Augmented Reality for the Development of Skilled Trades in Indigenous Communities: A Case Study

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Abstract: The main objective of this study was the design and validation of a mobile learning environment (ML) based on Augmented Reality (AR) visualization with the purpose of developing skilled trades in the field of carpentry in indigenous populations. A pedagogical model focused on lifelong learning was used, in order to promote the acquisition of skilled trades and knowledge in carpentry. The implementation of the ML environment was carried out in the Wayuu community, characterized by its high rate of poverty and limited access to education. During face-to-face meetings, three indigenous people participated in a learning process in which they were instructed on the use of trade tools and became familiar with the different types of trees and wood. To support this process, the AR was used together with the M-L environment. Subsequently, the participants built a chair applying the knowledge acquired during the learning process. During this stage, recordings of the indigenous people were made while they carried out the construction. Then, the performance of the apprentices was evaluated through a competency-based evaluation system, in which three experts analyzed the recordings. Finally, the three indigenous people were able to acquire skills in real time through their mobile device, following the instructions and observing 3D images and videos that showed the entire manufacturing process of a wooden chair, from sanding the material to final assembly and polishing. In addition, it was found that these indigenous people were able to successfully market the products they made in the carpentry workshop, thus improving their family income. The fundamental idea behind the pedagogical implementation of this model in the Wayuu indigenous community of northern Colombia is to provide them with training in various trades that allow them to obtain decent jobs and support their families. That is why the ML environment is ideal for vulnerable people, not only indigenous people, but also for those who are displaced, the elderly or deaf-mute. The visual approach used in this method dispenses with the need for voice and text making it accessible to everyone.

Keywords: M-Learning, Augmented reality, Job competencies, Indigenous populations

1. Introduction

Historically, the Wayuu population has inhabited the northern region of Colombia (Department of Guajira), it has been characterized by a high poverty rate and state abandonment in areas such as education and healthcare. Additionally, the difficulty in accessing its indigenous settlements, the lack of electricity and internet, the persistent malnutrition issues, and the scarcity of drinking water do not allow for social, economic, and educational development. Recent reports have concluded that more than 50% of Wayuu Indians' school-age population does not attend school, which evidences shortcomings in coverage (Hoyos, 2016).

According to Calcagno (2005), illiteracy rates among indigenous populations are concerning in Latin America, which reveals the need to generate urgent actions from governments and within communities, effective, productive, and life-long learning models that lead to poverty reduction, build and appropriate learning cultures that generate peoples with useful ancestral, epistemological, practical, ethical-coexistent, and autonomous knowledge for integral development and sustained progress.

In this order of ideas, it is of vital importance to reflect on, propose and implement pedagogical models for indigenous populations that convert them into learning cultures, places and customs where they develop technical skilled trades that improve their quality of life. Considering the foregoing, it is necessary to think of a proposal that generates cultures of learning throughout life, with autonomy, change and progress from knowledge, that overcomes dependence and solves problems from humanist and complex knowledge. In this sense, AR could be an option to facilitate the development of job competencies in indigenous populations.

Considering the above, the following research question is presented, with the objective of designing and validating an ML environment. How does mobile learning influence the development of carpentry skills in indigenous populations through a pedagogical model of learning to learn knowledge through throughout life?

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The findings of the study allow concluding that the mobile learning based on AR developed knowledge and technical job competencies using the pilot of a carpentry course in Wayuu Indians, additionally allowed the appropriation of knowledge through the visualization of 3D images with the use of printed markers of the inventory of tools and the inventory of materials mediated by an interactive graphic interface.

2. Augmented Reality

The term "AR" was coined by researchers Caudell and Mizell in 1992, who used it to describe a system designed to improve the assembly and installation process for electrical cables in aircrafts. Since then, it has been used in various studies and contexts to refer to systems that allow simulating activities and training users in order to improve their performance in specific tasks. Several researchers, such as Feiner et al. (1997) and Rosenberg and Feiner (1993), have used the concept of AR in their research related to the simulation of activities and training in specific tasks.

AR is defined in different ways according to the authors. Goldiez (2001) describes it as a technological field in which additional computer-generated elements are superimposed on the real world through a sensory screen. For his part, Kaufmann (2004) argues that AR allows users to visualize the real world with virtual objects superimposed or combined with the physical environment. Perey (2011) defines it as an emerging technology that allows real-time integration of processed digital information with real-world information through appropriate interfaces.

Martins and Santos da Rosa (2016) define AR as an enhancement of a person's visual experience with the real world through the integration of digital visual elements. They emphasize that it involves the combination of the real and virtual worlds, where computer-generated virtual objects are superimposed or merged with real objects. Kesima and Ozarslan (2012) mention that AR combines aspects of ubiquitous computing, tangible computing and social computing, providing unique possibilities by combining the physical and virtual aspects of the environment and allowing continuous and interactive control by the user.

In the field of AR, various applications have been developed in areas such as video games (Thomas et al., 2000), interactive books (Billinghurst et al., 2001) and educational applications for teaching geography (Shelton and Hedley, 2002) and geometry (Kaufmann, 2003). These applications often make use of markers, such as black and white images or QR codes, to recognize and track virtual objects in the real environment (Feng and Kamat, 2014). Chen et al. (2016) explain that a marker is based on geometric characteristics that are used to estimate a 3D object, such as segments, straight lines, contours, or points on cylindrical objects.

The combination of tangible models and AR has proven beneficial in engineering graphics education. Li et al. (2018) highlight that the use of tangible models allows students to physically interact with three-dimensional objects, which improves their spatial understanding and design skills. On the other hand, Zhang et al. (2020) argue that AR is a promising technology to improve the teaching of engineering graphics by combining virtual elements with the real environment, allowing students to visualize complex models in real time and obtain interactive feedback. Liang et al. (2021) highlight that the combination of tangible models and AR in engineering graphics education provides a more immersive and interactive learning experience, which promotes a deeper understanding of concepts and greater motivation for learning.

In conclusion, AR offers new possibilities to visualize and interact with phenomena that could only be approached theoretically before. It has been successfully applied in the educational field, improving content comprehension, information retention, motivation and academic performance (Radu, 2014; Di Serio et al., 2013).

2.1 AR in Indigenous Populations

This section presents research that explores the applications of AR in indigenous communities. Two studies stand out for using markers to generate AR content. The first study, carried out by Maigua (2012), aimed to develop graphic editing skills in indigenous people through the use of AR in the creation of a printed magazine on the indigenous history of Ecuador. This magazine used a "Magic Book", which is a bookmarked book that allows AR content to be generated via a smartphone. The study was carried out in a school for indigenous girls.

The second study, proposed by Martínez (2017), focused on developing image capture skills in indigenous communities, specifically in the field of bird watching. A camera, smartphone, and AR app were used to take photos of local birds, which were stored in the phone's memory. Printed markers were then created for each bird and observed in AR. These photographs allowed expanding the knowledge in this field.

In summary, these studies show that AR can be applied in indigenous communities for training in specialized trades through the use of markers and mobile devices. These findings support the following research proposal, which seeks to verify the effectiveness of AR in the formation of activities and the development of competencies.

2.2 Wayuu Population

The Wayuu population is made up of 278,212 indigenous people (DANE, 2015), of which 97% speak the Wayuunaiki language. The Wayuu society is characterized by having a complex and matrilineal family structure, organized into clans with 30 different clans, each with its own territory and totemic animal. The role of the "putchipu" or "palabrero" is of great importance, since they play the role of bearers of the word and mediators in the resolution of conflicts between the clans. The highest authority within the family rests with the maternal uncle, who intervenes in all family and domestic matters.

In the nuclear family context, children are led by the mother's brother rather than the biological father. Women have a leadership and organizational role within the clan and participate actively and independently in political affairs. The main activities of the Wayuu community include cattle raising, fishing, agriculture, and salt extraction by men, while women dedicate a large part of their time to the elaboration of backpacks, nets, hammocks and domestic tasks. (Ministry of Culture, Republic of Colombia, 2010).

2.3 Job Competencies

According to Novick and Gallart (1998), job competencies refer to the abilities of individuals to solve problems, select resources, manage technology, and develop interpersonal relationships. These competencies are defined as basic characteristics that are causally related to effective job performance and are manifested in various situations over time. Servicio Nacional de Aprendizaje, SENA (2005) defines them as knowledge, skills and attitudes necessary for efficient performance in the productive sector and their evaluation is based on the resolution of specific, critical and public situations.

Competency assessment involves collecting information and evidence of an individual's performance during a specific activity. Colardyn and Durand-Drouhin (1995) define it as the ability of individuals to carry out a job efficiently, evaluated through observations in the workplace, practical simulations, oral questions, projects, among others.

Competency assessment methods have been developed, such as Amerdinger's (2000) 360° assessment method, which uses a questionnaire to assess performance based on observable or desirable behaviors. This approach focuses on unbiased evaluation of performance by co-workers.

In summary, the evaluation and development of labor competencies are essential to achieve efficient performance at work. These approaches seek to identify strengths and areas for improvement, as well as establish objective criteria to evaluate performance and form effective work teams. Continuous skill development is crucial to adapt to the changes and challenges of the ever-evolving work environment.

2.4 AR Visualization Based Mobile Learning Environment

Mobile learning, refers to the use of mobile devices in educational contexts to provide flexible and ubiquitous access to learning content. According to Bello-Orgaz, Menasalvas, and Camacho (2020), it involves the use of smartphones and tablets to facilitate the delivery of educational materials. Li, Zhang and Huang (2021) point out that mobile learning offers personalized and contextualized learning opportunities through mobile technologies and specific applications. This allows students to access educational resources anytime, anywhere. Chen, Kong and Chow (2022) highlight that M-Learning focuses on the use of mobile devices and mobile applications to support teaching and learning.

In this research we designed a learning environment on basic carpentry in AR, for mobile platforms such as smartphone and tablets with the help of a free software called "Scope", which can be referenced in google, there you can generate 3D images, with the help of a menu, then you migrate to the free software also called "Unity Motor" to later be transferred to devices. The environment contained four learning session that are described below:

The first session was developed in two sessions. In the first session, novices were trained in the use of the AR-based application. The purpose of the second session was to introduce the novices to the basic carpentry tools, such as: hammer, saw, screwdriver, wrench, meter, power strip, clamp, pencil, chisel, brush, and brace. During the execution of this session, novices manipulated the markers to see the effect of AR on the mobile device, in this way they got to know the tools virtually (Marcincina, et al., 2013). In addition to virtually learning the tools, videos and animations on the use of these tools were presented (Figure 1).

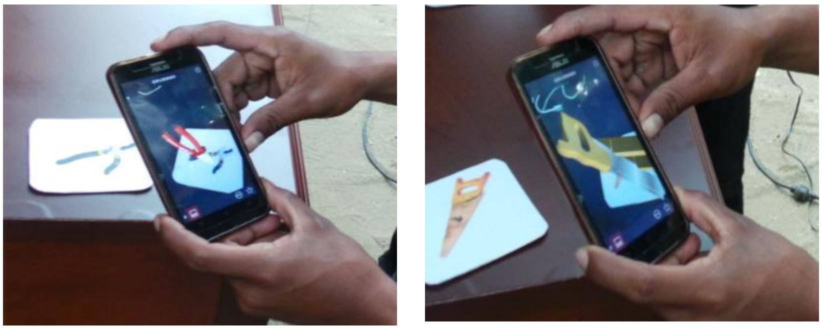

Figure 1: Novices manipulating images in AR

During the second session, novices learned the types of wood in the region suitable for carpentry work due to their physical properties such as density, hardness, and flexibility. Similarly, the application of Scope was opened, in the "Types of Woods" menu, the acknowledgement of the types of trees was carried out with the use of markers and the pine, snail, cedar and oak were observed in AR. In this session, each novice had the opportunity to operate the mobile device and observe the effect of the AR in order to learn about the shape of the tree and the appearance (or look)? of the wood after cutting (figure 2).

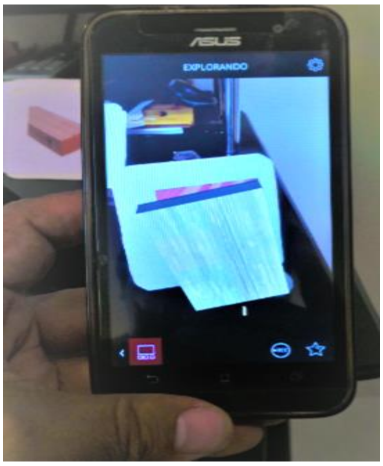

Figure 2: Cutting wood in AR

In the third session, novices were presented with video content of the recognition of tools, regarding uses and maintenance, likewise, they were presented with the topics of measurement and cutting of wood with explanation of cross-sectional and longitudinal cutting techniques, the first is characterized by being perpendicular to the piece of wood and is shorter while the second is done longitudinally. The theme of opening holes was also presented with the technique of pressing the Brace tool so that the drill opens the hole according to the predisposed marks.

In addition to the theme of union of pieces of wood, which is done in two ways, the first is to use the glue carpentry and the second, to secure the union with a nail. Finally the completed chair was presented, with verification of union of pieces, polishing, and finish.

In the fourth session, the novice was permanently advised by an expert carpenter, who supported the entire process of building the chair from start to finish. The corresponding steps were taken following the protocol process to build the nine pieces of the chair correctly. Construction began with the corresponding steps of measuring, cutting and joining the pieces. Followed by the steps of adjustment, polishing, and finish with the steps of verification and completed construction in real time (Figure 3).

Figure 3: Building the chair in real-time

3. Methodology

3.1 Theoretical Foundation

According to authors such as Smith (2010), in the field of carpentry, skilled trades are fostered through active practice and the acquisition of specific technical skilled trades. Apprentices are required to engage in hands-on projects that allow them to develop an in-depth understanding of the processes of measuring, cutting, fitting, and polishing pieces of wood. In addition, Vygotsky's (1978) constructivist theory highlights the importance of active learning and interaction with authentic materials and situations for the development of carpentry skilled trades. In traditional apprenticeship settings, factors such as the availability of adequate resources, expert supervision, and the opportunity to practice technical skilled trades are critical to successful carpentry apprenticeships (Johnson, 2005).

To validate the ML environment based on AR visualization, a case study was carried out with three indigenous people belonging to the Wayuu ethnic group from Torcoromana, Camarones district. These indigenous people in daily life are dedicated to fishing and goat herding, they have no knowledge of basic carpentry. They speak a dialect called "Wayuunaiki" and are illiterate in the Spanish language, the fact of not speaking Spanish limits being able to communicate with the people of the city, getting a job, in addition to not being able to access formal studies.

A fieldwork study was carried out, which according to (Burgess, R., 1984; Pelto, P., 2013), among social anthropologists, fieldwork is synonymous with collecting data through observational methods. However, for sociologists the term is also used to refer to the collection of data through a social survey or data from cultural anthropology that are derived from direct observation of behavior in a particular society. According with the last, a contact was made, with a Wayuu community leader who knew the Torcoromana indigenous people. The leader's role was to make the training proposal known to the indigenous settlement's chief and thus arrange a meeting between her and the researchers. After presenting the proposal to the chief, she authorized the entry of the team of researchers to the indigenous settlement. The training process was carried out in the school that had a board and desks, but without access to electricity or internet.

3.2 Study Design

The indigenous people interested in the training process were 15, they authorized the filming, photography, and use of the data obtained for educational purposes. Three participants who voluntarily agreed to be part of the research were randomly chosen, they are between the ages of 20 and 25 years old, these three indigenous people are identified in the following as: Andrés, Carlos, and Fabio. The three participating indigenous people have no knowledge of the carpentry skilled trades, they have no knowledge of the types of wood appropriate for this activity, and they have never been trained for this type of course trade. An indigenous person from the "Los Carbones" community was invited as a control group (E1), who was given a pictorial guide on the necessary steps to build a chair.

During the training stage, five face-to-face meetings were held between the indigenous people and the researchers who focused on the knowledge of the course developed in AR (Figure 4). In the first two sessions they recognized the inventory of carpentry tools and 13 fixed markers and 13 printed dynamic markers corresponding to the same number of tools were used and 8 markers were used to identify the types of wood and trees. Each Marker has the figure of the tool or wood material printed on one of its sides. In the third session they identified types of wood. In the fourth session they learned about cutting and joining pieces of wood. In the fifth session, with the help of a master craftsman, they built a chair individually.

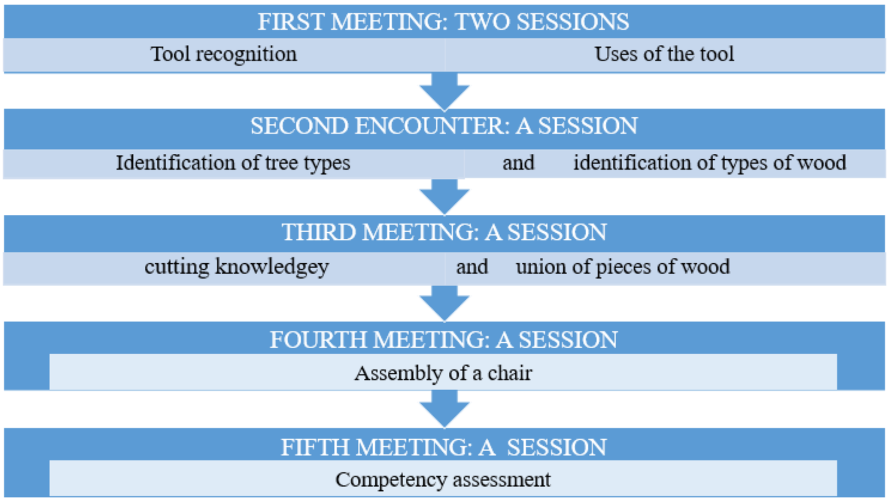

Figure 4: Face-to-face meetings

Finally, in the stage of assessment of skilled trades the indigenous people (sixth session) had the task of building a chair autonomously, Andrés, Carlos and Fabio were recorded, with the help of a professional cameraman, who carried out the recording process individually for approximately one hour for each of the three indigenous people, with the purpose of identifying the impact of the AR course on the development of skills in carpentry . The videos were then analyzed by three experts in carpentry, who have worked for 20 years in the carpentry trade and are instructors of a government institution called "SENA", who used a competency assessment system. The evaluations were carried out taking the average of the three evaluators per apprentice and per competence in each of the three phases (Appendix: Table 7).

This system was created by the researchers, specifically to evaluate the process of learning skilled trades in carpentry, the competency indices were developed by phases, which are described in the chapter on findings.

3.3 Assessment System

A carpentry competency assessment system applied to indigenous people is based on an approach that recognizes and values traditional carpentry knowledge and skilled trades within these communities. This system is based on the understanding that the skilled trades of carpentry in the indigenous context not only implies technical skilled trades, but also a deep connection with culture, tradition, and the natural environment.

According to González (2015), a competency-based assessment system in indigenous carpentry is based on the recognition of traditional skilled trades and the cultural knowledge inherent in this craft. This implies a deep understanding of the connection between the carpentry skills trade and the cultural identity of indigenous communities. On the other hand, Smith (2018) highlights the importance of considering environmental aspects in the evaluation by competencies in indigenous carpentry, recognizing the need to use natural resources in a sustainable manner and in harmony with the environment.

According to the approaches of González and Smith, the evaluation system by competencies in indigenous carpentry is based on a holistic approach that includes technical, cultural, and environmental aspects (Martínez, 2020). This involves valuing knowledge of native wood species, traditional carving, and assembly techniques, as well as understanding the designs and cultural symbols of each indigenous community.

The evaluation of skilled trades in indigenous carpentry is carried out through different methods, such as direct observation of carpentry projects, review of portfolios of previous work, and participation in community projects (Chávez, 2019). These methods allow to assess the technical skill and cultural knowledge of indigenous carpenters, as well as their ability to work collaboratively with the community and preserve cultural and environmental values.

In summary, an assessment system for competencies in indigenous carpentry is based on the recognition and appreciation of the technical, cultural and environmental skills of indigenous carpenters. González, Smith, Martínez and Chávez 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.

3.3.1 Description of the competencies assessment system

As mentioned above, the competencies assessment system was developed to assess the performance of the novices while building the chair. This competency assessment system was developed by the researcher taking into account the theoretical bases and conceptual foundations to be implemented in an indigenous community with three volunteer apprentices. The competency indicators in the three phases were prepared with the help of three experts in carpentry who gave their approval to be used in the final evaluation in real time. The system was validated by these three expert carpenters on the subject and presented three phases. Each phase consisted of competencies and indicators that allowed establishing the performance of the indigenous people before, during and after building the chair. Each performance indicator was assessed from 1-5, where 1 corresponds to the lowest score and 5 to the highest score.

The first phase determined indigenous knowledge of the tools and materials through three competencies and fifteen performance indicators (Table 1).

Table 1: First phase: Before building the chair

Competencies	Indicators
1. Describes and possesses in writing 2 Designs and steps of the process of building a Handcrafted chair.	1. Uses proper stroke tools, such as pencil and square, to mark the cut of the wood in the chosen pieces.
	2. Performs early maintenance on the cutting tools (saw), to achieve the cross cuts and longitudinal cuts properly.
	3. Accurately classifies the fastening tools such as: pliers and tongs to be used as indicated in the assembly of wooden pieces.
	4. Carefully prepares tools for cutting and lowering such as chisel and carpentry brush, with proper maintenance and cleaning of the parts.
	5. Identifies and correctly uses tools to polish or finely sand the wood (Rasp).
3. Organizes a complete inventory of tools and materials.	6. Assembles and properly adjust the drill bit on tools to open holes such as the brace.
	7. Identifies and uses, according to the wood's hardness, impact tools such as hammer on hard surfaces and mallet on finished surfaces.
	8. Chooses the right tool to screw or unscrew, as the case may be, by properly handling the screwdriver or fixed wrenches.
	9. Understands and specifically uses measurement tools such as the meter or terminal strip.
	10. Uses the scraping tool in the indicated way, to leave the surfaces of the pieces of wood in a smooth and soft way.
4. Possesses a panel of tools and inputs for the construction and a warehouse with different types of wood.	11. Identifies and uses the brush for cleaning and lacquering wooden pieces.
	12. Describes and differentiates elements such as nails and screws for joining pieces and glue carpentry.
	13. Classifies and arranges the type of wood suitable for cutting.
	14. Correctly calculates the quantity and type of wood to be used.
	15. Maintains in a perfect state with a periodic maintenance, tools such as: saw, brush, chisel and scraper.

The second phase assessed the performance of the indigenous people while building the chair. For this purpose, four competencies and fourteen performance indicators were proposed, which are described in Table 2.

Table 2: Second phase: While building the chair

Competencies	Indicators
1. Develops a constructive process of a handcrafted chair executing the design steps.	1. Accurately measures and marks the parts for cutting and verifies that the measurements are well taken on the marks.
	2. Cuts firmly and accurately transversally the pieces according to measurements and traced marks.
	3. Orders the parts in the correct assembly sequence and check that the parts are in good condition.
	4. Properly brushes the wood until smooth surfaces are obtained.
	5. Achieves surfaces in optimum presentation.
2. Analyze and understand the steps of measuring, cutting and polishing the pieces of wood.	6. Opens the holes making proper use of the drill bit and the marks for each piece of wood accurately.
	7. Accurately measures the depth, length and width of the holes in each piece of wood for a perfect fit.
	8. Accurately cuts each piece of wood longitudinally, according to the depth of the hole.
	9. Checks and polishes properly the tabs at the ends of the longitudinal cut piece.
3. Applies the steps of opening, depth, and polishing of the hole.	10. Accurately marks the piece of wood in the place indicated to open the holes, measures with precision width, length and depth.
	11. Examines the exact adjustments of the tabs of each piece of wood with respect to the depth of the hole.
	12. Adjusts the tabs and hole depth, brushes carefully for a quality finish.
4. Establishes and elaborates the adjustments of the joints.	13. Accurately joins the pieces of wood with glue. Calculates the time needed for it to dry.
	14. Nails accurately and in the right place. Firmly and accurately cuts excess tips.

Finally, the third phase assessed the characteristics of the chair after it was built by the indigenous people. To analyze the final product, two competencies and thirteen performance indicators were proposed (Table 3).

Table 3. Third phase: After building the chair

Competencies	Indicators
1. Develops a careful process of measuring, cutting, adjusting, and polishing pieces of wood.	1. Builds and assembles the nine (9) pieces of the chair following the procedure and evaluating with the checklist and quality.
	2. Evaluates that the assembled pieces are in the correct location.
	3. Uses the measuring, cutting, clamping, and impact instruments safely and firmly.
	4. Accurately cuts longitudinally and transversely.
	5. Makes joints, glues with nails, and other elements accurately.
2. Verifies the assembly and process for proper and quality construction of a handcrafted chair.	6. Precisely applies glue to joints.
	7. Inspects the final sanding for quality.
	8. Makes a final assessment to detect splinters or protrusions.
	9. Verifies with precision tests the assembly and final finishes.
	10. Self-evaluates the final product with a guide of indicators. Note, what do they reference if they cannot read; the guide of indicators is a voice? Is it an image?
	11. Use the materials in a reasonable way.
	12. Carries out the maintenance of the tools in an adequate way.
	13. Properly organizes and stores tools.

4. Findings

To identify the impact of the AR learning process on the development of skilled trades in carpentry, the indigenous people in the sixth session were videotaped while building a chair. Subsequently, the videos were reviewed and assessed with the aid of the competencies system.

The description of the results was based on the phases of the competencies assessment system and the performance indicators for each of the three novices in real time.

4.1 First Phase: Before Building the Chair

In the first phase, three competencies were assessed by means of fifteen indicators, the scores were obtained in a general way averaging the three scores assigned by experts in carpentry in each competency and thus establishing a value for each one that describes the performance of the indigenous people. (Figure 5).

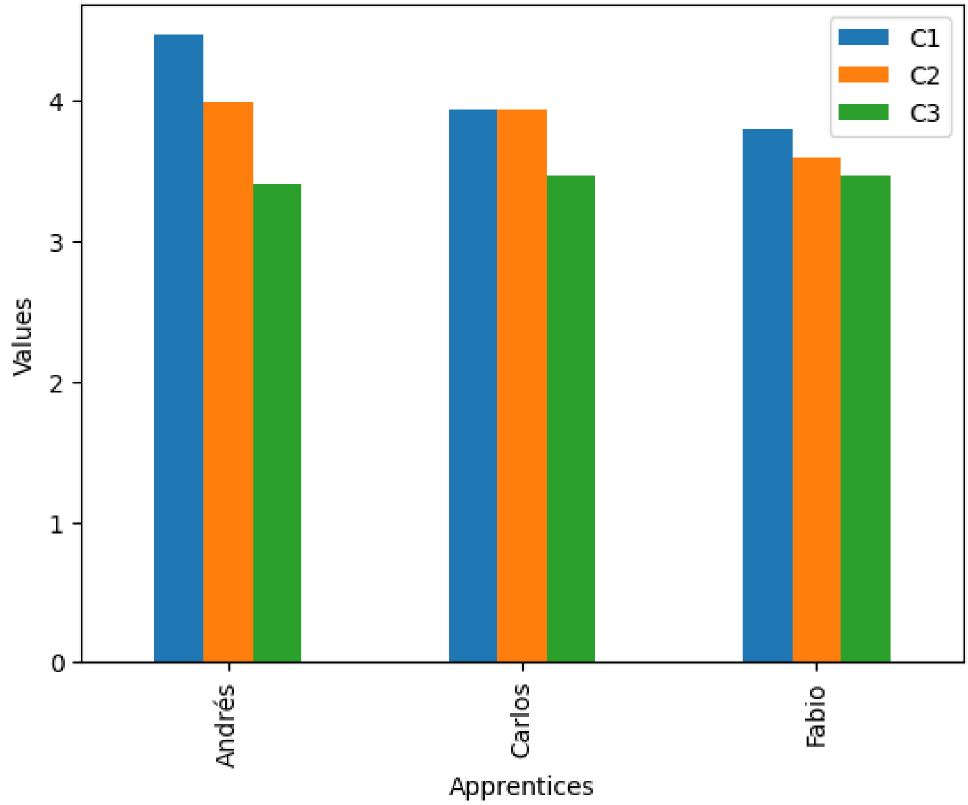

Figure 5: Graphic showing performance indicators

Below is an individual summary of phase I. (Table 4).

Table 4: Individual summary

Novice / Competence	Andrés	Carlos	Fabio
C1: Describes and possesses in writing designs and steps of the process of building a handcrafted chair.	Andrés showed competence in classifying and using the inventory of tools, as well as performing periodic maintenance on them. However, he had deficiencies in fixing the saw. Average rating: 4.45/5.0	Carlos demonstrated proper tool cleaning and maintenance and correctly classified measuring, cutting, and clamping tools. However, he had difficulty using the square for measurements. Average rating: 3.93/5.	Fabio carefully classified, used and prepared the tools for measuring, cutting, drilling and planning. However, he had problems with the cleaning and maintenance of the tools, as well as with the improper use of the tool for sanding wood. Average rating: 3.79/5.0.
C2: Organizes a complete inventory of tools and materials.	Andrés correctly identified the tools for certain tasks but had problems with the	Carlos adjusted and chose tools for specific tasks, but he had problems with the	Fabio adequately prepared the tools for specific tasks but had trouble identifying

Novice / Competence	Andrés	Carlos	Fabio
	proper handling of the screwdriver and the measurement scale. Average rating: 3.99/5.0.	scale and the screwdriver. Average rating: 3.93/5.0.	and using impact tools such as the hammer and scraper to polish wood. Average rating: 3.59/5.0.
C3: Possesses a panel of tools and inputs for the construction and a warehouse with different types of wood.	Andrés calculated the amount of wood accurately, but he had problems with the use of the brush to varnish and adjust with wooden nails. Average rating: 3.40/5.0.	Carlos excelled at maintaining tools and performing regular maintenance. However, he had problems with the use of the lacquer brush, the inappropriate use of materials and the inappropriate use of wood. Average rating: 3.46/5.0.	Fabio had difficulty nailing pieces of wood together, but successfully selected the correct type of wood and effectively used the calculated amount of wood. Average rating: 3.46/5.0.

Based on the information, it can be inferred that Andrés performed relatively better than the other trainees, followed by Carlos, and Fabio had the lowest overall performance.

4.2 Phase II: While Building the Chair

Phase II, which corresponded to the assembly of the parts, four competencies were assessed, followed by the description of the results. (Figure 6).

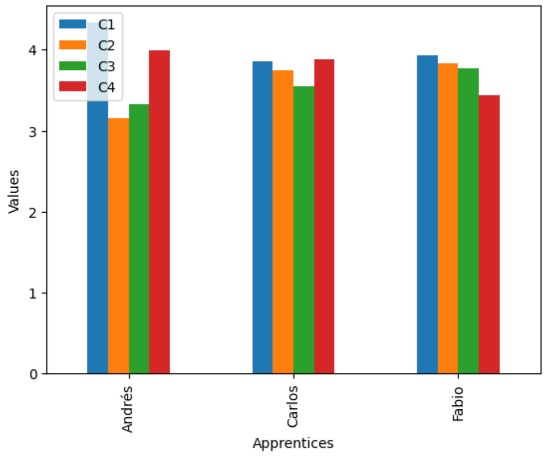

Figure 6: Graphic showing performance indicators

Below is an individual summary of phase II. (Table 5).

Table 5: Individual summary

Novice / Competence	Andrés	Carlos	Fabio
C1: Develops a constructive process of a handcrafted chair executing the design steps.	Andrés demonstrated precision in measuring, cutting, and ordering pieces of wood. He also achieved a correct brushing of the pieces. Average rating: 4.33/5.0.	Carlos precisely measured, marked and planed the pieces of wood. However, he lacked the firmness and precision to cut the pieces lengthwise and arrange them in the correct order of assembly. Average rating: 3.86/5.0.	Fabio accurately measured, marked and cut the pieces of wood. He got a nice superficial presentation. However, brushing him was not done properly. Average rating: 3.93/5.0.
C2: Analyze and understand the steps of measuring, cutting and polishing the pieces of wood.	Andrés had problems with the exact longitudinal cuts and the precise grinding of the tabs for the fit. Average rating: 3.16/5.0.	Carlos punched holes accurately and checked tabs properly. However, he had problems with accurate ripping to the depth of the hole. Average rating: 3.74/5.0.	Fabio used the drill correctly, cut the pieces accurately lengthwise, and polished and checked the ends of the pieces. However, he had trouble measuring the depth of the hole accurately. Average rating: 3.83/5.0.

C3: Applies the steps of opening, depth, and polishing of the hole.	Andrés had difficulty marking the exact location of the holes and accurately examining/adjusting the flanges. Average rating: 3.33/5.0.	Carlos had difficulties marking the pieces accurately and achieving the expected performances. He also faced challenges fitting the tongue into the hole and properly planning the parts. Average rating: 3.55/5.0.	Fabio precisely marked the pieces of wood and examined the fit and depth of the hole. However, he had difficulty achieving a perfect fit between the tongue and the hole. Average rating: 3.77/5.0
C4: Establishes and elaborates the adjustments of the joints.	C4: Andrés successfully joined the pieces of wood but faced challenges cutting off the excess tips of the wooden nails. Average rating: 3.99/5.0.	Carlos successfully glued the pieces together and accurately cut the excess tips of the wooden nails. However, the location of his fingernails was not precise. Average rating: 3.88/5.0	Fabio used and drove the nails in the right place, cut the excess firmly, but did not glue the pieces together well. Average rating: 3.44/5.0.

In general terms, Andrés performed better in competition 1 compared to the other two students. However, his performance decreased in competitions 2 and 3. Carlos and Fabio had similar averages in the competitions, with some strengths and weaknesses in different steps of the carpentry process.

4.3 Phase III: After Building the Chair

Phase III assessed two competencies in each of the three novices, the findings are described below. (Figure 7).

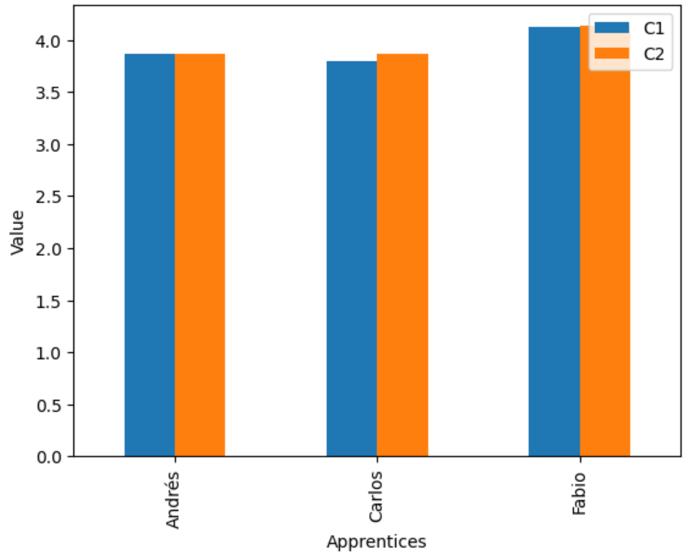

Figure 7: Graphic showing performance indicators

Below is an individual summary of phase III. (Table 6)

Table 6: Individual summary

Novice / Competence	Andrés	Carlos	Fabio
C1: Develops a careful process of measuring, cutting, adjusting, and polishing pieces of wood	Andrés successfully built and assembled the wooden chair, making sure each piece was in the right place and using the tools correctly. However, he faced challenges joining the pieces precisely with nails and glue. Average rating: 3.86/5.0.	Carlos correctly built and assembled the chair, evaluating the correct placement of the pieces and making precise cross-sections. However, he had trouble achieving precise joints and glues using nails and glue. Average rating: 3.79/5.0.	He made precise longitudinal and transversal cuts. However, he used tools irregularly and was unable to glue the pieces together accurately. Average rating: 4.12/5.0

Novice / Competence	Andrés	Carlos	Fabio
C2: Verifies the assembly and process for proper and quality construction of a handcrafted chair	Andrés maintained the same average rating of 3.86/5.0. He checked for splinters in the wood, used the necessary materials, and kept the tools clean and organized. However, he lacked precision when applying the glue and inspecting the quality of the final sanding.	Carlos inspected the quality of the sanding, evaluated the protrusions in the pieces and performed proper maintenance on the tools. However, he faced difficulties in accurately applying the glue at the joints and using the materials sensibly. Average rating: 3.86/5.0.	Fabio successfully built and assembled the wooden chair, following the protocol and ensuring the correct placement of the pieces. Average rating: 4.12/5.0.

Based on the information, Fabio had the highest average rating, indicating a better overall performance. Andrés and Carlos had similar average marks, but Fabio scored slightly higher. (See graph 4).

In conclusion, it was found that Fabio exhibited outstanding performance in the three phases evaluated, demonstrating solid and consistent skilled trades in the construction and assembly of the wooden chair. Andrés was in second place, presenting difficulties in specific steps of the process, while Carlos was in third place, showing an acceptable overall performance but less outstanding than the other two trainees. These findings highlight the importance of practice and experience in developing carpentry skilled trades.

The implementation of AR in ML environment has been shown to have a significant impact on the development skilled trades in carpentry. AR provides a rich and interactive learning experience that facilitates the understanding and application of technical concepts and skills.

Regarding the results of the Apprentices, it was observed that AR contributed positively in specific areas. For example, in the C1 competition, the real-time visualization of instructions and virtual models allowed Andrés and Carlos to correctly build and assemble the parts, improving the precision in the execution of tasks. However, limitations were identified in the proper use of tools in the C2 competence, suggesting the need for more interaction and real-time feedback to guide and correct the handling of specific tools.

On the other hand, Fabio excelled in several competencies, indicating that AR can influence individual performance by aiding in accurate tool identification and selection, as well as accurate cutting and adjustment. However, the need to improve aspects such as the correct use of glue and the precision in the assembly of the pieces was pointed out. However, the invited apprentice's performance in tasks such as cutting, hole opening, and general chair polishing was below expectations, as evaluated by the three experts. He achieved an average score of 2.5/5.0, indicating the effectiveness of AR visualization.

In summary, the implementation of AR in learning environments shows promise for the development of skilled trades in carpentry. Its ability to provide a visually enriched and immersive experience can enhance the understanding and application of technical skills. However, continued attention is required to overcome the identified limitations and maximize the potential of AR in learning environments.

5. Conclusions

The ML environment based on AR aiming at fostering technical job knowledge and competencies development in Wayuu Indians allowed the appropriation of knowledge through the visualization of 3D images with the use of printed markers of the inventory of tools and the inventory of materials mediated by an interactive graphic interface. The environment was developed on a mobile platform where the indigenous people performed simulations of movements in a natural way and visualized on screen the effect of the AR originated from the marker positioned under the camera of the device.

In this sense, the approach of the carpentry tools, their functions and uses through the implementation of a course of "basic carpentry" with AR support allowed the indigenous people to have the opportunity to know and manipulate tools unknown in their community, and with the inclusion of a technology with platform and mobile devices. The Wayuu indigenous community benefited because they developed carpentry trade job competencies on the process of building a chair, which managed to commercialize successfully in the market thus improving their family income.

Visual technology also ensured that the indigenous people acknowledged the tools of the carpentry trade with 13 fixed markers and 13 dynamic printed markers corresponding to the same number of tools used in the training process. Also, it facilitated to the indigenous people the knowledge of the types of trees of the region, the structure, the use, and the characteristics, mainly the visualization of the type of wood after the cut, 8 markers were used that identified the types of wood and trees.

Similarly, it is important to mention that the technology was characterized by portability in the devices, weight, size and autonomy of battery power, avoiding the travel of indigenous people and bringing the ML environment to the indigenous settlement. This technological innovation had an educational component that allowed to improve in terms of knowledge the learning of a trade in indigenous communities that do not speak Spanish. Said technology facilitated for the indigenous man to manage times, review contents and learn at their own pace.

On the other hand, the proposed competency assessment system allowed evaluating the skills of measuring, cutting, joining and assembling pieces of wood, managing the inventory of tools and the use of materials. The competence evaluation system showed good results in the performance of the activities in the process of integral construction of a wooden chair, and it was observed that the indigenous people managed to satisfactorily complete all the processes of the protocol that involves the technical assembly of a wheelchair wood. One of the three participating indigenous people (A1) was randomly chosen and compared with the invited indigenous person (E1) who did not have training with the visual method, where the efficiency of the learning process using AR can be observed. (Table 7).

It can be concluded that the ML environment applied in training processes with indigenous populations, excluded people and people with communication limitations, are viable and effective for the development of technical job knowledge and competencies. In addition, the AR improves the motivation and creativity of novices (Wei et al., 2014), since it allows them to manipulate devices, approach contents virtually, directly observe the object in three dimensions, and actively participate in the construction of knowledge (Bujak et al., 2014; Redondo et al., 2013).

Finally, with the support of the ML environment, made it possible to achieve an effectiveness of the training proposal in the carpentry trade in indigenous populations. Visual method allows achieving greater educational inclusion for people with learning difficulties, basically because it allows inserting the virtual into the real environment without the need to travel to an institution. Visual method allows achieving greater educational inclusion for people with learning difficulties, basically because it allows inserting the virtual into the real environment without the need to travel to an institution. In the future, can develop a methodology that allows the use of the AR in a way that adapts to different topics linked to the improvement and fulfillment of the study plans and courses proposed based on the needs of people and communities. For future implementations, it is recommended to make the model more flexible and apply it to other illiterate populations, such as peasants, displaced persons and street dwellers, this will allow more people in a condition of illiteracy to access learning opportunities and development of skilled trades.

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Appendix

Table 7: Assessment Evaluators

Phase I	Competencies (C)	Indicators (I)	Apprentice A1				Apprentice 2				Apprentice 3			
			Evaluators				Evaluators				Evaluators			
			E1	E2	E3	Average	E1	E2	E3	Average	E1	E2	E3	Average
I. Knowledge of tools and materials - Pre	1. Describes and possesses in writing designs and steps of the process of building a handcrafted chair.	1. Uses proper stroke tools, such as pencil and square, to mark the cut of the wood in the chosen pieces.	5	4	5	**4,66**	4	4	3	**3,66**	4	4	4	**4,0**
		2. Performs early maintenance on the cutting tools (saw), to achieve the cross cuts and longitudinal cuts properly.	5	4	4	**4,33**	4	4	4	**4,0**	3	3	3	**3,0**
		3. Accurately classifies the fastening tools such as: pliers and tongs to be used as indicated in the assembly of wooden pieces.	3	5	4	**4,0**	4	4	4	**4,0**	5	4	4	**4,33**
		4. Carefully prepares tools for cutting and lowering such as chisel and carpentry brush, with proper maintenance and cleaning of the parts.	5	5	4	**4,66**	4	4	5	**4,33**	4	4	4	**4,0**
		5. Identifies and correctly uses tools to polish or finely sand the wood (Rasp).	5	5	4	**4,66**	4	4	3	**3,66**	3	3	5	**3,66**
		TOTAL AVERAGE C1	**4,46**				**3,93**				**3,79**			
	2. Organizes a complete inventory of tools and materials.	6. Assembles and properly adjust the drill bit on tools to open holes such as the brace.	5	4	5	**4,66**	5	5	4	**4,66**	4	4	4	**4,0**
		7. Identifies and uses, according to the wood's hardness, impact tools such as hammer on hard surfaces and mallet on finished surfaces.	5	4	4	**4,33**	4	4	4	**4,0**	4	4	3	**3,66**
		8. Chooses the right tool to screw or unscrew, as the case may be, by properly handling the screwdriver or fixed wrenches.	3	4	3	**3,33**	3	3	3	**3,0**	3	3	4	**3,33**
		9. Understands and specifically uses measurement tools such as the meter or terminal strip.	4	4	3	**3,66**	5	4	4	**3,66**	4	4	4	**4,0**
		10. Uses the scraping tool in the indicated way, to leave the surfaces of the pieces of wood in a smooth and soft way.	4	4	4	**4,0**	5	4	4	**4,33**	3	3	3	**3,0**
		TOTAL AVERAGE C2	**3,99**				**3,93**				**3,59**			
	3. Posee un panel de herramientas e insumos para la elaboración y un depósito con diferentes tipos de madera	11. Identifies and uses the brush for cleaning and lacquering wooden pieces.	3	3	3	**3,0**	3	3	3	**3,0**	3	3	3	**3,0**
		12. Describes and differentiates elements such as nails and screws for joining pieces and glue carpentry.	3	3	3	**3,0**	3	4	3	**3,33**	3	3	3	**3,0**
		13. Classifies and arranges the type of wood suitable for cutting.	4	4	4	**4,0**	4	4	4	**4,0**	5	5	4	**4,66**
		14. Correctly calculates the quantity and type of wood to be used.	3	3	3	**3,0**	3	3	3	**3,0**	4	4	3	**3,66**
		15. Maintains in a perfect state with a periodic maintenance, tools such as: saw, brush, chisel and scraper.	4	4	4	**4,0**	4	4	4	**4,0**	3	4	5	**4,0**
		TOTAL AVERAGE C3	**3,40**				**3.46**				**3,46**			
		GENERAL AVERAGE	**4,0**	**4,0**	**3,8**	**3,9**	**3,9**	**3,8**	**3,6**	**4.0**	**3.66**	**3,4**	**3,7**	**3,7**

Phase III	Competencies (C)	Indicators (I)	Apprentice 1				Apprentice 2				Apprentice 3			
			Evaluators				Evaluators				Evaluators			
			E1	E2	E3	Average	E1	E2	E3	Average	E1	E2	E3	Average
Product evaluation	1. Develops a careful process of measuring, cutting, adjusting, and polishing pieces of wood.	1. Builds and assembles the nine (9) pieces of the chair following the procedure and evaluating with the checklist and quality.	4	4	4	**4,0**	4	5	4	**4,33**	5	5	4	**4,66**
		2. Evaluates that the assembled pieces are in the correct location.	4	4	4	**4,0**	4	4	4	**4,0**	5	4	5	**4,66**
		3. Uses the measuring, cutting, clamping, and impact instruments safely and firmly.	5	5	4	**4,66**	3	4	4	**3,66**	4	3	4	**3,66**
		4. Accurately cuts longitudinally and transversely.	4	3	4	**3,66**	3	4	5	**4,0**	5	5	4	**4,66**
		5. Makes joints, glues with nails, and other elements accurately.	3	3	3	**3,0**	3	3	3	**3,0**	3	3	3	**3,0**
		TOTAL AVERAGE C1	**3,86**				**3,79**				**4,12**			
	2. Verifies the assembly and process for proper and quality construction of a handcrafted chair	6. Precisely applies glue to joints.	3	3	3	**3,0**	3	3	3	**3,0**	3	3	3	**3,0**
		7. Inspects the final sanding for quality.	3	3	3	**3,0**	4	5	4	**4,33**	5	5	5	**5,0**
		8. Makes a final assessment to detect splinters or protrusions.	4	4	4	**4,0**	3	4	5	**4,0**	5	4	3	**4,0**
		9. Verifies with precision tests the assembly and final finishes.	4	4	4	**4,0**	3	4	4	**3,66**	4	4	5	**4,33**
		10. Self-evaluates the final product with a guide of indicators. Note, what do they reference if they cannot read; the guide of indicators is a voice? Is it an image?	4	4	4	**4,0**	4	4	3	**3,66**	4	5	4	**4,33**
		11. Use the materials in a reasonable way.	4	4	4	**4,0**	3	3	4	**3,33**	5	4	4	**4,33**
		12. Carries out the maintenance of the tools in an adequate way.	4	4	4	**4,0**	4	4	4	**4,0**	3	4	5	**4,0**
		13. Properly organizes and stores tools.	4	4	5	**4,33**	4	5	4	**4,33**	5	4	3	**4,0**
		TOTAL AVERAGE C2	**3,86**				**3,86**				**4,13**			
		GENERAL AVERAGE	**3,86**	**3.8**	**3.93**	**3,86**	**3,53**	**4.06**	**3.86**	**3,84**	**4,06**	**4.06**	**4.06**	**4,13**

Phase II	Competencies (C)	Indicators (I)	Apprentice 1				Apprentice 2				Apprentice 3			
			Evaluators				Evaluators				Evaluators			
			E1	E2	E3	Average	E1	E2	E3	Average	E1	E2	E3	Average
II. During the assembly of the chair	1. Develops a constructive process of a handcrafted chair executing the design steps	1. Accurately measures and marks the parts for cutting and verifies that the measurements are well taken on the marks.	5	5	5	**5,0**	4	4	4	**4,0**	4	4	4	**4,0**
		2. Cuts firmly and accurately transversally the pieces according to measurements and traced marks.	4	4	4	**4,0**	3	3	3	**3,0**	4	4	4	**4,0**
		3. Orders the parts in the correct assembly sequence and check that the parts are in good condition.	4	5	4	**4,33**	4	4	3	**3,66**	4	4	4	**4,0**
		4. Properly brushes the wood until smooth surfaces are obtained.	4	4	4	**4,0**	4	5	4	**4,33**	4	4	3	**3,66**
		5. Achieves surfaces in optimum presentation.	5	4	4	**4,33**	5	4	4	**4,33**	4	4	4	**4,0**
		TOTAL AVERAGE C1	**4,33**				**3,86**				**3,93**			
	2. Analyze and understand the steps of measuring, cutting and polishing the pieces of wood.	6. Opens the holes making proper use of the drill bit and the marks for each piece of wood accurately.	3	3	3	**3,0**	4	4	4	**4,0**	4	4	4	**4,0**
		7. Accurately measures the depth, length and width of the holes in each piece of wood for a perfect fit.	3	4	4	**3,66**	4	4	3	**3,66**	3	3	4	**3,33**
		8. Accurately cuts each piece of wood longitudinally, according to the depth of the hole.	3	3	3	**3,0**	3	4	3	**3,33**	4	4	4	**4,0**
		9. Checks and polishes properly the tabs at the ends of the longitudinal cut piece.	3	3	3	**3,0**	4	4	4	**4,0**	4	4	4	**4,0**
		TOTAL AVERAGE C2	**3,16**				**3,74**				**3,83**			
	3. Applies the steps of opening, depth, and polishing of the hole.	10. Accurately marks the piece of wood in the place indicated to open the holes, measures with precision width, length and depth.	4	3	3	**3,33**	4	4	4	**4,0**	4	4	5	**4,33**
		11. Examines the exact adjustments of the tabs of each piece of wood with respect to the depth of the hole.	3	4	3	**3,33**	4	4	3	**3,66**	4	4	4	**4,0**
		12. Adjusts the tabs and hole depth, brushes carefully for a quality finish.	3	3	4	**3,33**	3	3	3	**3,0**	3	3	3	**3,0**
		TOTAL AVERAGE C3	**3,33**				**3,55**				**3,77**			
	4. Establishes and elaborates the adjustments of the joints.	13. Accurately joins the pieces of wood with glue. Calculates the time needed for it to dry.	5	4	4	**4,33**	3	3	4	**3,33**	3	3	3	**3,0**
		14. Nails accurately and in the right place. Firmly and accurately cuts excess tips.	4	3	4	**3,66**	3	4	4	**3,66**	3	3	3	**3,0**
		15. Utiliza y clava las puntillas con la medida precisa y en el lugar adecuado. Corta con firmeza y precisión las puntas sobrantes.	4	4	4	**4,0**	5	4	5	**4,66**	4	4	5	**4,33**
		TOTAL AVERAGE C3	**3,99**				**3,88**				**3,44**			
		GENERAL AVERAGE	**3.8**	**5**	**3.73**	**3,75**	**3.8**	**3.86**	**3.86**	**3,77**	**3,86**	**3,86**	**3.86**	**3,77**

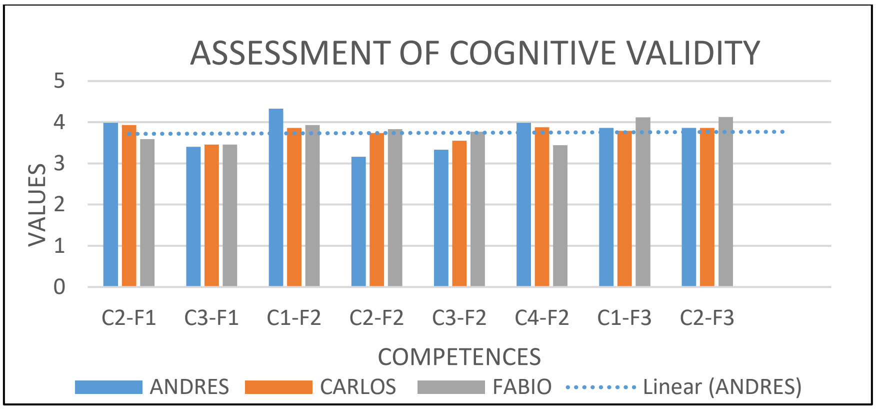

Figure 8: Assessment of cognitive validity

Table 8: Evaluation of the efficiency of the tool in E1 and A1

Column_1	A1	E1
C1-F1	4,46	3,24
C2-F1	3,99	3,2
C3-F1	4,78	3
C1-F2	4,33	3,5
C2-F2	4,76	3,74
C3-F2	4,28	3,55
C4-F2	4,75	3,33
C1-F3	4,86	3,57
C2-F3	4,85	3,21