Augmented Reality in Retail: Metrics in the Furniture Department

Leal-Enríquez E. and Gutiérrez-Antúnez A.R.

***Abstract*—This article explores the implementation of Augmented Reality (AR) in retail, focusing on the furniture sector. It outlines the process undertaken to gain Retail business managers' approval for a proof of concept utilizing AR, supported by a Storyboard demonstrating potential business benefits. The proof of concept aimed to illustrate how AR could increase sales and decrease return rates of furniture by allowing customers to visualize products in their own space before purchasing. Metrics for evaluating 3D model suppliers used in the AR platform are also discussed. The company's team developed the platform internally using Google's ARCore technology. This study highlights the practical applications of AR in retail and its impact on enhancing consumer interaction and operational efficiency.**

***Index Terms*—augmented reality, retail, proof of concept, implementation, economic benefit.**

I. Introduction

THe retail world is continually evolving, influenced by various factors from product specifics to the broader social, economic, and technological contexts in which they are exchanged [1]. Recent technological advancements have significantly enhanced customer experiences, improving customer satisfaction and loyalty towards brands. Notably, technologies like Virtual Reality and Augmented Reality have been pivotal in aligning customer interests with various products [2]. Among these, Augmented Reality is distinguished by its straightforward and transparent customer interactions [3]. This technology opens up many possibilities, especially in retail, by shifting the traditional consumption paradigm and altering how customers interact with products [4]. Its adoption offers multiple benefits for retailers, such as enhancing customer experiences, reducing product returns, expanding the utility of sales floors, and increasing the sales of large, complex-to-display items, thereby fostering brand loyalty and other positive outcomes [5], [21], [6]. Before discussing this paper's development, we begin with a fundamental question:

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A. What is Augmented Reality?

Augmented Reality (AR) represents a critical component of Industry 4.0, a term originally coined in Germany to explain the concept of smart manufacturing. This paradigm involves the seamless interconnection of all manufacturing processes and the integration of advanced digital technologies within industrial settings. Augmented Reality (AR) enhances real-world environments, significantly improving manufacturing efficiency and process optimization [8]. Industry 4.0 also encompasses other key technologies such as the Internet of Things (IoT), Cyber-Physical Systems (CPS), collaborative robotics, big data analytics, 3D printing, and Artificial Intelligence (AI), each contributing uniquely to the transformation of industrial settings [8].

Augmented Reality (AR) is a technology that overlays digital information in the real world as seen through mobile devices or digital glasses. Unlike Virtual Reality, which creates an entirely immersive experience in a different setting, AR integrates digital elements into the user's actual surroundings [9].

B. Types of Augmented Reality

Augmented Reality (AR) display levels are determined by the complexity of the markers that trigger AR objects or information. At the basic level, level zero, information is encoded in barcodes or QR codes. Level one uses simple visual markers, such as images that might resemble a circle. Level two employs Global Positioning System (GPS) markers, reliant on the user's mobile device and location. The highest level, level three, requires digital glasses to recognize the markers necessary for experiencing AR [10]. AR can also be categorized into three types based on functionality: overlay, location, and projection. The overlay type involves using a physical object or marker, such as a QR code, to display AR content. The location type uses the user's geographical position, typically via GPS or a compass in their device, to display relevant AR content. Finally, the projection type uses devices like projectors or mirrors to display AR content in the user's environment without the need for surface detection [11].

C. How does Augmented Reality work?

It works by integrating virtual objects and real scenarios merged or combined to create mixed worlds based on visualisation and interactivity of real elements and virtual scenarios.

Some of the techniques used to model or render objects in AR are photogrammetry, 3D reconstruction (from 2D photographs), direct modelling by digital artists and/or combination of different techniques (using 3D scanners) [12].

D. Augmented Reality applications

Augmented Reality (AR) has various applications across different fields. In medicine, it is used to simulate surgical procedures. In advertising, it enhances promotional materials with interactive content. AR also aids in treating phobias by integrating objects related to the phobia into a patient's real environment. In tourism, it functions as a translator and provides navigational assistance at tourist sites. In sports, it offers additional information about players and games, while in automotive applications, it provides drivers with real-time road and weather updates [13], [14].

E. Retail Applications

Virtual fitting rooms are currently being implemented in retail, where the user can see how a garment fits without wearing it physically. For example, at the shop 'Zara', the fitting room requests measurements of the user's body. It puts them together with information from other customers with similar complexions to determine the size that best fits and would better suit the customer.

Another application is digital mannequins, which are projected in a space and can easily change their look or be projected on window displays to attract customers' attention and invite them into the store.

Finally, concept and pilot tests of AR implementations in the Furniture category are underway. For example, Ikea, the Swiss furniture shop, launched the 'Ikea Place' app, allowing users to place a wide variety of furniture, including sofas, armchairs, and stools, in real size within their environment using Augmented Reality [15], [16].

With these premises in mind, this article presents the results of a concept test in the retail sector within the furniture category in Mexico. It also details the techniques and negotiations employed to execute this test (the real name of the company will be omitted to respect privacy and maintain confidentiality, and the company shall hereon be referred to as *Copp*).

II. Storyboard: Furniture department

A first step in convincing the business (the company Copp) to carry out an Augmented Reality proof-of-concept in the Furniture category was to make a Storyboard that clearly shows how the proof-of-concept would be carried out (Storyboard previsualization enables teams to see images and text layouts before starting videos, software programming, or videogames. This process helps various business departments understand the project's objectives clearly and easily [17]). Fig. 1 shows the Storyboard used to help convince the managers of the Furniture category to try the Augmented Reality technology. The narrative of the Storyboard begins with the visualization of a couple's dream and desire to enhance their living space by acquiring a furnishing piece, exemplified by an armchair. Upon visiting the Copp store, the couple encounters a selection of armchairs, raising questions about the furniture's compatibility with their space and existing decor. At this juncture, a salesperson steps in, offering them the chance to visualize the armchair and other furniture items in their home via Augmented Reality by navigating a web page on their mobile phone without downloading additional applications. After returning home, this technology enables customers to envisage how the armchair would integrate into their setting, verifying dimensions and stylistic harmony with their decoration (see Fig. 2), akin to the experience of IKEA Place (one source of inspiration for this in-house proof of concept was IKEA Place [16]). [18].

After the presentation of this Storyboard, teams within the company were put together to carry out this project. The areas involved in this project were primarily three (the effective management of individual projects is not enough in today's organisations. Thus, the managerial approach and simultaneous interaction and effective linking will help to lead to a successful project within the business [19]):

- Furniture Department
- Technological Innovation
- Copp Research Center

Each of these areas had a strategic task so that the proof of concept could be carried out [19]. The work of each of the areas and their contributions to the project will be described below.

III. Interaction amongst areas

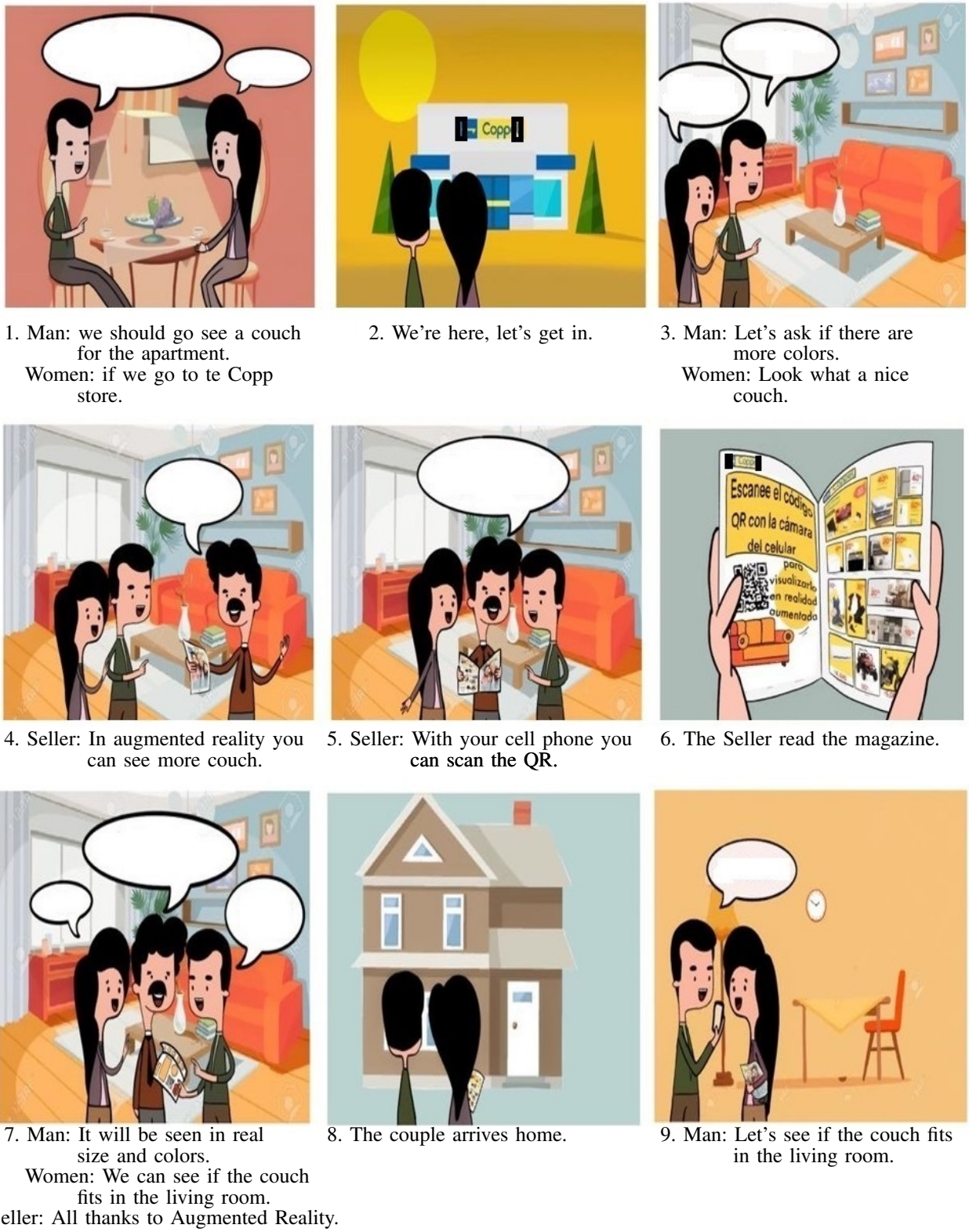
The first area that drove this proof of concept was the area of Technological Innovation.

A. Technological Innovation

This area aligned and coordinated the Augmented Reality initiative. The first step was to establish the implementation of Augmented Reality technology in the furniture retail channel (displaying furniture in Augmented Reality has proven effective within furniture Retail businesses as it helps to reduce the returns of large Furniture items since the customer can measure and see the Furniture in their home in Augmented Reality before purchasing it [16], [20]). This was achieved mainly by establishing that this technology will help to reduce customer returns, and the achievable percentage increase in sales. The company's sales databases were accessed for these calculations, and the data regarding returns for February, 2021, were obtained (this month was chosen because the analysis of carrying out the AR concept test began on these dates, as well as being the closest date on which we had access to the returns data for the Furniture category for the 2021 cycle). Table I shows the number of gross returns in Mexican pesos accounting for the ten most returned products in the month of February. In this same figure, the original image of the company was kept in its original language, and a query using SQL language was also used to obtain this information.

The total losses for these ten furniture items reached 37,464,013 Mexican pesos (about 1,784,000 USD), a figure derived from sales across 1,600 stores in Mexico. Such substantial returns indicate the potential for Augmented Reality (AR) to decrease these numbers significantly. Notably, the returned couches accounted for a loss of 3,359,858 Mexican pesos. Presenting this data helped to underscore the value of a proof of concept for AR within the furniture sector. This approach aligns with strategies recommended by Berman for implementing proof of concept studies [21].

An additional argument that initiated the proof of concept was the projection that Augmented Reality could enhance the furniture department's sales by 5%. Notably, this projected



1. Man: we should go see a couch for the apartment.
Women: if we go to te Copp store.

2. We're here, let's get in.

3. Man: Let's ask if there are more colors.
Women: Look what a nice couch.

4. Seller: In augmented reality you can see more couch.

5. Seller: With your cell phone you can scan the QR.

6. The Seller read the magazine.

7. Man: It will be seen in real size and colors.
Women: We can see if the couch fits in the living room.
Seller: All thanks to Augmented Reality.

8. The couple arrives home.

9. Man: Let's see if the couch fits in the living room.

Figure 1: Storyboard that illustrates the inception of a couple's aspiration to purchase Furniture and the subsequent invitation from the store's clerk to experience the Augmented Reality technology.

profit increase underwent a thorough review and received validation by the company (for confidentiality reasons, this number will not be presented in this paper).

Based on these projected profits, the Innovation Department collaborated with the Research Center to develop a platform for implementing Augmented Reality in Furniture.

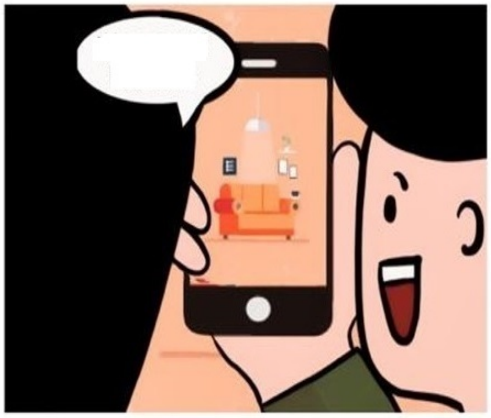
B. Copp Research Center

Initially, the intention was to hire an external supplier to create an Augmented Reality platform for showcasing furniture, akin to the IKEA Place application (IKEA Place is an app by the Swedish company that offers a vast selection

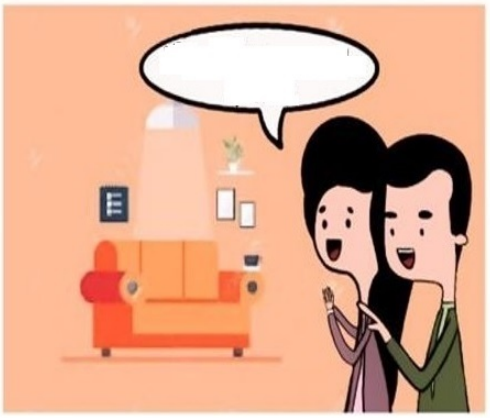
10. Man: With QR code the AR is deployment.

11. Women: AR is displayed on the mobile device.

12. Women: Let's try it. Man: Yes here in the living room.



13. Women: The couch combines and adjusts to the measurements.



14. Thanks to Augmented Reality we buy and we don't have to return it.

Figure 2: Storyboard that show the role of Augmented Reality in facilitating customers' purchase decisions. It depicts a sequence of events commonly encountered by couples during decision-making.

TABLE I: PRODUCTS MOST RETURNED TO THE STORE IN A MONTH (FEBRUARY 2021)

Amount of Months to take account	Furniture	Amount of money loss in Mexican pesos
1	COLCHON (MATTRESS)	-7,631,651
1	ANTECOMEDOR (DINING TABLES)	-4,839,504
1	COMEDOR (DINING ROOM SETS)	-4,237,587
1	SOFÁ (SOFA)	-3,359,859
1	ROPERO (WARDROBE)	-3,359,859
1	SOFA CAMA (SOFA BED)	-2,376,478
1	SALA (LIVING ROOM SET)	-1,932,338
1	RECLINABLE (RECLINER)	-1,612,401
1	CABECERA (HEADBOARD)	-1,352,410
1	CAMA (BED)	-1,284,197
1	ESCRITORIO (DESK)	-1,245,891
1	COMODA (DRESSER)	-1,008,042
1	ALACENA (PANTRY/CUPBOARD)	-993,970
1	BURO (NIGTHSTAND)	-710,621
1	MESA DE TV (TV STAND)	-654,651
1	MESA MULTIUSO (MULTI-USE TABLE)	-439,281

of furniture visualized in AR for customer convenience. See Alves for more details [18]). This approach served as a positive demonstration of AR's emerging role in Retail. However, reviewing the supplier's pricing revealed a two-tiered cost structure. The first tier included a fee for each instance of virtual interaction, priced at USD 60 monthly for every 1,000 clicks, increasing with higher traffic. The second tier entailed an unrestricted usage fee for a single sales channel, set at approximately USD 2,700 monthly.

Regarding the quotation for the rendering of 3D models, the pricing was established according to the complexity of the Furniture pieces. Typically, the cost is approximately 200 USD per model, delivered in .glb and .usdz formats for Android and iOS platforms, respectively.

A projected financial simulation for leasing the Augmented Reality platform yielded an estimated annual expense of $\$32,400$ USD. This figure is subject to increase with the incorporation of additional features. Upon detailed cost analysis, it was determined that the anticipated increase in sales and reduction in product returns would render the leasing

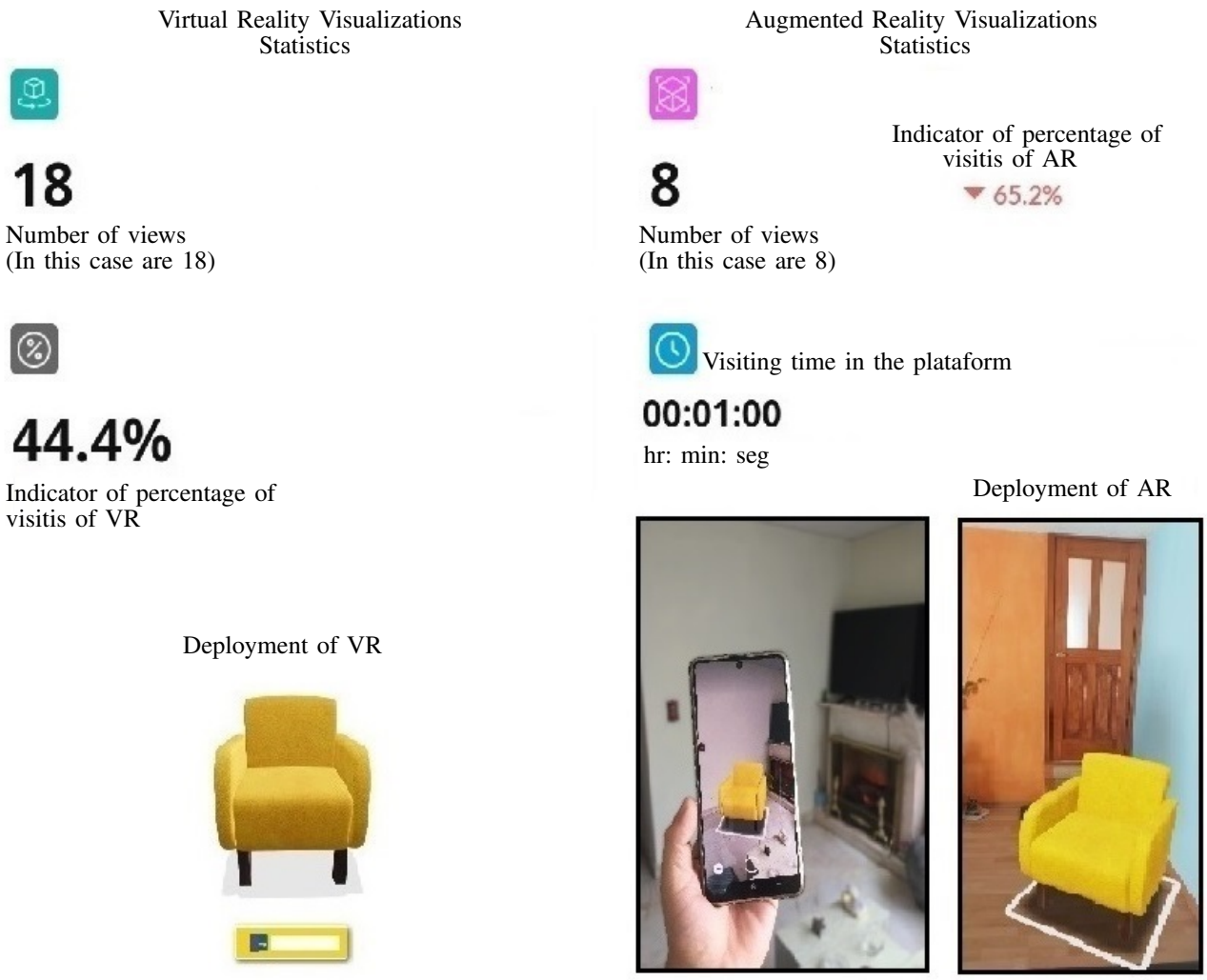


Figure 3: Visual summary of the Augmented Reality platform of an external supplier to the company. In this platform you can see the basic statistics (top image) of product visualisations and in the three images below you can see how the 3D models are displayed in Virtual Reality and Augmented Reality.

expenditure feasible for the company. Nevertheless, the corporate decision favored an in-house development approach, leading to the Copp Research Center's initiative to create a proprietary platform utilizing WebAR technology (for more information on this technology developed by Google, visit https://developers.google.com/ar/develop/webxr/model-viewer).

For this proof of concept, a dedicated landing page and a 3D model deployment platform were developed (the deployment platform serves as a specialized environment for hosting and user interaction with 3D models). Integration into the existing e-commerce system was deemed premature at this stage (the proof of concept, being in its initial phase, warranted the creation of an independent webpage outside the company's primary e-commerce framework). Figure 4 showcases the landing page, which features a selection of six furniture items for user interaction (the showcased furniture was curated by the company's Furniture department). The interface guides users from selecting furniture to viewing it in a virtual reality setting, complete with interactive buttons that facilitate a shift to an AR view. An additional survey captures user feedback on their AR experience. In one key visual, a red sofa is placed within an AR representation of an apartment (optimized for mobile use, the page layout is designed for intuitive navigation and ease of use). The AR functionality, developed using Google's ARCore and the <model-viewer> web component, allows for interactive 3D model viewing without the need for additional app downloads (Google's ARCore facilitates immersive AR experiences that merge digital with physical spaces, accessible via webpages without requiring app installation, for further details visit [URL] [22]). In tandem, an instructional video was created to aid customer engagement with the AR platform (refer to Fig. 5).

C. Furniture Department

The Furniture Department, through a sequence of deliberative meetings, identified six key furniture pieces for the proof of concept: a yellow armchair (the centrepiece), a black desk, a red sofa, a bookshelf, a green desk, and a black chair, as depicted in Figure 4. These items were selected based on their dimensions and popularity in sales. After selecting

1: Furniture chosen for the test test (six pieces)

2: Flagship couch of the pilot test (virtual reality)

3: Front developed in house

4: Deployment in AR within a real physical space

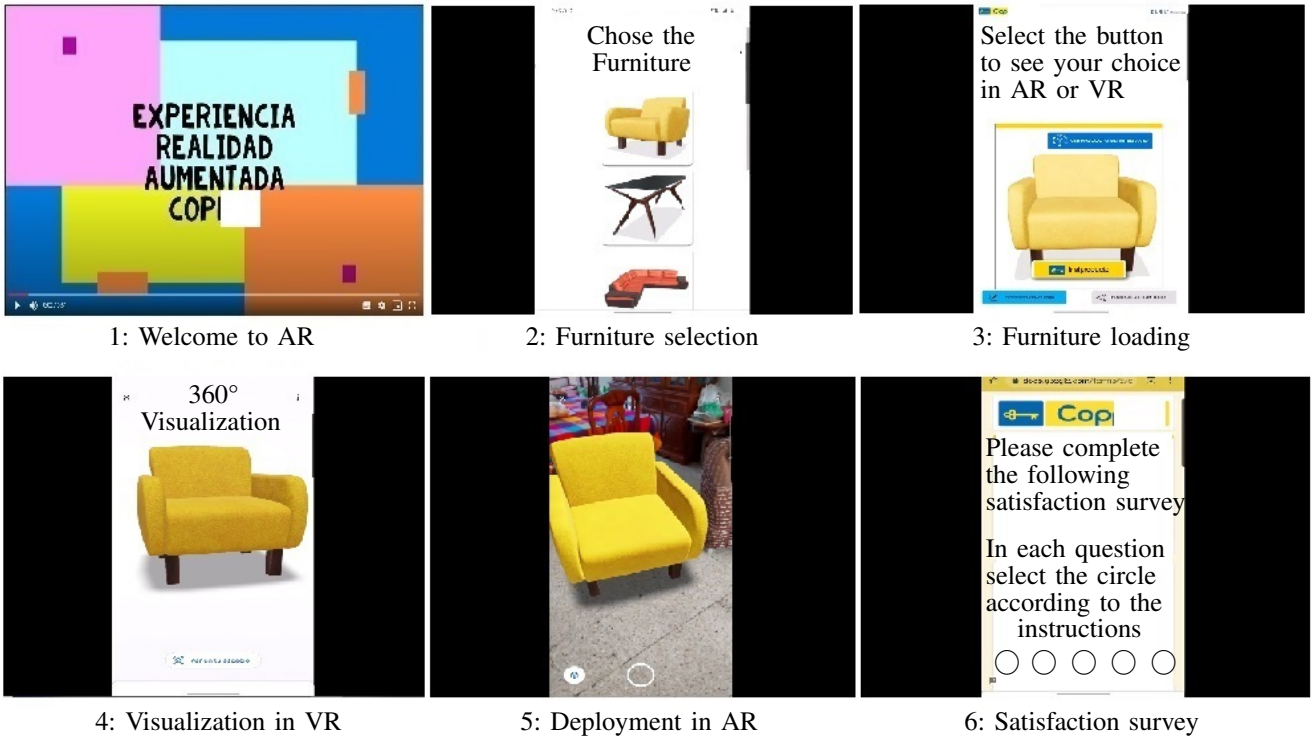
5: Survey applied. 1 is strongly 5 is strongly agree

6: Deployment in AR of red armchair

Figure 4: Landing page and Augmented reality platform made for the proof of concept in HTML language and ARCore. The name of the company as well as some parts of the landing page were blurred for confidentiality reasons. This Landig page has 6 frames.

these furniture pieces, the department chose a supplier to create the 3D models. The yellow armchair served as a standard for evaluating potential suppliers. The evaluation criteria included model color accuracy, geometry, texture quality, and cost-effectiveness. Figures 6-8 summarize the comparative assessment of three suppliers, focusing on color fidelity, texture resolution, and geometric accuracy.

Fig.6 displays the color evaluation of the models rendered by the suppliers compared to the original (standard) model. For this assessment, a comparison metric based on relative error was utilized. This metric, measuring deviations across the RGB channels (Red, Green, Blue), facilitated the identification of the supplier who most accurately replicated the original model's color, as detailed in equation (1).



1: Welcome to AR 2: Furniture selection 3: Furniture loading

4: Visualization in VR 5: Deployment in AR 6: Satisfaction survey

Figure 5: Main frames of the video tutorial recorded to guide customers through the Augmented Reality proof of concept: Furniture department. Some frames have been omitted and blurred for confidentiality reasons.

$$e_r(x) = \frac{\mu_c(x) - \mu_j(x)}{\mu_c(x)}, \tag{1}$$

where x is one of the RGB channels. μ_c is the average color of the yellow armchair (pattern model) taken from a frontal image (see Fig. 6). μ_j represents the average color of the yellow armchair rendered by supplier j (for $j = 1, 2, 3$), the number 1 correspond to the first supplier, and so forth, up to the third supplier. μ_c is the average color of the standard yellow armchair. The relative error results with respect to the three RGB channels are depicted in Figure 6, with Supplier 1 achieving the closest match to the standard model's color. The average relative error was the lowest among the three suppliers (see Relative Error column in Fig. 6).

Fig. 7 presents the geometric fidelity of the three supplier's models compared to the standard reference model (Geogebra software facilitated the geometric comparison among suppliers by uploading the frontal frames of the 3D models. For more information, visit https://www.geogebra.org/classic?lang=es). It is evident that the rendering of Supplier 2 exhibited the closest geometric resemblance to the standard model. Although this geometric comparison was not the sole determinant in the supplier selection process, it provided valuable insights for suppliers on necessary model adjustments. Furthermore, Fig. 7 highlights, with rectangles, the areas where the geometric discrepancies from the reference model are most noticeable at first glance.

Fig. 8 displays the texture comparison between the models provided by the suppliers and the standard model. Suppliers 1 and 3 achieved textures most similar to the standard model. This texture assessment, in conjunction with the color evaluation presented in Figure 6, led to the selection of Supplier 1 to develop the models for the Augmented Reality proof of concept within the Furniture Department.

After selecting the supplier, the Furniture department thoroughly validated the Augmented Reality platform's usability, complemented by a video tutorial to assist customers during the proof of concept (see Fig.4). The proof of concept was launched over three weeks following this validation process. During this phase, participating customers were invited to complete a survey, which the company's Research Center had meticulously developed to gauge the success of the initiative effectively.

IV. Proof Results

A. Methodology used to conduct the user study

The survey questions were meticulously crafted utilizing a methodology that incorporates the company's experiential insights and established survey design techniques referenced in the literature (see [23]). Firstly, discussion began with the different areas involved as to what kind of questions should be asked so that the information and statistics obtained could contribute to measuring the main hypotheses for this test, these being that Augmented Reality helps to increase furniture sales, AR increases the use of the Copp App and decreases product returns (Furniture Department).

Methodology:

- Choice of Furniture: Selection was based on meetings with the Furniture department, prioritizing the 20 most frequently returned items for display on the landing page.
- Design Meetings: Collaborative sessions with the Innovation and Furniture departments ensured the landing page remained simple yet visually appealing.
- Survey Accessibility: Easy access to the survey was provided via a direct link and QR code, taking into

Suppliers	Values of Color Red	Green	Blue	Color Hexadecimal	Relative error Red	Green	Blue
Pattern Model	237	169	2	#eda902	0%	0%	0%
Supplier 1	230	187	63	#a07116	3%	11%	3050%
Supplier 2	235	204	107	#cb9929	1%	21%	5250%
Supplier 3	255	213	67	#d09c2d	8%	26%	3250%

Figure 6: Color quality results from three suppliers are presented, including the relative error concerning the standard model, the average color per channel, and the hexadecimal color values. 'R,' 'G,' and 'B' denote the colors Red, Green, and Blue, respectively, while 'HEXA' is the abbreviation for Hexadecimal.

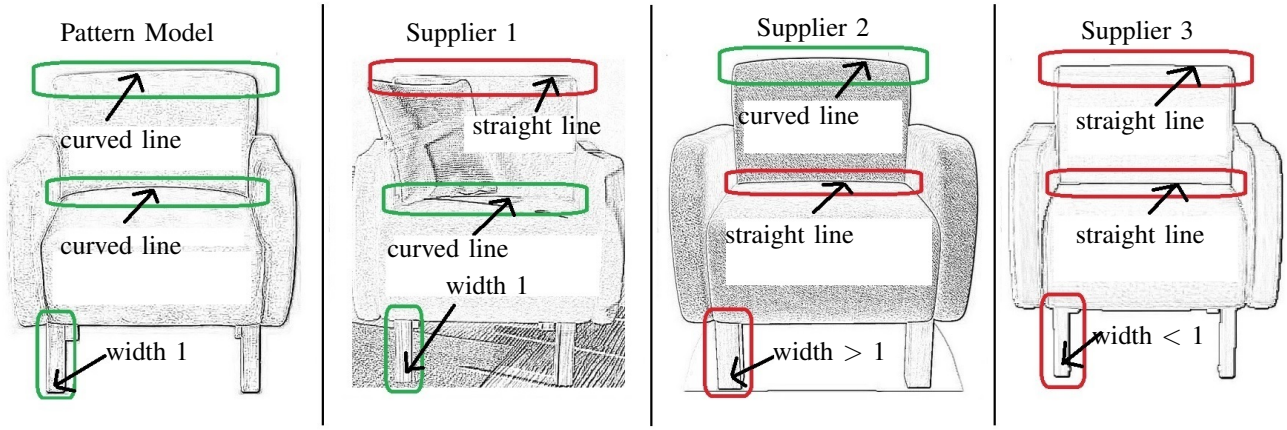


Figure 7: Geometric assessment of the models rendered by the suppliers relative to the standard reference model. While this comparison did not serve as the decisive criterion for supplier selection, it facilitated the identification of required geometric corrections in the supplier's models. Discrepancies from the reference chair model were delineated with rectangles for precise modification guidance. Rectangles red discrepancie and rectangles green similarities.

account the sociodemographic data of Copp customers (refer to Table II).

- Question Formulation: Questions were crafted to statistically validate the Augmented Reality proof of concept hypotheses without directly querying users about these hypotheses.

Table II shows a summary of the respondents' main sociodemographic characteristics. The total number of participants was 155. Socioeconomic status classification was based on criteria from the Department of the National Institute of Statistics and Geography (INEGI) of Mexico [24]. To qualify as upper class, an average income of 77,975 Mexican pesos per month is required; the middle class is defined by an income of 22,927 Mexican pesos per month, and the lower class by 11,343 Mexican pesos per month, according to 2021 data.

The survey was administered via a Google Form accessible through a button on the designated Landing page, as depicted in Figure 4. The results in Figures 9 and 10 indicate that 58.1% of respondents believe the Augmented Reality tool would influence their purchasing decisions, while 48.4% suggest it could reduce Furniture returns. Additionally, 45.2% feel that Augmented Reality enhances the shopping experience, potentially increasing user engagement with the Copp App. These insights suggest a probable increase in sales and a reduction in the likelihood of product returns.

V. Discussion and Conclusions

Approximately 76% of the literature reviewed on the applications of Augmented Reality (AR) in retail discusses

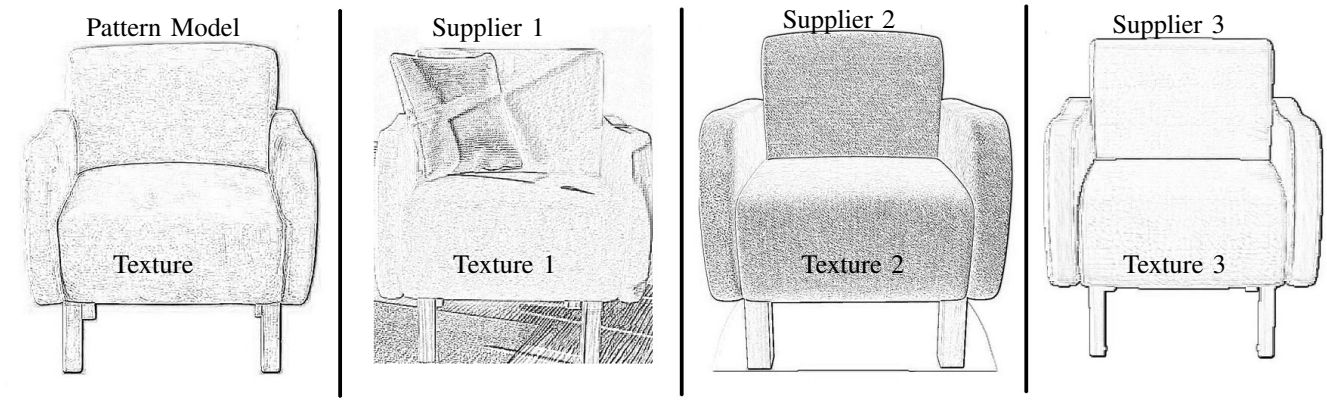


Figure 8: Comparison between textures of the models rendered by the suppliers compared to the standard model. It can be noted that supplier 1 (Texture 1) and supplier 3 (Texture 3) had the closest approach to the Pattern model (Texture).

TABLE II: SUMMARY OF SOCIODEMOGRAPHIC DATA

Total of respondents 155			
Socioeconomic Status	Lower class	Lower class	Middle class
Age range	18-25	26-35	35-50
Number of respondents	48 Copp customers	60 Copp customers	47 Non-customers

studies or laboratory experiments. At the same time, the remaining 24% focuses on research surveys where AR is not implemented. Notably, there needs to be more documentation on conducting effective AR tests in retail with real customers and actual implementations in a sales channel, such as a company's app. This paper outlines a methodology for executing a genuine proof of concept in a retail setting and developing a proprietary AR app tailored to the business's specific needs, considering AR's ability to place virtual objects in desired locations [25].

AR can increase sales and reduce product returns in the furniture category. Implementing this technology requires a proof of concept that involves stakeholders from innovation, software development, external suppliers, and the furniture category.

For the successful implementation of Augmented Reality technology in Retail, it is advisable to adhere to the following steps:

- Develop a storyboard that visually demonstrates to managers the contribution of augmented reality (AR) technology to enhancing customer experiences within the Furniture department (see Fig. 1).
- Collaborate with personnel from the innovation and software development teams, the Furniture department, and external suppliers to foster a multifaceted approach.
- Construct a model deployment platform for AR using WebAR, a technology supported by Google AR Core (see [22]).
- Design a landing page seamlessly integrating the WebAR deployment platform to facilitate user interaction (see Fig. 4).
- Formulate a survey to evaluate the effectiveness of the proof of concept, thereby providing empirical support for the potential expansion of AR technology on a national and omnichannel scale. This strategic move aims to augment furniture sales and minimize returns via AR technology (see Figures 9 and 10).

Efforts are progressing to integrate the internally developed AR platform into the e-commerce framework, with expectations that this innovative technology will be adopted across the entire enterprise.

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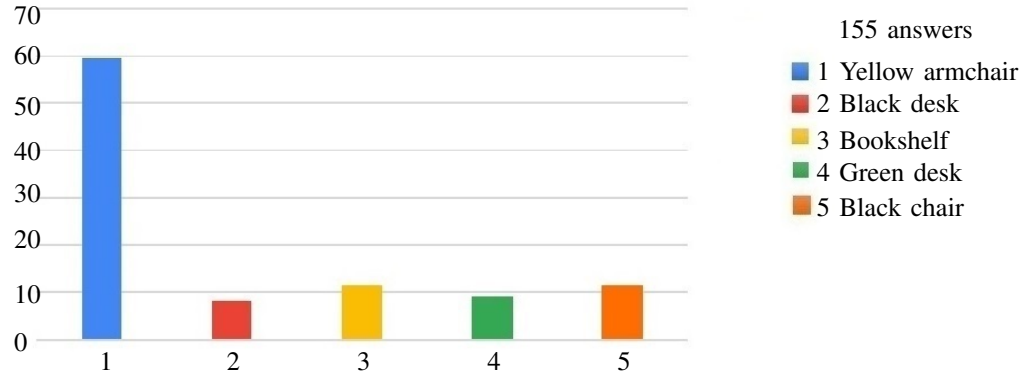
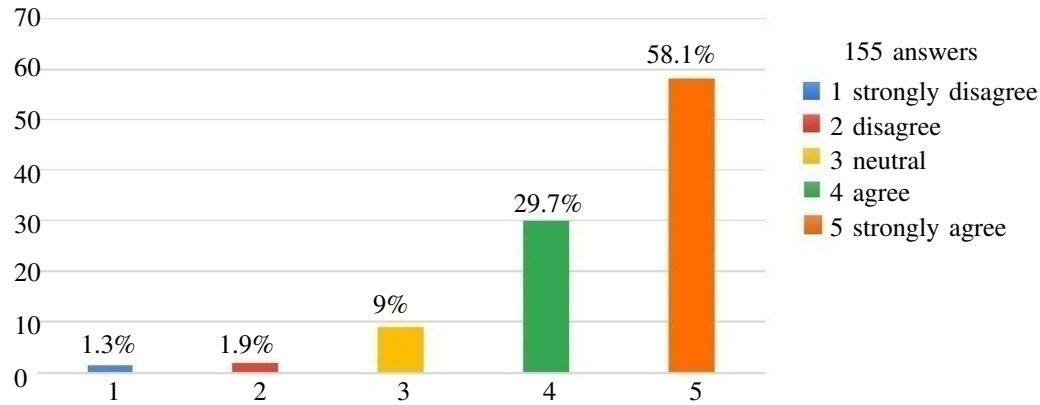
Question 1: What products did you choose for the Augmented Feality experience?



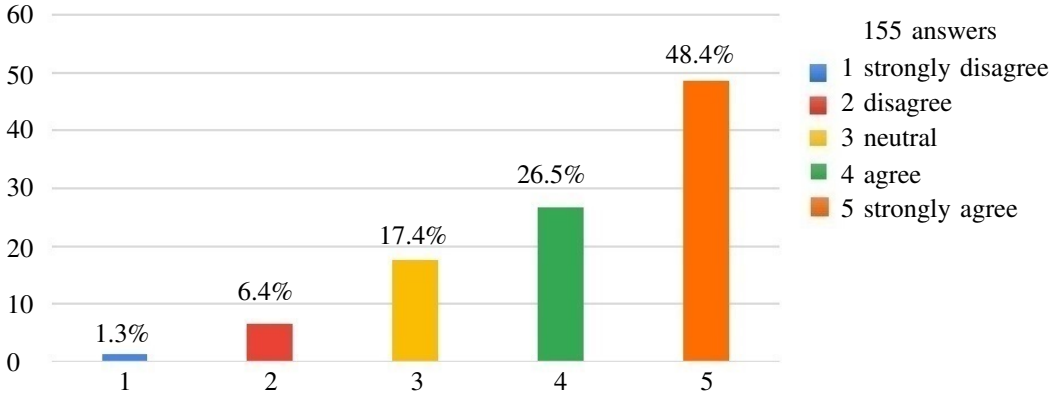
Percentage of Furniture selection to be displayed in Augmented Reality.

Question 2: How much do you think this tool would influence your purchasing decision?



Percentage of response selection for question 2, of the satisfaction survey.

Question 3: How much do you consider that this tool would decrease Furniture returns?



Percentage of response selection for question 3, of the satisfaction survey.

Figure 9: Results of the surveys conducted during the Augmented Reality proof of concept for the Furniture department. The scale used is from 1 to 5, where 1 is strongly disagree and 5 is strongly agree.

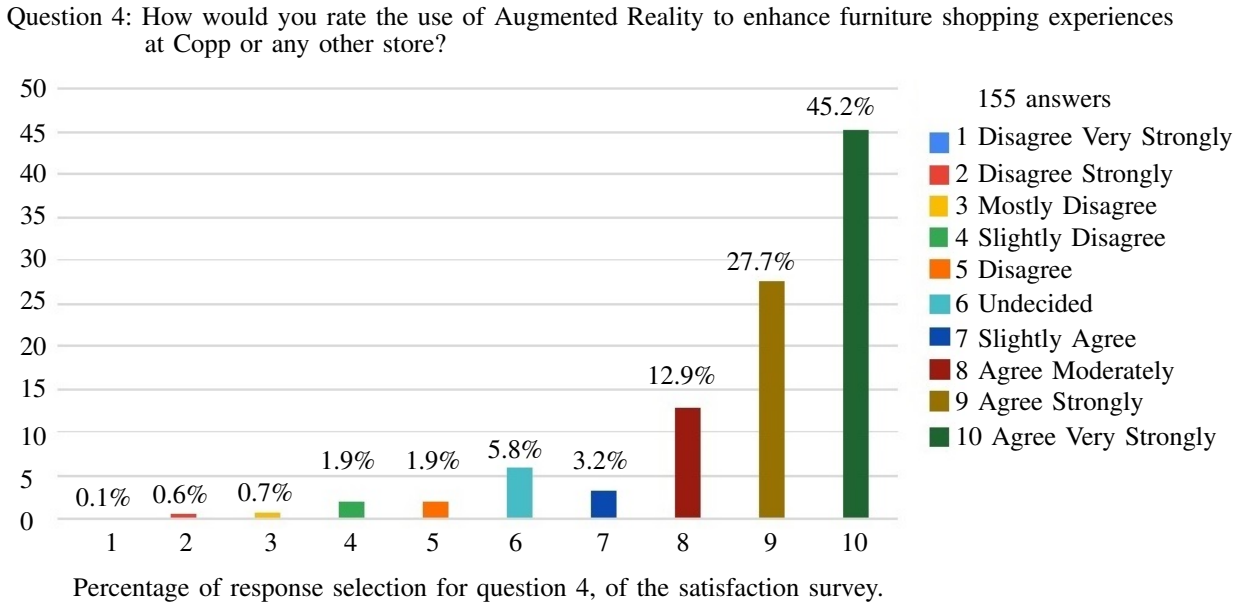


Figure 10: Scale of responses: starts from Disagree Very Strongly 1 to Agree Very Strongly 10. It can be noted that approximately 45% think positively that Augmented Reality will improve the shopping experience.

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