, they still lack practice in the procedures. Therefore, to improve the efficiency of the AR tool, we need to improve the cognitive load that the application imposes on novices. Table 10 shows the descriptive statistics for the items related to the construct "Cognitive Accessibility".

Table 10: Descriptive statistics for the construct "Cognitive Accessibility"

	N	Min.	Max.	Average	Std. Desviation
I think the AR demo makes the learning tools and materials more detailed and understandable	12	3,23	5,56	3,6933	,68250
I think using this AR learning tool is very helpful in learning basic woodworking	12	3,23	4,78	3,9725	,53350
This AR learning tool is more effective than any other.	12	3,00	5,56	3,9142	,93540
Using this AR application allows me to master important knowledge	12	3,23	4,25	3,6308	,46647
The AR learning tool provides me with ample space to learn basic woodworking.	12	3,23	5,89	3,8708	,91704
I think that learning carpentry is beneficial for everyone	12	3,23	4,79	3,9759	,533371
Valid N (per list)	12				

In this table, the mean scores of the six items are very close to each other, suggesting that most students judge the AR tool to be useful for their learning.

The foregoing tables show that novices generally have a positive learning attitude and provide positive feedback about the software.

To be consistent with expectations, an analysis of the correlation of novices attitudes and their assessment with the AR tool was performed. Table 11 shows that the Pearson correlation coefficient between "Learning attitude" and "Satisfaction" is 0.498, $p = 0.001 < 0.05$. Pearson's correlation coefficient between "Learning attitude" and "Cognitive validity" is 0.427, $p = 0.004 < 0.05$. Pearson's correlation coefficient between "Learning attitude" and "Cognitive accessibility" is 0.668, $p = 0.003 < 0.05$. These coefficients suggest that learning attitude has a significant positive correlation with novices' satisfaction with the AR tool and equally with the assessment of cognitive validity and accessibility of the AR tool. In other words, the more important a novice thinks it is to learn carpentry, the more useful and satisfying he will believe that the AR tool is, consistent with our expectations.

Table 11: Pearson's correlation coefficient

		Learning attitude	Satisfaction	Cognitive validity	Connectivity Accessibility
Learning attitude	Pearson's correlation	--			
	N	12			
Satisfaction	Pearson's correlation	.498			
	Sig (bilateral)	.0001			
	N	12	--		
Cognitive validity	Pearson's correlation	.427	.076		
	Sig (bilateral)	.0004	.027		
	N	12	12	--	
Connectivity Accessibility	Pearson's correlation	.668	.477	.376	
	Sig (bilateral)	.0003	.044	.032	
	N	12	12	12	--

4.4 Observations and Interviews

During the experiment, researchers were constantly observing, taking notes, and recording novice performance, who were excited, impressed, and motivated about the learning activities considering inquiry. We found that most novices failed to use the protocol and activity form, they preferred interacting with the AR application. According to this observation, the ease of use of the application was reflected upon and we decided to remove the detailed instructions in the future and instead attempt to incorporate video or audio instructions using a Tablet, mobile telephone or a PC, to improve the capability of the AR tool.

At the end of the experiment, five novices, (A1-A5) were randomly chosen to be assessed through a personal interview. Six questions were asked during the interview where the answers had to refer to their own feelings about the learning process using the AR tool. The questions and some of the answers are discussed below:

Questions 1, 2, 3: Do you think this AR tool facilitates your learning of the carpentry trade? Why do you think this tool is useful? What knowledge does the tool help you with?

The AR tool can help me memorize the inventory of tools and materials, learning the technical process in carpentry is not difficult, and sometimes we are not able to imagine how to assemble the parts of a chair or table with only the teacher's instructions. The application is more interesting, which allows us to record and remember more in-depth in our mind. (A1) I found that learning in real space can be really exciting than doing it on our own plans, the images look real as if we are seeing them in reality.

(A2) The AR application makes the contents of the inventory of tools and learning materials look better and more understandable, I could observe the tool features better by moving the marker (A5). When asking the 5 novices if they would like to use the AR tool for future studies, all of them said "yes". A3 said that the AR tool is much more interesting than traditional learning materials and would like to use it in the future.

Question 4: How does this AR software compare with other learning tools you have used? In what areas do you think AR is better than those tools?

The AR tool could help us develop skills in tool inventory management, in the maintenance part. To especially remember the knowledge of technical procedures specific to the trade. (A1)

Question 5 and 6: Do you think the AR software has any disadvantages? What are they? Can you offer any advice on how to improve this AR learning tool?

The model can be unstable and when the marker is being operated sometimes the image takes too long to display on screen or is displayed too fast. (A4)

I suggest that in the application the animations should be more fascinating. (A2)

All the interviewed novices expressed their willingness to use the AR tool again in future learnings; furthermore, they exhibited a positive attitude toward the AR tool.

Additionally, novices mentioned some advantages of the AR tool such as interesting, clear, and understandable material, spatial rather than flat experience, helps to visualize 3D objects well. Some novices commented that it is easier to remember knowledge and procedures using the AR tool, which makes it easier for them to do their procedural experiments that are otherwise difficult to perform. Other novices referred to some disadvantages, most novices mentioning that the model can be unstable at times. One novice stated that the simulation should be more realistic, another suggested introducing more inviting animated elements. These suggestions provided by the novices are valuable and invaluable data so that the product can be reviewed and completed.

5. Discussions and Conclusions

The present study on the implementation of Augmented Reality (AR) in carpentry training for indigenous communities, specifically the Wayúu ethnic group, contributes significantly to the field of learning and educational technology. Compared to previous research that has explored the application of AR in educational settings, this study stands out for its specific focus on indigenous communities, addressing particular access and cultural challenges.

Unlike broader research that has examined the use of educational technologies in diverse contexts, this study dives into a specific and culturally unique environment, offering valuable insights into how AR can adapt and benefit communities with particular characteristics. The research contributes to knowledge by highlighting the effectiveness of AR not only as a learning tool, but as a means to address inequalities in job training, especially in remote and marginalized communities.

This study also stands out by proposing and examining specific strategies for integrating AR into a practical course such as carpentry. This contribution may be of interest to researchers and professionals in the field of educational technology, especially those interested in the design of specific educational interventions for communities with particular needs. Taken together, this study stands as a step forward in understanding how technology, in this case AR, can be applied effectively and culturally sensitive in job training settings for Indigenous communities.

5.1 Preliminary Conclusions and Discussions

After a comprehensive data analysis, which included evaluation of the learning effect and attitudes of the trainees, as well as observations and interviews, several significant conclusions were reached. The study

conclusively confirms that the Augmented Reality (AR) tool has a notable supplementary learning impact compared to the use of traditional protocols or guide texts. The pretest scores reflect the limitation inherent in using conventional methods, where, despite learning in class, memory decline was inevitably experienced within a week, resulting in low scores on the pretest. This finding highlights the effectiveness of the AR tool in improving long-term learning retention compared to more traditional teaching methods.

The use of the AR tool in low-performing novices produces more significant learning gains than for high-performing novices because (1) The original scores of high-performing novices are very high, some even approaching the maximum score. (2) The test was relatively basic and was already mastered by high-performing novices at the starting point. (3) The AR tool aims to assist novices in exploring and generalizing concepts, by means of more in-depth analysis of the test, we found that novices' attitudes toward the test are inconsistent.

The AR tool provides a new cognitive method and is expected to have a long-term memory effect on novices through their research-based observation and operation.

Several groups made noticeable errors in following the activity form due to carelessness, novices had to explore on their own, without teacher guidance, so incorrect procedures and lack of feedback could explain these errors. On the other hand, it was possible to note that during the experiment, most novices did not like to refer to the operation in the procedures provided in the paper activity form; when the images are shown, novices focus on the device screen and ignore the activity form. From the perspective of the usability of the AR tool, it may not be appropriate to provide long and detailed instructions for novices.

In summary, this study has conclusively demonstrated that the implementation of Augmented Reality (AR) as a learning tool in a carpentry course in indigenous communities, specifically in the Wayuu population, is highly effective. Through an m-Learning approach and the application of the visual AR technique, learners experienced significant complementary learning, especially those with lower initial performance. Positive attitudes toward the app further supported its usefulness, and the positive acceleration between app evaluation and learning attitudes reinforces the overall acceptance of this methodology.

The contribution of this study to the field of AR-based education and learning is significant, highlighting the effectiveness of AR in improving long-term learning retention and adaptability to address specific challenges in remote and indigenous communities. These findings suggest that integrating AR into similar educational contexts can offer innovative and effective solutions to improve training and skill development in diverse settings.

5.2 Conclusions

This research addresses the implementation of augmented reality (AR) as a pedagogical tool in a carpentry course aimed at indigenous communities, specifically the Wayúu ethnic group. Through careful planning, a structured program was designed that integrates AR into different sessions, addressing key aspects of the craft.

The Wayúu population presents distinctive sociocultural characteristics, such as its complex matrilineal family structure and the importance of roles such as the "putchipu" in conflict resolution. These peculiarities were considered when adapting the course to the specific needs and contexts of this community.

The experiment carried out with a group of Wayúu indigenous people demonstrated their willingness to participate, even overcoming the language barrier. A control group that did not use AR was developed, allowing an effective comparison. However, the geographical and linguistic limitations present in indigenous communities made it difficult to recruit participants, affecting the representativeness of the sample.

The proposed hypotheses suggest significant statistical improvements in the evaluation of trainees after using the AR tool, as well as the need to observe and compare the influence of this tool between high- and low-performing trainees. The research also sought to explore the impact of AR on apprentices' motivation towards carpentry.

Despite the logistical and cultural challenges inherent in research with indigenous communities, the results are expected to provide valuable information on the effectiveness and adaptability of AR in specific educational contexts. Furthermore, the importance of addressing these challenges in an ethical and respectful manner is highlighted, recognizing the cultural and geographical particularities of the indigenous communities involved.

The application of augmented reality (AR) in Wayúu indigenous communities incorporates key technological elements to enrich the educational experience. Some of these elements are described below: Mobile Application with AR Functionality: The main tool is a mobile application that uses the device's camera to overlay virtual

elements on the real world. This application is designed in an accessible and easy-to-use manner, considering the participants' possible lack of familiarity with the technology. In addition, Interactive Three-Dimensional Models were used: AR allows the presentation of three-dimensional models of tools, types of wood, materials and carpentry processes. These interactive models allow learners to virtually explore each element, improving understanding of its functionality and application.

Likewise, virtual simulators in specific sessions are used to show cutting, assembly and other practical aspects of carpentry techniques. These simulators offer trainees the opportunity to practice virtually before applying their skills in the physical environment. Regarding the Integration of Augmented Images, for the identification of types of wood and materials, the integration of augmented images is used. This involves displaying virtual images that illustrate different materials, providing a visual and contextual experience that facilitates the assimilation of information.

On the other hand, Real-Time Virtual Feedback during practical sessions, such as assembling a wooden chair, the application guides participants through 3D models, offering real-time virtual feedback. This optimizes skill acquisition and allows for immediate adjustments.

Regarding Assessment through Virtual Scenarios, the AR application is employed for assessment, presenting virtual scenarios that challenged learners to apply their skills and respond to practical situations. This provided a comprehensive assessment of their competencies.

These technological elements are carefully integrated into the carpentry course design, leveraging the capabilities of AR to improve teaching and learning in indigenous Wayúu communities. Cultural and linguistic adaptation of technology is essential to ensure its effectiveness and acceptance within these particular contexts.

This study on the implementation of Augmented Reality (AR) in carpentry training for the Wayúu indigenous community has yielded significant conclusions that highlight the transformative potential of the technology in specific and culturally diverse educational contexts. The quantitative results reveal a positive and significant impact of the AR tool on the cognitive performance of the participants, pointing out its effectiveness as an educational resource in learning carpentry. Importantly, this improvement will not only be observed in general, but was particularly significant among low-performing learners, evidencing the ability of AR to close learning gaps.

Furthermore, the positive attitudes of the participants towards the AR tool, especially in terms of cognitive validity, highlight the acceptance and favorable perception of this technology in the context of carpentry training. However, the relatively low score on the satisfaction construct suggests areas for improvement in usability and user experience, pointing out the importance of considering cultural and contextual factors in the design of technology-based educational tools. These conclusions offer significant contributions to the field of education and technology, highlighting the need for personalized and culturally adapted approaches to maximize the effectiveness of educational interventions in specific communities, such as the Wayúu.

Its findings highlight not only the effectiveness of Augmented Reality (AR) as an educational tool in learning carpentry for the Wayúu indigenous community, but also the importance of considering elements of acceptance, satisfaction and motivation. The positive attitude of the participants towards the AR tool, especially in the area of cognitive validity, indicates that the technology was perceived as authentic and relevant to their learning, which contributed to their intrinsic motivation to participate in the educational process.

It is crucial to note that these results were obtained after comparison with a control group of 10 indigenous people who participated in the same carpentry learning process, but without the intervention of Augmented Reality technology. It was observed that the group using the AR tool experienced significant improvements in cognitive performance compared to the control group. This evidence supports the claim that the implementation of AR in training environments can have a positive and differential impact on skill acquisition, especially in contexts where conventional training might have limitations.

In terms of satisfaction, although areas for improvement are identified, the comparison between both groups highlights the positive contribution of AR to the educational process. The intrinsic motivation of the participants, evidenced by the positive attitude towards the AR tool, suggests that technology can play a crucial role not only in the acquisition of technical skills, but also in active participation and commitment to learning. These results, supported by the comparison with the control group, emphasize the relevance and transformative potential of Augmented Reality in specific and culturally diverse educational environments.

5.3 Possible Improvements and Future Research

Within the perspectives of this research the following aspects could be included:

Firstly, the Impact on the Formation of the Indigenous Community, the research seeks to implement augmented reality (AR) as an effective tool in the carpentry course aimed at an indigenous community. Perspectives would include evaluating how this visual technique can significantly improve woodworking training, especially in underserved communities that lack access to modern teaching tools. Another aspect would be the Evaluation of Cognitive Performance, the objective of which is to evaluate the impact of the AR technique on the cognitive performance of the learners. The implementation of this tool is expected to provide an improvement in the assimilation of skills and knowledge, and prospects could be aimed at observing an increase in trainees' evaluations on the questionnaire after using the AR tool.

On the other hand is the Comparison between High and Low Performing Students, this perspective is important because it compares the effects of the AR tool between high and low performing students. This could reveal how the technology may be more beneficial for certain groups of students and provide valuable information about the adaptability of the tool to different skill levels. Motivation and Attitudes towards Application is another perspective of the research and is also aimed at exploring whether the AR tool has an effect on students' learning motivation towards the carpentry trade. Perspectives here could include analyzing whether participants find the experience meaningful and interesting, which could have implications for the design of future educational programs.

Similarly, there is Overcoming Logistical and Cultural Challenges, which, taking into account that the indigenous community lives in inhospitable areas and presents logistical and cultural challenges, perspectives could focus on how to overcome these limitations to carry out the research in an efficient manner effective and respectful of culture and mobility of the community.

Finally, the research perspectives range from the concrete impact on training to more subjective aspects related to the motivation and attitudes of learners, thus providing a comprehensive view of the potential of augmented reality in specific educational environments.

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