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Application of Augmented Reality in Printed Products as an Innovation Alternative for the Printing Industry in Brazil

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Abstract

The present work aims to present possibilities for the innovation process of activities developed by the graphic industry in Brazil, using augmented reality technology (AR). A literature review was carried out and two methods were used to collect data: a survey questionnaire and semi-structured interviews. The first method was the elaboration and application of a survey questionnaire among representatives of companies in the Brazilian printing industry. The other method used was the development of semi-structured interviews between representatives of technology companies in Brazil specializing in AR technology. The results of the work present the data obtained with the methods used for data collection. The results obtained from the survey questionnaire indicated that the application of augmented reality in printed products is a resource little explored by the printing industry in Brazil. The technology companies participating in the study had a consensus about the possible offering of all technical support necessary for the functionality of AR technology. The researchers believe that the results obtained in this work consolidate relevant information about possibilities for innovation in the activities carried out by the Brazilian printing industry.

Keywords
Printing Industry 1, Printed Products 2, Technology 3, Augmented Reality 4 and Innovation 5.

1. Introduction
The printing industry began with the advent of letterpress printing led by Johannes Gutenberg in the mid-15th century. From then on, there was a systematic development in the process of transmitting information, which enabled the democratization of knowledge on an unprecedented scale. Currently, the process of transmitting information using resources such as computers and other devices connected to the internet is almost instantaneous.

The contemporary challenge for the printing industry has become to justify the importance and need for printed products in a global context with high use of digital resources. After the spread of the internet and its application in corporate and domestic environments, relationships between people began to migrate from analog to digital contexts. Over the last decade, it has been possible to observe the widespread use of smartphones in several nations, a process that is still constantly growing. This process is causing drastic changes in people's relationships with the media and is related to the knowledge of how to perform specific tasks. Considering current business, companies should not remain isolated when negotiating goods and services but rather interact among participants throughout the production process in the search for better results (Webb and Romano 2017).

The development of digital technologies, which occurred with greater emphasis from the last decades of the 20th century, has enabled the creation of new business models to produce goods and services. In this context, even traditional companies specializing in analog technologies could innovate their production processes by increasing digital resources. Digitalization is one of the main factors that will direct a large part of production processes towards the context of the fourth industrial revolution. Thus, everything that can become digital will be digitized. Although many physical resources may be scarce, digital resources are abundant. The companies that will stand out positively in the ongoing technological revolution will be those that can adapt more quickly to new digital models to produce goods and services (CEPI 2015).

Product innovation involves the development of new goods and services, and this process is a critical factor for changing markets, in which the creation of new products represents the possibility of success, renewal, or even survival of companies (Eisenhardt and Tabrizi 1995). Augmented reality (AR) technology began to be disseminated with greater emphasis at the end of the 20th century. Currently, the considerable improvements in mobile computing devices that are easily accessible to a greater number of users, and the increase in internet connection speeds have become attractive factors for the development of new applications to use this technology (Qiao et al. 2019).

The use of printed products, on several occasions, is linked to the provision of services. A person seeks to purchase a published printed product to obtain the information and knowledge contained in the product. A printed catalog promotes the offer of products and services. Printed packaging may, in addition to packaging a product for logistical purposes, represent a communication channel between manufacturer and consumer. In this context, printed products represent the possibility of disseminating knowledge and experiences with different functionalities and can have added value.

This study was based on the following research question: How can stakeholders involved in the activities of the Brazilian printing industry innovate the offering of products and services using digital technologies?

The aim was to seek information about the advantages of integrating already consolidated processes and new technologies to improve the results of activities carried out by the Brazilian printing industry.

1.1 Objectives

The general objective of this study is to present possibilities for the innovation process of activities developed by the printing industry in Brazil, using augmented reality technology (AR).
The specific objectives of this study included:

a. Identify the characteristics and particularities of AR technology in academic literature.
b. Develop and apply a survey questionnaire to companies in the printing industry in Brazil, to check the level of adherence to AR technology used with printed products.
c. Verify the strategy for outsourcing information technology (IT) services as a possibility for partnership between technology companies, specializing in AR applications, and stakeholders from the printing industry to contribute to innovation strategies in the creation and production of printed products in the Brazilian market.

2. Literature Review

The manufacturing of printed packaging currently represents the printing market segment with the greatest economic growth in the printing industry. Some of the main factors that contribute to the growth of the printed packaging market correspond to the characteristic of being a printed product that cannot be replaced by digital products, the dual functionality of packaging as an element to provide protection and communication, the trend towards demographic urbanization with an emphasis in emerging countries and consequent improvement in income levels. Also, the trend of changing consumption habits should be considered with the option of purchasing fractionation, with an emphasis on food (Costa 2018).

The printing industry can no longer consider its customers as passive agents in the process of creating and developing its products. The integration between clients and companies in the project creation process will enable greater value generation in the results obtained (Viljakainen et al. 2016). The way of thinking about marketing strategies has undergone several changes in the last two centuries. The most impactful transformation that occurred in the transition between the 20th and 21st centuries is known as “the new dominant logic of marketing” (Vargo and Lusch 2004). This thinking considers that previously, marketing presented a concept centered on consumer goods, in which tangible products were negotiated with little interaction between the parties. From now on, marketing emphasizes the vision of services, with most products being intangible and commercial relationships being centered on the strong relationship between companies and customers.

A study carried out by (Tiekstra et al. 2016) involved 217 companies in the printing industry in 11 European countries. In this study, those involved recognized the need to develop new strategies that can consolidate the permanence of the printing industry in the context of digital media. The main needs for changes mentioned involve the efficiency of digital platforms with the use of the internet to sell printed materials, the flexibility of printing service on many substrates, increased value in printed products, and the printing of products not associated with traditional communication media (printing functional). The study also identified the need to improve communication between everyone involved in the printing production process, emphasizing the importance of service-oriented productions. The results of the research carried out indicated that 41% of the participating companies offered innovative solutions in printed products and 48% remained in traditional activities. Another important piece of information obtained in the study indicated that, in most companies, the main source of revenue came from traditional printed products. The delimitation of what could be classified as innovation in printed products considered the following modalities: electronic printing, smart printing, functional printing, and the combination of physical printing and digital resources, for example: (QR code) and augmented reality (Tiekstra et al. 2016).

The configuration of the printing industry in Brazil and other countries, as a business model that can endure and adapt to the context of the digital era, requires rapid perception of changes in the demand for printed products, which should preferably be consolidated alongside service platforms to generate added value (Costa 2018).

Until a few years ago, the high cost of devices associated with AR was the main limitation to the dissemination of the technology. Currently, this limitation is being mitigated through the high commercialization of portable devices such as smartphones and tablets, with most of these devices having compatible hardware characteristics for the application of AR technology (De Pace et al. 2018). Portable devices of various models are enabling the secondary development of AR technologies, in which virtual information is superimposed on the perception of the real world for users to view. These devices have integrated resources such as cameras, GPS, trackers, high-capacity processors, and internet connectivity (Yaoyuneyong et al. 2016).

The penetration of smartphones is reaching saturation levels in several consumer markets, while a new trend is occurring involving the mobile electronic devices market. People have shown interest in the possibility of using wearables that can provide solutions for everyday activities in situations that just the use of smartphones cannot (Seneviratne et al. 2017). While handheld smart devices are becoming popular in many countries, the continuous development of technologies has led to the preliminary introduction of other portable devices with better adaptation to the human anatomy (Yaoyuneyong et al. 2016). Some examples of wearable devices include smart watches, smart glasses, electronic bracelets and jewelry, and electronic clothing, among other possibilities (Seneviratne et al. 2017).

The application of AR in the printing media sector is a relatively new strategy. However, it is a resource that is getting attention through the growth and speed in the use of digital technologies. The use of AR resources associated with printed products is not restricted to the possibility of extending the space available for inserting information. Furthermore, the intention of combining resources allows the expansion of the user's sensory perception, who will be able to interact with the combination of physical and digital resources (Georgiadou and Margaritopoulos 2019).

A printing company responsible for the printing process on various substrates is at the end of the value chain of the printing production process and only prints substrates. A digital printing company could have greater participation in the process of configuring printed media with AR applications and could even provide and manage all the necessary infrastructure. Advertising agencies identify themselves as pioneering agents in the media innovation process and are therefore responsible for offering all the necessary support for marketing production to their clients (brand owners). Large clients (brand owners) outsource their marketing work to advertising agencies (Siltanen et al. 2017).

3. Methods

Using the keywords: (printing industry) and (industry 4.0), a bibliometric process was initially carried out to obtain information associated with the research question. The following scientific databases were used for the bibliometrics process: Web of Science; ScienceDirect; Taylor & Francis and Google Scholar.

Two methods were then used to collect data, a survey, and semi-structured interviews. The survey was carried out online, by *Google Forms*, and included the participation of professionals from different regions in Brazil. There was a presentation of the research, as well as its objective among associations of the Brazilian printing industry. The research communication was carried out via e-mail between the researcher and the printing industry associations in Brazil. Therefore, the message containing the access link to the content of the survey questionnaire was forwarded to printing companies represented by regional associations. The semi-structured interviews were carried out through the participation of professionals working in four technology companies located in the southeast region of Brazil, specializing in AR resources. The information obtained through semi-structured interviews was subsequently subjected to textual data processing using the IRAMUTEQ software.

4. Data Collection

The objective of using the survey questionnaire was to verify the level of adherence to AR technology applied to printed products in the printing industry in Brazil. The main positive contributions to the application of the survey questionnaire in this study were: the ease of disseminating the questionnaire to the different regions of Brazil, the ease of analyzing the data obtained, the diversity in the format of the questions proposed, the low cost for application, the control on the complete completion of the answers and the direction of the questionnaire according to the participants' initial answers.

The objective of carrying out semi-structured interviews was to verify the strategy of outsourcing information technology services as a possibility of a partnership between technology companies, specializing in AR applications, and stakeholders from the printing industry in Brazil, contributing to the innovation process for the creation and production of printed products. This stage of the research included the participation of four companies specialized in the development of AR technology with the possibility of use in printed products. The participation of each company was made possible through interviews recorded via mobile phone, in which the researcher was the interviewer.

The IRAMUTEQ software (*Interface de R pour les Analyzes Multidimensionnelles de Textes et de Questionnaires*) was developed by the Frenchman Pierre Ratinaud and uses programming language (python) added to statistical tools from the R software. The IRAMUTEQ software allows impartial analyses of textual content enabling obtaining relevant information and directions for use in studies and research (Souza et al. 2018). In this way, text segments with vocabulary differences are arranged in other elementary context classes that are also generated through software analysis. Among other analyses made possible through the software, the following stand out, descending hierarchical classification, factorial correspondence analysis, similarity analysis, and word cloud (Camargo and Justo 2013).

5. Results and Discussion

5.1 Survey Questionnaire

The survey applied in this study was specifically aimed at professionals in the printing industry in Brazil and had the collaboration of 80 persons from different regions of the Brazilian territory.

The survey research consisted of objective questions that were mandatory and only one optional essay question. The first five questions of the questionnaire were the same for all participants. The fifth question aimed to identify the participants' previous experience with the use of AR technology in printed products, with the answer to this question being conditional for directing the questionnaire into two possibilities for the completion sequence.

The first question only requested the respondent's consent to participate in the research, complying with the Brazilian General Personal Data Protection Law. The researcher presented his contact information for any clarification that was necessary regarding the purpose of the research.

The second question asked the participant to indicate the location of their professional activity in Brazilian territory. According to the responses, (70%) of the participants represented professionals from the printing industry working in the southeast region of Brazil, (16,2%) of the participants represented professionals from the printing industry working in the south region of Brazil. The greater concentration of companies in the Brazilian printing industry in the south and southeast regions is mainly associated with greater demographic density and a high concentration of industrial companies from different segments in these regions. Printed products, with emphasis on packaging, are items linked to other industrialized products. Therefore, the location of printing companies in regions with a high number of industrial companies from different segments favors the logistical process of supplying printed products associated with other products.

The third question asked the participant to indicate the number of employees working in their company. The results indicated that 23,8% of participants worked in companies with a maximum of 9 employees, 35% of participants worked in companies with between 10 and 49 employees, 20% of participants worked in companies with between 50 and 249 employees, and 21,3% of participants worked in companies with more than 250 employees.

The fourth question of the questionnaire asked the participant to indicate the specific demand for printing made by their company. According to the responses obtained in the survey: 32 responses among the participating companies were related to the production of publishing printing; 30 responses among participating companies were related to the production of promotional printing; 46 responses among participating companies were related to the production of printed packaging, and 26 responses among participating companies were related to the creation and design. There were also responses associated with other specificities of printed production but in smaller numbers. For this question, the participant could choose more than one available alternative. Small printing companies, which represent a large part of the Brazilian printing industry, tend to diversify their operations by producing publishing, promotional print, and packaging. This result indicates that the printed packaging market in Brazil could be an attractive sector for innovation strategies with the increase of AR technologies.

The fifth question of the questionnaire asked the participant to indicate their company's previous history of experience in using augmented reality features in printed products. This question aimed to direct the participant to two possibilities for completing the questionnaire. If the participant stated that they had no experience with projects involving the use of AR in printed products, there would be a need to answer only two more questions to complete the questionnaire. If the participant claimed to have experience using augmented reality in printed products, they would need to answer five more questions to complete the questionnaire. Most of the participating companies did not have experience in producing printed products with the application of AR technology. This result indicates that there may be a gap to be filled in the dissemination of knowledge about AR technology as a digital resource for innovation in printed products in Brazil.

For participants who marked the option (No) in the fifth question, stating that they did not have experience using AR, the questionnaire would direct to two more questions as follows.

In the sixth question, the participant could select more than one alternative, according to their understanding, of the possible need for using AR technology with printed products. The result demonstrated that: 37 participants indicated that improving marketing aspects would be the main justification for using AR with printed products; 36 participants indicated that improving communication aspects of the printed product regarding the functionality of a product or service would be the main justification for using AR with printed products; 31 participants indicated that improving aspects of instruction and education would be the main justification for using AR with printed products; 28 participants indicated that aspects regarding sustainability would be the main justification for using AR with printed products. This result indicated an opportunity for innovation in the marketing communication of printed products, using AR technology.

The seventh question of the survey questionnaire, for participants who marked the option (No) in the fifth question, stating that they did not have experience using AR resources, had an optional answer. This question aimed to verify the participants' perception, of the possible need for innovation related to printed products, through the insertion of AR. Most responses to this question consisted of positive statements about the possibility of innovating printed products through the application of AR.

The questionnaire would be directed to five more questions for participants who marked the option (Yes) in the fifth question, stating that they had experience in AR resources.

In the sixth question, for participants who selected the option (Yes) in the fifth question, the participant could select more than one alternative, according to their previous experience, regarding the possible needs for using AR with printed products. The result demonstrated that: 14 participants indicated that improvements in marketing aspects were the main reason for using AR with printed products; 9 participants indicated that the improvement in communication aspects of the printed product regarding the functionality of a product or service was the main reason for using AR with printed products; 7 participants indicated that improvement on aspects of instruction and education was the main reason for using AR with printed products and 8 participants indicated that communication about sustainability aspects was the main reason for using AR with printed products. This result indicated some trends regarding innovation in the marketing communication of printed products, using AR resources.

The result of the seventh question of the survey questionnaire, for participants who marked the option (Yes) in the fifth question, indicated that most projects already consolidated using AR with printed products included the partnership of technology companies specialized in AR. This result indicates the partnership between companies in the printing industry and technology companies in Brazil as a good alternative for the innovation of printed products using AR resources.

The result of the eighth question of the survey questionnaire indicated that most projects using AR resources with printed products were well accepted by customers. This result demonstrates that innovation in printed products using AR resources can be seen as a promising strategy for companies in the Brazilian printing industry.

The result of the ninth question of the survey indicated that, according to the participants in the research, there is a considerable demand for using AR with printed products. Furthermore, according to the participants, many customers in the Brazilian market for printing products, currently do not know about AR technology. This result indicates that the consolidation of new projects with the use of AR resources can increase the demand for this type of technology as an innovation factor for printed products.

The tenth question of the survey questionnaire was optional. The participant was asked to describe, based on his experience, some possibilities of innovation for printed products, using AR resources. All responses described positive statements about the possibility of innovating printed products using AR resources. Participants highlighted the fact that AR technology can enable the creation of greater interactivity between customers and companies through printed products.

Table 1. Objective Questions and Answers of the Survey Questionnaire.

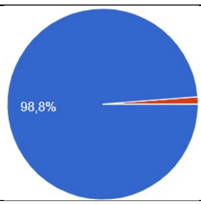
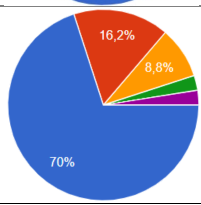
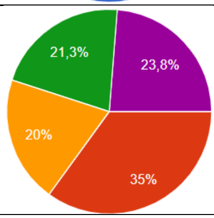
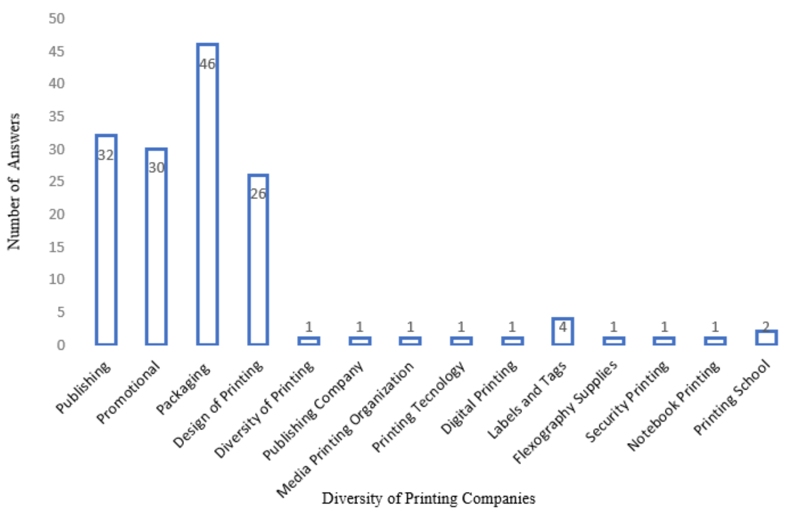
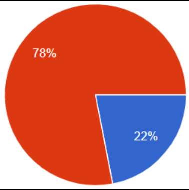
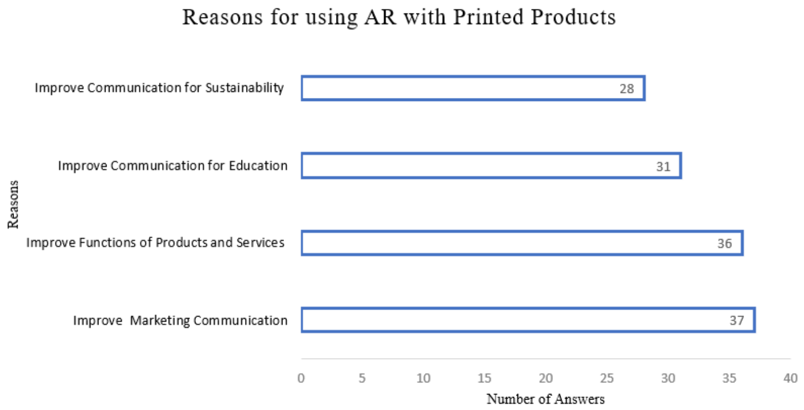
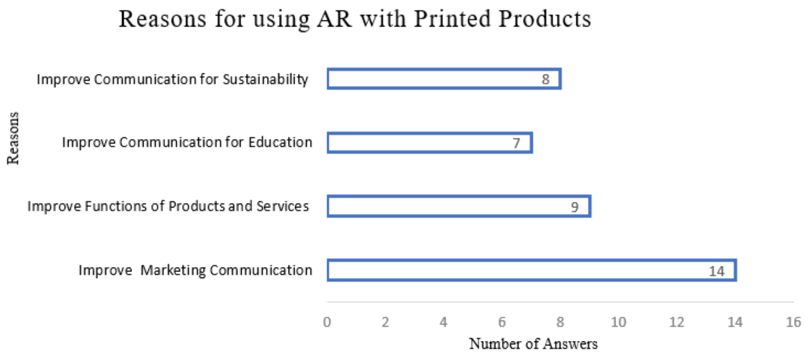
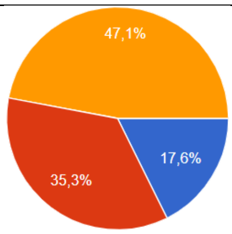
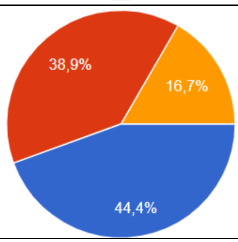
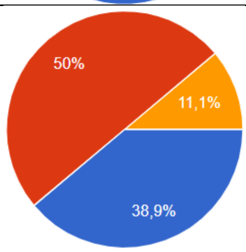
Questions	Answers	
I declare that I understand the objectives of my participation in the research and agree to participate. I also register that I agree to the processing of my data for the specific purpose of this research, under Law no. 13.709, Brazilian General Personal Data Protection Law (LGPD).		Yes No (1,2 %) (81 answers)
The company you are part of is in which region of Brazil?		North (2,5%) South Southeast Center East Northeast (2,5%)
Select from the options below the alternative that presents the number of workers working in the company you are part of:		Maximum of 09 Between 10 and 49 Between 50 and 249 More than 250
The company you are part of meets which of the possibilities presented, regarding the demand for printed production? (you can select more than 1 option):		

Table 2. Objective Questions and Answers of the Survey Questionnaire. (Cont'd)

Has the company you work for produced any printed products with the application of Augmented Reality technology?		No Yes
Among the options, do you consider which of the alternatives is the best justification for the inclusion of Augmented Reality with printed products? (you can select more than 1 option):		
Among the options, what were the purposes of including the Augmented Reality feature in the printed products produced by the company you are part of? (you can select more than 1 option):		
What was the origin of the software used to apply Augmented Reality technology with printed products produced by the company you are part of?		The software used was developed by another company, in a non-personalized way, for our specific needs. The software used was developed by another company, in a customized way, for our specific needs. The software used was developed by our company.
After consolidating the experience of applying Augmented Reality technology with printed products, was there interest on the part of the customer in maintaining the resource?		Yes, the experience brought positive results for the customer, and the process remains. Yes, the experience brought positive Results, and the customer is interested in expand the application. No, the experience did not bring good results, and the process was inactivated.
Based on the activities developed by the company you are part of, do you consider that there is growth in demand from customers for the application of Augmented Reality in printed products?		Many customers currently do not know about the possibility of applying Augmented Reality technology with printed products. Yes, we have seen more interest from our customers about Augmented Reality resources. No, customers do not seem to show interest in the application of Augmented Reality technology with printed products.

The results obtained through the application of the survey questionnaire indicated that the use of AR technology in printed products, as an innovation resource, is a process little used by the printing industry in Brazil. Most of the participants claimed to have no experience in projects to create printed products with AR technology. Participants who claimed to have experience in using AR technology in projects involving printed products stated that they had consolidated positive results for their customers. There was widespread consensus among participants about the possibility of innovating the offer of printed products using AR resources, with an emphasis on the possibility of improving marketing strategies. Table 1 shows the objective questions and the answers obtained by the survey questionnaire.

5.2 Semi-structured Interviews

The semi-structured questionnaire consisted of five questions, formulated in coherence with the theoretical framework of this research and aimed at companies specialized in the development and application of AR technologies.

The interview script contained the following questions:

a. What are the possibilities offered by the company applying AR with printed products using mobile devices such as smartphones, smart glasses, and smartwatches)?
b. What are the possible advantages offered to companies for project creation and maintenance services involving AR technology, linked to printed products, through the outsourcing of information technology services?
c. According to the history of the evolution of AR applications in recent decades, how do you see the prospect of growth in the use of this technology?
d. With the possibility of improving network connection, by the Internet (5G), what is the company's perspective, considering the demand of the Brazilian market, for the use of AR through mobile devices and applications via the web?
e. What are the main difficulties currently facing the dissemination of the applicability of AR resources in printed products in the Brazilian market?

For reasons of confidentiality, the technology companies were defined as (Alpha Company), (Beta Company), (Gamma Company) and (Delta Company). It is important to highlight that, for ethical reasons, all information obtained through the participation of technology companies is presented in this study in such a way that it is not possible to directly associate the results with any of the participating companies.

To facilitate the presentation and identification of analyses, word classes were defined considering respectively the following association between numbers and colors:

(a. Class 1-red) - (b. Class 2-gray) - (c. Class 3-dark green) - (d. Class 4-light green)
(e. Class 5-light blue) - (f. Class 6-dark blue) - (g. Class 7-magenta)

The percentage index of the textual word class segments was obtained using the descending hierarchical classification (CHD) analysis of the entire textual content of the interviews. Through CHD analysis, it becomes possible to check which parts of the analyzed text are the classes, which are present in the colored corpus option. This way, it was possible to verify that the content of the interviews obtained with the companies: (company Alfa), (company Gama), and (company Delta) were linked to all classes of words. The content of the interview obtained with (Beta company) was not linked to the class (7-magenta).

To better clarify the division of word classes obtained by software analysis, the classes were titled based on the context in which they were extracted from the interview content. This analysis is made possible through the resource called colored corpus, which is one of the software's resources for CHD analysis. This resource allowed the researcher to view all the textual content analyzed with the textual segments arranged in the colors relevant to each of the word classes. The class (1-red) was titled: *Limitations for the Popularization of AR Technology in Brazil*. The analysis of the textual content belonging to this class of words made it possible to verify the greater emphasis on the following statements made by the interviewees: the need for portability of a large part of the Brazilian population of smartphone devices with hardware resources with processing capacity for the use of the AR technology; need to improve internet connectivity in a democratic way in Brazilian territory for better application of AR technology; lack of knowledge of a large part of the Brazilian population about AR technology. Figure 1 shows the title given to the class (1-red) with the main words belonging to the class.

Limitations for the Popularization of AR Technology in Brazil

5G internet, processing, bottleneck, advanced, internet, connection, improvement, turn, application, infrastructure, technology, use, come, good, access, clear, native, QR-code, arise, issue, industry, enable, smartphones, pandemic, exist, camera, device, necessary, digital, old, develop, end, possibility, idea, leave, augmented reality, process, stay, need, advantage, depend, route, problem, identifier, aspect, relationship, best, fact, last, size, system, next, practical, proposal, seek, potential, nature, mobile

Figure 1. Main words associated with the red class obtained through CHD analysis.

The class (2-gray) was titled: *Software Structure and Functionality of AR Technology*. The analysis of the textual content belonging to this class of words made it possible to verify the greater emphasis on the following statements by the interviewees: possibilities for creating and managing software platforms necessary for the functionality of AR technology; ways of managing and editing AR content by users (ease of use); possibility of creating and managing AR applications for use on smartphones; benefits for customers (brand owners) on updating the software infrastructure necessary to use AR technology; possibility of reframing tangible products as the main justification for applying AR to printed products. Figure 2 shows the title given to the class (2-gray) with the main words belonging to the class.

Software Structure and Functionality of AR Technology

marker, upload, need, content, management, platform, image, software, update, recognize, link, work, new, call, format, printed, utilize, advantage, worry, eyebrow, month, read, start, design, computer, augmentation, application, rise, achieve, cell phone, place, place, perform, material, use, augmented reality, xar, function, trigger, visualization, people, team, end, generate, client, user, need, depend, via, relationship, system, practical, proposal, limitation, apple, screen, vision, principle, line, embark

Figure 2. Main words associated with the gray class obtained through CHD analysis.

The class (3-dark green) was titled: *User/Customer Interaction with AR Technology Features*. The analysis of the textual content belonging to this class of words made it possible to verify the greater emphasis on the following statements by the interviewees: examples of benefits generated for customers (brand owners) who use AR technology as a resource for innovation in products and services offered to the market; possibilities for using AR

User/Customer Interaction with AR Technology Features

client, area, application, production, website, xar, same, solution, team, case, apple, embark, retail, creation, realize, create, download, model, specific, visual, implement, believe, platform, want, store, come, only, content, product, own, offer, communication, people, generate, simple, company, general, need, depend, via, aspect, last, eyebrow, month, beginning, design, access, return, present, diverse, determined, play

Figure 3. Main words associated with the dark green class obtained through CHD analysis.

technology according to the resources offered by technology companies (project customization); attention to the need for autonomy of clients/users to use AR technology as an attractiveness factor regarding the applicability of the technology. Figure 3 shows the title given to the class (3-dark green) with the main words belonging to the class.

The class (4-light green) was titled: *Hardware Infrastructure and Resource Compatibility for the Use of AR Technology*. The analysis of the textual content belonging to this class of words made it possible to verify the greater emphasis on the following statements by the interviewees: the need for compatible mobile devices for the use of technology by users (smartphones, wearables); need for compatibility of hardware components in smartphones to better take the advantages and possibilities of the AR technology; need to consolidate satisfactory user experiences with AR technology as a factor in the adoption of the technology in the market; possibilities for expanding the applications of AR technology in the Brazilian market with products and services in various segments. Figure 4 shows the title given to the class (4-light green) with the main words belonging to the class.

Hardware Infrastructure and Resource Compatibility for Using AR Technology

smartphone, glasses, imagine, virtual reality, accessible, wearable, device, hand, developed, person, render, television, develop, start, access, wearables, dispose, cost, attention, emerge, shape, enable, perceive, use, universe, Facebook, know, experience, biggest, technology, achieve, thing, talk, new, year, apply, industry, market, problem, identify, fact, potential, nature, limitation, vision, present, interact, consume, bring, notion, important, border, right, curve, context, build, layer, seek, current

Figure 4. Main words associated with the light green class obtained through CHD analysis.

The class (5-light blue) was titled: *Possibilities of Elements for Generating Images in AR*. The analysis of the textual content belonging to this class of words made it possible to verify the greater emphasis on the following statements by the interviewees: exemplification of possibilities and objects that can be used with AR technology; possibilities for using AR technology to create videos and represent three-dimensional images; possibilities of using AR technology to try out products in virtual format; possibilities for editing AR content linked to printed products to provide a new meaning for products and services; possibility of using AR images in three-dimensional format, linked to printed teaching materials as a possible resource for improving the teaching and learning process. Figure 5 shows the title given to the class (5-light blue) with the main words belonging to the class.

Possibilities of Elements for Image Generation in AR

3D, video, support, body, design, human, floor, visualize, three-dimensional, face, character, table, transform, object, image, example, mode, material, treat, engage, trigger, exit, physical, buy, printed, environment, size, screen, context, real, book, thing, handout, associate, want, apply, user, call, offer, call, exist, rise, creation, simple, education, offer, product, need, identify, relationship, best, mobile, read, computer, rise, limitation, principle, retail, back, present

Figure 5. Main words associated with the light blue class obtained through CHD analysis.

The class (6-dark blue) was titled: *Possibilities for Expanding AR Technology in Brazil*. The analysis of the textual content belonging to this class of words made it possible to verify the greater emphasis on the following statements by the interviewees: the need for democratization of access to smartphones compatible with the application of AR technology among the Brazilian population; expectations for the expansion of AR technology in Brazil with the spread of broadband internet connectivity (5G); need to generate added value on AR applications, as an essential factor for better identification of the functionalities and benefits provided by the technology in the user's view; need for strategies to reframe traditional products with the use of AR technology. Figure 6 shows the title given to the class (5-dark blue) with the main words belonging to the class.

Possibilities for Expanding AR Technology in Brazil

Brazil, find, global, front, entry, different, believe, book, game, way, main, compatible, barrier, market, end, think, general, good, offer, company, together, publishing, tend, resource, possess, say, line, notion, transition, development, use, augmented reality, big, product, treat, help, technology, biggest, see, person, consider, project, world, functionality, happen, available, case, year, insert, only, industry, cellular, mode, native, aspect, ultimate, practical, proposal, seek, nature

Figure 6. Main words associated with the dark blue class obtained through CHD analysis.

The class (7-magenta) was titled: *Attractive Factors for Public Engagement with AR Technology in Brazil*. The analysis of the textual content belonging to this class of words made it possible to verify the greater emphasis on the following statements by the interviewees: the need for understanding, on the part of those responsible for creating content, about the user's perception in the process of applying AR technology; need for creativity to generate added value to the content linked to AR applications, considering the offer of products and services; need for general public perception of the potential of AR technology as a factor for innovation in production processes; need for user maturity regarding the use of AR technology; creation of marketing strategies to encourage user behavior to disseminate the use of AR technology. Figure 7 shows the title given to the class (7-magenta) with the main words belonging to the class.

Attractive Factors for Public Engagement with AR Technology in Brazil

public, brand packaging, challenge, help, natural, engagement, understand, metaverse, gamification, provide, strategic, create, leave, tool, question, business, possible, game, technological, enter, pass, store, shape, happen, real, find, virtual, perceive, next, determined, important, border, direct, curve, seek, current, interest, win, door, consumption, confuse, experience, become, say, education, use, speak, end, strategize, give, reality, interactive, active, only, person, process, open, possibility, digital

Figure 7. Main words associated with the magenta class obtained through CHD analysis.

The results of data collection from semi-structured interviews indicated that the Brazilian market has companies with the necessary knowledge to develop projects involving AR technology. All companies participating in this stage of the research have experience in offering the creation and maintenance of the resources necessary to apply AR technology with printed products. The treatment of data obtained in the interviews using the IRAMUTEQ software indicated that there is a correlation between the activities carried out by the four participating companies. There was consensus among participating companies regarding the consideration of AR technology as an innovation resource that is still little explored by the Brazilian printing industry. Furthermore, all companies participating in this stage considered the prospect of growth in the use of AR in the Brazilian market, especially with the spread of smartphones and other mobile devices (wearables), as well as the expansion and improvement of broadband internet connectivity.

6. Conclusion

This research work aimed to present possibilities for the innovation process of activities developed by the printing industry in Brazil, using AR technology. The digital transformation ongoing presents technological segmentation called enabling technologies, among which AR is present. In this context, AR technology presents itself as an important resource for the innovation of various production processes currently.

The bibliographical research also allowed us to verify consensus among different authors on the need to improve integration and communication between stakeholders involved in the printing industry's production chain. In this context, integration between clients (brand owners), designers, printing companies, and possibly other members is an essential factor for the consolidation of projects with the prospect of providing added value to printed products.

Currently, there is increasing democratization in access to AR technology, driven by the increase in the sale of mobile computing devices. It was possible to identify, through the research data collection instruments, that the application of AR technology has the prospect of growth in the Brazilian market.

The results obtained through the survey questionnaire indicated that the application of AR in printed products is a resource that is still little explored by the printing industry in Brazil. Participants, in general, stated that there is a considerable demand for the use of AR technology as an alternative for innovation in projects for the creation and production of printed products.

The technology companies participating in the study had a consensus about the possible offering of all technical support necessary for the functionality of AR technology. However, in general, there was a consensus among the participating companies that the applications of AR technology in printed products should preferably be associated with the possibility of adding value to the services linked to these products. The results allow consider that technology companies, specializing in the development of AR resources, can configure a new stakeholder in the production chain involving printing production in Brazil.

The triangulation of the results obtained in this study allows the consolidation of relevant information about possibilities for innovation in activities developed by the Brazilian printing industry through the integration between traditional printed products (promotional prints, publishing, packaging) and digital resources (augmented reality).

It is important to highlight that the development of this research took place between 2020 and 2022, a period in which restrictive measures to combat the COVID-19 pandemic made research activities considerably difficult.

Possible research to complement this study could use the case study method, to verify the application of AR resources in printed products already consolidated in the market. This verification would be useful for identifying possible changes in the results of the commercialization of printed products, after the application of AR resources as an alternative for incremental innovation for these products.

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