Revista ARACÊ
ISSN: 2358-2472

THE USE OF ADDITIVE MANUFACTURING IN THE DEVELOPMENT OF NEW PRODUCTS AND TECHNOLOGIES IN BRAZIL: A SYSTEMATIC REVIEW

https://doi.org/10.56238/arev6n4-157

Submitted on: 11/11/2024 **Publication date:** 12/11/2024

Miguel Olimpio de Paula Netto[1], Camila Souza Carvalho[2], Tatiana Tavares Rodriguez[3], Ercilia de Stefano[4], Moisés Luiz Lagares Júnior[5] and José Alberto Barroso Castañõn[6].

ABSTRACT
Additive manufacturing (AM), or 3D printing, has grown significantly in recent decades, revolutionizing several sectors by making it possible to create complex parts with less material waste. This article aims to analyze the use of AM in Brazil, focusing on its applications in the development of new products and technologies, in addition to identifying the main research challenges and trends. In this article, a systematic literature review was carried out, based on 55 articles published between 2014 and 2024, categorized by application areas, such as education, health, civil construction, assistive and industrial technologies, in addition to the identification of the processes and materials most used today. The results show that AM in the country is still dominated by consolidated technologies, such as FDM/FFF, with emphasis on health and the industrial sector. However, the exploitation of more advanced materials and techniques remains limited due to a lack of investment and skilled labor. The study concludes that, for Brazil to advance in the field of AM, it is necessary to diversify research with new materials and emerging technologies, in addition to investing in the training of professionals. These factors are essential for additive manufacturing to become a more competitive and sustainable alternative in the development of products and innovations in the country.

Keywords: Additive Manufacturing. 3D printing. Technological innovations. Product Development. Sustainability. Training.

[1] UFJF
Master's Degree in Built Environment - PROAC
Federal University of Juiz de Fora
[2] UFJF
Master's student in Built Environment - PROAC
Federal University of Juiz de Fora
[3] UFJF
Dr. in Civil Engineering with emphasis in Geotechnics
Federal University of Juiz de Fora
[4] UFJF
Post-doctorate in Civil Engineering - COPPE
Federal University of Rio de Janeiro
[5] UFJF
Dr. in Mechanical Engineering - FEMEC
Federal University of Uberlândia
[6] UFJF
Dr. in Transportation Engineering - COPPE
Federal University of Rio de Janeiro

Revista ARACÊ
ISSN: 2358-2472

INTRODUCTION

Although additive manufacturing is commonly associated with a recent manufacturing process, having gained relevance in the mid-2010s, it emerged in 1983 in Japan as a process known as Stereolithography. Since then, this process has been gaining notoriety due to its wide range of applications and its technological potential in terms of versatility and agility in the manufacture of unique and customizable products (Kocovic, 2017).

Although the process still has limitations, there are numerous associated advantages. According to Priarone, Catalano, and Settineri (2023), the reduction of up to 69% in the weight of components used in the automotive industry resulted in significant energy savings and a reduction in the carbon footprint, generating extremely positive environmental impacts. In addition, Wu and EL-Refaie (2020) highlight that additive manufacturing allows the construction of electrical machines with mechanical, electromagnetic, and thermal properties superior to those obtained by conventional manufacturing processes, making the process not only cleaner, but also more efficient.

The versatility and adaptive capacity of additive manufacturing are mainly associated with its ability to manufacture complex geometries (Wohlers; Caffrey, 2013), including intricate designs of microchannels in components. This characteristic makes additive manufacturing the only process capable of producing such geometries (Panara et al., 2022).

Another relevant aspect is the ability of additive manufacturing to move through several areas. In the metal-mechanic area, for example, (Zhang et al., 2018) manufactured parts using tungsten carbide powder (WC) and cobalt powder (Co), essential materials in the production of steels and tools. These parts had superior mechanical properties to those manufactured with the same materials by conventional methods. In the biomedical field, Duan et al. (2022) manufactured biocompatible synthetic bone tissues, with excellent mechanical properties, to aid in the repair of damaged bones. It is worth mentioning that this is an example of complex geometry manufacturing.

Numerous studies in the literature indicate the versatility and high technological potential of additive manufacturing, especially regarding the ability to produce high-quality parts with low investment and high agility in the manufacturing process. However, little is addressed in the Brazilian literature about the impact of this manufacturing process in academia and industries, especially in product engineering processes. Although additive

Revista ARACÊ
ISSN: 2358-2472

manufacturing represents a significant advance in this field, it is necessary to verify the directions that academia and Brazilian industries have followed.

In view of this, the present work proposes to carry out a comprehensive and systematic review of the impacts of additive manufacturing in the Brazilian industrial and academic context, with the objective of identifying the main products, research trends and methodologies developed in the national scenario. In addition, the challenges associated with the use of additive techniques pointed out in the literature will be analyzed, as well as their advantages and disadvantages. From this context, the following hypothesis is formulated:

The use of additive manufacturing in Brazil has the potential to significantly transform the development of products and technologies in various sectors, such as healthcare, construction, education, and assistive technology, making manufacturing processes more efficient, sustainable, and affordable. However, the advancement of this technology is limited by the lack of investment and skilled labor. Based on this hypothesis, the research questions that guide this study are:

How is additive manufacturing being applied in Brazil in the development of new products and technologies? What emerging research trends can leverage the use of additive technologies in Brazil?

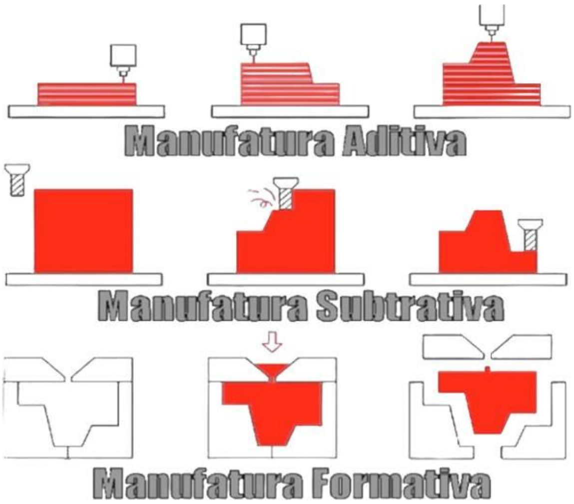
In view of this, the present work proposes to carry out a comprehensive and systematic review of the impacts of additive manufacturing in the Brazilian industrial and academic context. The main objective is to answer questions such as: what are the studies carried out, aiming to identify the products developed, the emerging research trends, the most used technologies and materials, in addition to the methodologies applied in the national scenario. To achieve these objectives, the review was conducted as follows: the theoretical framework is presented in Section 2, where the main concepts and advances related to additive manufacturing are discussed, with emphasis on the global scenario and applications that may influence the Brazilian context. Section 3 deals with the methodology and processes adopted in the systematic review, detailing the criteria for selecting the studies, the data collection procedures, and the analysis tools used. In Section 4, the results of the research are presented and discussed, focusing on the use of additive manufacturing in Brazil. Section 5 explores the national context and emerging research trends, highlighting the areas with the greatest potential for growth. Finally, the conclusions and recommendations for future research and applications are presented in Section 6.

Revista ARACÊ
ISSN: 2358-2472

THEORETICAL FRAMEWORK

Manufacturing processes can be broadly categorized into three main approaches: subtractive, formative, and additive manufacturing. As described by Wiltgen and Lopes (2022), additive manufacturing, also known as 3D printing, builds objects layer by layer, adding material until the desired geometry is formed, making it ideal for creating complex geometry with precision and minimal waste. Subtractive manufacturing, meanwhile, involves removing material from a solid block through processes such as milling, turning, or machining, carving the final part from a larger material. Formative manufacturing molds materials into specific shapes through processes such as forging, stamping, or injection molding, applying external forces to shape the material without significant addition or removal. Each of these approaches offers different advantages and applications, according to the requirements of the project and the desired properties of the final product, as illustrated in Figure 1, where a brief representation of each process can be viewed along with the titled process.

Figure 1 – Manufacturing processes



Source: Wiltgen e Lopes (2022)

Regarding conventional manufacturing processes, Gade, Vagge, and Rathod (2023) conducted a systematic review with the aim of discussing the advantages of additive manufacturing compared to subtractive methods, highlighting the ability to avoid internal deformations and stresses. The study showed benefits in terms of time, cost and quality in the prototyping of functional components, revealing the superiority of the additive method. Another relevant study is the systematic review carried out by Pant et al. (2021), which explores how additive manufacturing outperforms subtractive processes in the aerospace

Revista ARACÊ
ISSN: 2358-2472

industry, enabling the creation of lighter parts with better mechanical properties and improved fuel efficiency. In addition, Belgiu, Turc, and Carausu (2020) evaluated the advantages and disadvantages of additive manufacturing compared to subtractive manufacturing, concluding that additive manufacturing offers greater efficiency and cost-effectiveness in prototyping polymeric products. Another highlight is the study by Cecchel and Cornacchia (2024), which demonstrated additive manufacturing as a superior solution for the rapid production of sand molds, presenting superior mechanical properties compared to traditional casting methods.

Regarding the impacts caused by the additive process in the industry, Aguiar et al. (2023) presents a review on the use of rapid prototyping through 3D printing in product development, exploring the advantages and disadvantages of this technology in the production process. The study proposed several improvements to optimize processes and highlighted as main advantages the customization of products, the efficient use of materials and the possibility of creating complex geometries. These characteristics make it possible to produce light and functional parts, which are unfeasible to be manufactured by traditional methods. However, some disadvantages were explained, such as the high cost of equipment, the limitation of available materials and the lack of qualified labor for maintenance and operation. The study concluded that rapid prototyping by 3D printing is an innovative technology, with the potential to significantly improve product development by optimizing time and resources. However, the expansion of this technology still faces challenges, such as the need to reduce equipment costs and expand the variety of materials available.

Regarding academic research trends, Sonkamble and Phafat (2023) discuss the current capabilities and future prospects of Electron Beam Technology (EBT), a metal additive manufacturing (AM) process used to produce metal components directly from electronic data of the desired geometry. Its applications stand out mainly in the aerospace and biomedical industries. Complementing this discussion, Alkunte et al. (2024) examines the advances and challenges in the field of functionally graded materials (FGMs) manufactured by additive methods, addressing the different manufacturing techniques and materials used, as well as exploring their applications in areas such as structural engineering, automotive, biomedical, robotics, electronics, 4D printing, and metamaterials. In addition, Garofalo et al. (2024) contextualizes the growing use of additive manufacturing in maritime companies and institutions, which initially applied this technology for prototyping and product development, and are now beginning to expand its use to the production of end-use parts and tooling. The study also highlights that the slow adoption of additive manufacturing in the maritime sector is mainly attributed to a lack of education in technology and additive strategies.

Regarding the technologies used in the field of additive manufacturing, Peng et al. (2021) reviews post-processing technologies aimed at improving the surface quality and mechanical properties of parts produced by 3D printers using the Fused Deposition Modeling (FDM) process, the most widely used method in 3D printers available on the market. In addition, Mohamed and Surmen (2024) explore the use of additive manufacturing in biomimetic solutions, highlighting technologies such as FDM, selective laser sintering (SLS), binder jetting, stereolithography, and selective laser melting (SLM). Finally, Vafadar et al. (2021) analyzes key metal-driven additive manufacturing processes such as powder bed melting (PBF), directed energy deposition (DED), binder jetting (BJ), and nanoparticle jetting (NPJ), offering a detailed analysis of industrial applications and the challenges faced by these technologies. In the current context, these are the main technologies present in the field of additive manufacturing, although other processes may exist, most of them would fit into one of the methods described above, with occasional variations.

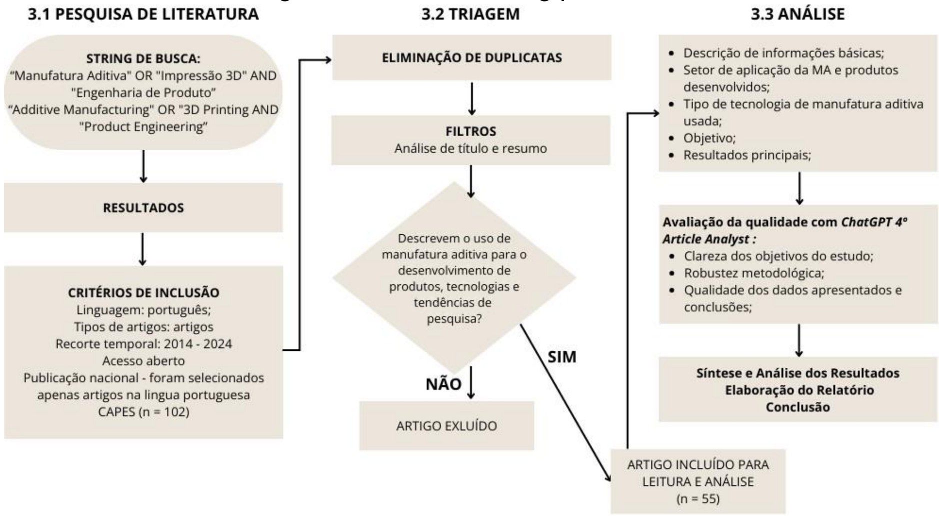
Based on the briefly discussed review, the wide range of applications of additive manufacturing and its growing relevance in both academia and industries is evident. This growth is driven by the numerous advantages associated with the process and the high technological potential that additive manufacturing offers. Currently, this technology is being widely used and studied in various sectors and areas of knowledge, especially with regard to manufacturing processes and product development as previously evidenced, thus reinforcing its importance in the industrial and academic scenario.

METHODOLOGY

Considering that the main objective of this systematic literature review is to analyze how Brazil has used additive manufacturing in the development of products and technologies, identifying the main areas of application, the challenges faced and the research trends, the present investigation is configured as a literature review research, according to Gil (2022). The structure of the study is presented visually in the flowchart in Figure 2.

Revista ARACÊ
ISSN: 2358-2472

Figure 2 – Manufacturing processes



Source: Prepared by the authors

LITERATURE RESEARCH

The first step involved searching for relevant literature in the CAPES database, due to its wide coverage of scientific publications in Brazil. For the research, the following keyword sequences were used:

- Keywords in Portuguese: "Additive Manufacturing"OR "3D Printing"AND "Product Engineering"
- Palavras-chave em língua inglesa: “Additive Manufacturing"OR "3D Printing AND "Product Engineering”

The keyword sequences were carefully selected to ensure the return of scientific studies that address the defined themes, such as: verification of the national context on additive processes, methodologies applied in Brazil, and research trends. In addition, the following criteria were adopted:

- Publication date: The time filter used covers publications between the years 2014 and 2024.
- Availability: Studies should be available in the database with open access.
- Origin: Only studies published at the national level were considered.
- Peer-reviewed: Only peer-reviewed studies were considered.

Revista ARACÊ
ISSN: 2358-2472

The criteria applied were selected to achieve a significant number of studies that described the panorama of additive manufacturing in Brazil and helped in the interpretation of the national scenario in relation to additive manufacturing processes.

SCREENING

The next step involves screening the research items. Articles that do not address the use of additive manufacturing for the development of products or technologies in industrial and academic sectors were excluded from this study, as well as opinion publications, reviews without qualitative or quantitative analyses, publications without empirical data, and studies that do not have the full text. In addition, the articles were filtered based on the following criteria:

- Title and abstract: Articles whose titles and abstracts did not refer directly to the theme were discarded.
- Content: Based on the context presented in the titles and abstracts, a brief partial reading of the main points of the studies, such as results and conclusions, was carried out, discarding those that did not meet the requirements previously outlined.
- Duplicates: Duplicate articles have been removed from the analysis.

The initial search identified articles, 102 in Portuguese and 226 in English, which were analyzed and filtered based on previously established criteria. The filtering analysis was performed by the entire team, separately for each study. The selected studies were approved by a majority of the reviewers, thus ensuring that only relevant articles, according to the established criteria, were included in the search.

ANALYSIS

After the filtering process, the selected articles were analyzed, with the extraction and categorization of the data according to their area of activity and context of application. The studies were then subdivided according to the following factors:

- Application sector: Identification and concise presentation of the application sector covered in the study.
- Type of additive manufacturing technology: Classification of the type of additive manufacturing technology used in the analyzed studies.

Revista ARACÊ
ISSN: 2358-2472

- Description of the study objective: Brief description of the main objectives of each study, highlighting the goals of the researchers.

This categorization allowed a detailed analysis of the application scenario of additive manufacturing in Brazil, offering a comprehensive view of the sectors and technologies involved. The data were organized and presented in tabular format, containing the information previously described.

During the process of analyzing the quality of the selected studies, with the number of reviewers being par, any disagreements arose regarding the methodological quality and context of the studies analyzed. To resolve such divergences, ChatGPT 4.0 Article Analyst was used, a tool developed by ChatGPT users (2024), which analyzes articles in PDF format for their methodology, relevance, and results achieved. To refine the use of the tool, the following input was inserted:

"Analyze the article evaluating its methodological quality and relevance, based on: Clarity of the study objectives, Methodological robustness and Quality of the data presented, in addition to results and conclusions."

After data extraction and analysis, a narrative synthesis of the results was carried out, highlighting the general overview of the use of additive manufacturing in Brazil, including the main trends, most involved sectors, and the types of products or technologies developed. In addition, the challenges and benefits identified in the use of this technology were analyzed. The results were organized in a final report, following the guidelines of the PRISMA methodology, which includes steps such as the identification of relevant studies, screening with inclusion and exclusion criteria, data extraction in a standardized way, and the elaboration of a clear and objective synthesis of the findings.

RESULTS AND DISCUSSIONS OF THE APPLIED METHODOLOGY

As described in the previous section, the search carried out in the Capes Journals database resulted in the identification of 102 articles in Portuguese and 226 in English. Articles in English were excluded based on previously established criteria. The selected articles were then organized according to their areas of application, being divided into six main categories: development of educational products, products aimed at the health area, products for the civil construction sector, assistive technologies, industrial development, and products in various areas.

Revista ARACÊ
ISSN: 2358-2472

The process of selection and filtering of articles in Portuguese is detailed in Table 1, in a generic way. The table shows the total number of studies initially found in the databases, the number of studies discarded after applying the inclusion and exclusion criteria, and the final number of studies selected for analysis.

Table 1 – Articles analyzed in Portuguese

Area	Total	Selected	Discarded
All articles reviewed	102	55	47
Product development in the field of education	21	12	9
Product development in the health area	27	14	13
Product development in the construction industry civil	4	4	0
Product development - technologies Assistive	15	8	7
Product development in technologies Industrial	18	11	7
Product development in various areas	17	6	11

Source: Prepared by the authors

The analysis of the results and the presentation of the selected articles are deepened in the subsequent subsections, providing a more detailed and comprehensive view of each of the delimited areas, where the articles were divided.

PRODUCT DEVELOPMENT IN THE FIELD OF EDUCATION

As previously mentioned, a total of 21 studies were analyzed in this subsection, of which 9 were discarded. The area of application analyzed covers content related to the development of products or methodologies aimed at supporting basic and higher education in schools and universities. These studies focused on innovative solutions that use additive manufacturing to create educational tools, promoting improvements in the teaching-learning processes, both in the academic and pedagogical environments, and can be seen in Table 2.

Table 2 – Product development in the educational area

Educational Area		
Name	Article	Technology and material
3D Printing and the Development of Educational Products	(Onisaki; Hey, 2019)	Filament Manufacturing Cast (FFF) - PLA
Chest drainage simulator: Development of a low-cost model for training physicians and medical students	(Bettega et al., 2019)	Not specified
Reconstruction and 3D printing of the Neurocranium of a dog with the use of computed tomography as a tool to assist in the teaching of veterinary anatomy	(Santos; Modified, 2020)	Cast Filament Fabrication (FFF) - thermoplastic in filament

Revista ARACÊ
ISSN: 2358-2472

3D Printing as a Resource for the Development of Didactic Material: Associating Maker Culture with Problem Solving	(Bertti; Silveira; Net, 2020)	Fused Deposition Modeling (FDM) - PLA ou ABS
Development of a Vaginal Educator Through the Additive Manufacturing Process (3D Printing)	(Martins et al., 2017)	Fused Filament Fabrication (FFF) - PLA
Three-dimensional representation of teeth mammals and their use as a didactic resource in the training of Science and Biology teachers	(Silva et al., 2023)	Not specified
Development of Printed Models 3D for Science Teaching	(Palaio; Almeida; Patreze, 2018)	Fused Deposition Modeling (FDM) - PLA
Application of 3D printing models as a tool for practical experimental activities in the teaching of Physics	(Capeloto et al., 2023)	Fused Deposition Modeling (FDM) - PLA
Active learning through Rapid prototyping in an Undergraduate Course in Energy Engineering	(Ferreira; Freitas-Gutierres, 2022)	FDM (Fused Deposition Modeling) - Not specified
Didactic model for the teaching of Science, construction through 3D printing: analysis and evaluation in the teaching-learning process	(Oliveira; Ferreira; Martins, 2022)	FDM (Fused Deposition Modeling) - ABS
Learning Vertebral Anatomy Human Through the Use of 2D and 3D Lumbar Vertebral Models	(Bona et al., 2020)	FDM (Fused Deposition Modeling) - Not specified
3D Printing in the Evaluation of Constrictive Pericarditis	(Abrantes et al., 2024)	FDM (Fused Deposition Modeling) - Thermoplastic filaments

Source: Prepared by the authors

The first selected article, developed by Onisaki and Vieira (2019), deals with the application of 3D printing in the development of educational products, highlighting the use of Cast Forming Manufacturing (FFF) with thermoplastics such as PLA. Technology has been used to create and customize teaching materials in subjects such as science, history, arts, and technology, offering flexibility to meet the specific needs of teaching. The study delimits its area of application in the creation of innovative pedagogical tools.

The second article, by Bettega et al. (2019), focuses on the use of 3D printing in the development of a low-cost simulator for teaching the thoracic drainage technique. The technology was used to create an anatomical model of the human rib cage, employing different materials to simulate body structures, highlighting the importance of medical training.

The third article, by Santos and Andrade (2020), addresses 3D printing in the teaching of veterinary anatomy, allowing the creation of three-dimensional models of the neurocranium of dogs. Using computerized tomographs, the models served as educational tools and aided in surgical planning.

Revista ARACÊ
ISSN: 2358-2472

Bertti, Silveira, and Neto (2020) explore the use of 3D printing in a public school in Paraíba, Brazil, integrating maker culture and problem-solving with active methodologies such as Design Thinking. The technology used was the Winbo Mini printer, offering new ways to engage students with prototypes and personalized materials.

The fifth article, by Martins et al. (2017), applies 3D printing in physiotherapy and women's health, specifically in the development of a vaginal educator for the treatment of pelvic floor dysfunctions, highlighting the use of polylactic acid (PLA) for the printing process.

The sixth study, by Silva et al. (2023), addresses the creation of anatomical models of mammalian teeth for the teaching of zoology and biology, using 3D printing as a didactic resource. The process used FDM (Fused Deposition Modeling) technology with ABS filament.

The seventh article, by Palaio, Almeida and Patreze (2018), analyzes the creation of three-dimensional models of microalgae for science education, using 3D printing with PLA filament to assist in the study of biological diversity.

Capeloto et al. (2023) applies 3D printing in Physics teaching, developing three-dimensional models for practical experiments in schools. The process was carried out with the XYZ – Da Vinci 1.0 Pro printer, using PLA filament to create safe and effective materials.

The ninth article, by Ferreira and Freitas-Gutierres (2022), uses 3D printing in the teaching of Energy Engineering, allowing students to develop practical and functional projects in the classroom, promoting more active and collaborative learning.

Oliveira, Ferreira, and Martins (2022) focus on the creation of an anatomical model of the circulatory system for science education, highlighting the use of FDM 3D printing with ABS polymer and modeling in SolidWorks software to build a life-size model.

The eleventh article, by Bona et al. (2020), applies 3D printing in veterinary medicine for the treatment of vertebral osteosarcoma in dogs, using the PETG material to create a vertebral spacer after the removal of a tumor, contributing to post-surgical stability.

The twelfth article, by Abrantes et al. (2024), uses 3D printing to evaluate and plan surgeries related to constrictive pericarditis, with a focus on creating anatomical models to facilitate medical education and practice. FDM technology was used to print cardiac models from tomographic images.

Revista ARACÊ
ISSN: 2358-2472

The analysis of the articles reveals a strong trend in the Brazilian scenario to integrate 3D printing into the development of educational products, highlighting its application in various disciplines, such as science, biology, physics, and health. Fused Filament Manufacturing (FFF), especially with the use of PLA and ABS, emerges as the most used technology, due to its accessibility, safety, and versatility in the creation of personalized teaching materials. The use of 3D modeling in software such as SolidWorks and Blender has proven to be essential in the process of creating models, while the maker approach and active methodologies, such as Design Thinking, reinforce the interactive and collaborative character of educational practices. Even in fields such as veterinary medicine and physical therapy, studies are geared towards educational empowerment, demonstrating a convergence in the use of 3D printing to enhance teaching and facilitate learning through tangible, interactive resources. This trend points to a path where 3D printing is consolidated as a crucial tool in the development of innovative educational solutions, which meet both the needs of professional training and the demands of teaching at different levels and areas of knowledge.

PRODUCT DEVELOPMENT IN HEALTHCARE

As previously mentioned, a total of 27 studies were analyzed in this subsection, of which 13 were discarded. The application area addressed involves the development of products and methodologies aimed at the health area, with a focus on innovative solutions using additive manufacturing. These studies explored the creation of tools and technologies applied in the field of hospital medicine, promoting advances in medical treatment processes, in addition to developing equipment capable of solving challenges present in both academic and hospital environments. The analyzed contributions of this research area can be seen in Table 3.

Table 3 – Product development in the health area

Medical Area		
Name	Article	Technology and material
Use of prosthetic limbs manufactured from 3D printing for amputees	(Rodrigues; Stocco, 2020)	Fused Deposition Modeling (FDM) - PLA e ABS
3D Printing Face Shields for protection of health workers against COVID-19 infection	(Andrade et al., 2020)	Fused Deposition Modeling (FDM) - ABS

Revista ARACÊ
ISSN: 2358-2472

CT Scan Ultra Low Radiation Dose Multidetectors and 3D Printing as Aids for Guided Surgery in Implant Dentistry	(Rodrigues et al., 2020)	Fused Deposition Modeling (FDM) - PLA
Preoperative correction planning of supramalleolar deformities through 3D printing: Case Report	(Baumfeld et al., 2021)	FDM (Fused Deposition Modeling) - PLA
Three-Dimensional Prototyping-Guided Partial Shoulder Arthroplasty	(Maia et al., 2024)	Selective sintering A laser (SLS), polyamide PA 12
Mask design development as personal protective equipment through 3D printing	(Ramos; Lee; Teixeira, 2023)	FDM (Fused Deposition Modeling) - TPE e PLA
3D Printing of Magnetic Separator: An Accessible Approach to Sample Preparation in COVID-19 Diagnosis	(Silva-Neto et al., 2023)	FDM (Fused Deposition Modeling) - PLA
3D Bioprinting of Tissues and Organs: a technological prospect	(É et al., 2020)	Bioprinting of Gels - Biodegradable polymers and cellular hydrogels
Application of 3D printing technology in the treatment of Hoffa's fracture pseudarthrosis	(Mendonça et al., 2022)	FDM (Fused Deposition Modeling) - ABS
Use of three-dimensional printing for Diagnostic and therapeutic aid of tibial pylon fractures	(Wustro et al., 2024)	FDM (Fused Deposition Modeling) - Not specified
Open source browsing and printing 3D applied to the treatment of mandibular osteoma	(Silva et al., 2023)	FDM (Fused Deposition Modeling) - PLA e SLA
Treatment of Vicious Consolidation of the Distal Radius: Corrective Osteotomy Through Planning with Prototyping in 3D Printing	(Belloti et al., 2021)	FDM (Fused Deposition Modeling) - PLA
3D printed orthosis for the shoulder: case report	(Assad et al., 2017)	Fused Deposition Modeling (FDM) - ABS Plus
Open source browsing and printing 3D: basic principles and simulations in Surgery and Traumatology Oral and Maxillofacial	(Guidolin et al., 2022)	FDM (Fused Deposition Modeling) - CPE+ (Chlorinated PolyEthylene)

Source: Prepared by the authors

The first selected article, developed by Rodrigues and Stocco (2020), explores the application of 3D printing in the development of prostheses for amputees, using Fused Deposition Modeling (FDM) technology with materials such as PLA and ABS. The main advantage highlighted was the creation of low-cost and customizable devices, capable of partially or fully replacing the functions of the lost limbs. The study delimits its area of expertise in the development of health products, with the possibility of integrating myoelectric systems to increase functionality.

The second article, developed by Andrade et al. (2020), investigates the application of 3D printing in the production of face shields during the COVID-19 pandemic. The technology was used to address the shortage of PPE in hospitals, with the creation of ABS plastic supports for acetate sheets. The study focused on the health area, more specifically on the protection of professionals during the health crisis.

The third article, developed by Rodrigues et al. (2020), addresses the use of 3D printing in dentistry, specifically in the production of personalized surgical guides for implantology. FDM technology, with PLA, was used to create guides from tomographic images, improving the accuracy of dental implants. The focus of the study is the development of medical tools for application in dental surgeries.

The fourth article, by Baumfeld et al. (2021), highlights 3D printing in orthopedic surgical planning, creating 3D models of the ankle for deformity correction surgeries. FDM technology with PLA allowed for accurate planning of osteotomies, contributing to greater surgical efficiency. The study is focused on orthopedic health.

The fifth article, by Maia et al. (2024), explores the creation of anatomical models for shoulder arthroplasties, using selective laser sintering (SLS) with polyamide. The objective was to optimize surgical planning and the customization of prostheses. The study delimits its area of application in orthopedics.

The sixth article, by Ramos, Lopes, and Teixeira (2023), addresses the production of reusable face masks to protect against SARS-CoV-2, with an innovative design using TPE and PLA filaments, aiming at comfort and sealing efficiency. The study focuses on public health solutions.

The seventh article, by Silva-Neto et al. (2023), describes the creation of a low-cost magnetic separator for RNA extraction, applied in the diagnosis of COVID-19. The device was developed with FDM 3D printing, using PLA, to speed up the preparation of clinical samples.

The eighth article, by É et al. (2020), deals with 3D bioprinting for regenerative medicine, addressing the use of biodegradable polymers and stem cells in the creation of biomimetic tissues for transplants, with a focus on reducing rejection and waiting time.

The ninth article, by Mendonça et al. (2022), explores 3D printing in the surgical planning of femoral condyle fractures, using biomodels for preoperative simulations and improving accuracy in implant placement. The study focuses on orthopedics.

The tenth article, by Wustro et al. (2024), investigates 3D printing in the diagnosis and planning of tibial pylon fractures, creating three-dimensional models of fractures that were compared with CT scans to assist in orthopedic treatment.

Revista ARACÊ
ISSN: 2358-2472

The eleventh article, by Silva et al. (2023), applies 3D printing in oral and maxillofacial surgical planning, creating biomodels for the removal of mandibular osteomas, with the use of free software and FDM and SLA 3D printing.

The twelfth article, by Belloti et al. (2021), addresses 3D printing in the treatment of vicious consolidations of fractures of the distal radius, using anatomical models for surgical planning and improvement in the visualization of deformities.

The thirteenth selected article, developed by Assad et al. (2017), deals with the application of 3D printing in health, with a focus on the development of orthoses for shoulder stabilization. The technology used was 3D printing by Fused Deposition Modeling (FDM), using ABS Plus thermoplastic, which offers greater mechanical resistance. The 3D scanning was done with the Sense scanner from 3D Systems, and the modeling was performed with Solid Edge and Magics software.

The fourteenth selected article, developed by Guidolin et al. (2022), deals with the application of 3D printing in Oral and Maxillofacial Surgery and Traumatology, assisting in surgical planning and the construction of biomodels for personalized surgical guides. The technology used was FDM (Fused Deposition Modeling) 3D printing, with the CPE+ (Chlorinated PolyEthylene) material for the creation of anatomical models and surgical guides. Free software, such as 3D Slicer, 3D Builder and Meshmixer, were used in the process of modeling and segmentation of images obtained via computed tomography.

The analysis of the articles reveals that the Brazilian scenario has widely adopted 3D printing as an essential tool in the development of solutions aimed at hospital medicine, with a focus on surgical planning, personalized prostheses and medical devices. The most used techniques are Fused Deposition Modeling (FDM), highlighted by the use of materials such as PLA and ABS, and Selective Laser Sintering (SLS), which has proven to be fundamental in orthopedic and bioprinting applications. These studies highlight the versatility of additive manufacturing both in the creation of anatomical biomodels and in the manufacture of personal protective equipment (PPE) and diagnostic devices, such as magnetic separators. The trend of integrating free software for surgical planning also stands out, allowing the execution of more complex surgeries in environments with limited resources. The development of medical products through 3D printing follows a trajectory of innovation and customization, demonstrating the commitment of national research to optimize treatments and diagnoses with affordable and effective solutions for the healthcare system.

Revista ARACÊ
ISSN: 2358-2472

PRODUCT DEVELOPMENT IN THE AREA OF CIVIL CONSTRUCTION

As mentioned earlier, a total of 4 studies were analyzed in this subsection. The application area addressed focuses on the development of products and methodologies aimed at civil construction, using additive manufacturing as the main innovation tool. These studies explored the creation of technological solutions applied to the sector, aiming to improve construction processes and develop innovative equipment capable of solving challenges both in academic environments and on construction sites. The contributions of this research area can be seen in Table 4.

Table 4 – Product development in construction areas

Construction Areas		
Name	Article	Technology and material
Feasibility Study of Manufacturing Sustainable Composite Filament for 3D Printing from a Wood Fiber Waste Reinforced PLA Matrix	(Spohr; Sánchez; Brands, 2021)	Fused Deposition Modeling (FDM) - PLA + Pó de madeira
3D printing with cementitious materials: A comparative analysis of residential projects	(Carbonari et al., 2023)	Extrusion - Cement
The Industrialization of Construction with Earth Through 3D Printing	(Taparello, 2016)	Unspecified - Ground Compacted
Use of marble waste for application as filler of PLA filaments for application in 3D printing	(Siqueira et al., 2024)	FDM (Fused Deposition Modeling) - PLA

Source: Prepared by the authors

The first selected article, developed by Spohr, Sánchez, and Marques (2021), deals with the application of 3D printing in the development of sustainable filaments for the manufacture of products aimed at civil construction. The study investigates the feasibility of producing a composite filament from a PLA matrix reinforced with wood fiber waste, seeking to create a more environmentally friendly material with improved mechanical properties. The technology used was Fused Filament Fabrication (FFF), also known as Fused Deposition Modeling (FDM), using waste from the furniture industry to add sustainability to the additive manufacturing process.

The second selected article, developed by Carbonari et al. (2023), deals with the application of 3D printing in civil construction, with a focus on the development of residential projects using cementitious materials. The technology aims to speed up the construction process, reduce costs and waste, and promote sustainability through the use of recycled materials and innovative systems. The main technology used was 3D printing by extrusion of cementitious materials, using methods such as Contour Crafting, D-Shape

Revista ARACÊ
ISSN: 2358-2472

and Concrete Printing, allowing the construction of houses and architectural elements through layered deposition.

The third selected article, developed by Taparello (2016), explores the application of 3D printing in civil construction, specifically in construction with earth. The study investigates the use of land as the main material for the creation of buildings, highlighting its environmental and economic advantages, such as low cost, sustainability and thermal comfort. The technology discussed involves 3D printing with compacted earth, using robots and automated machines to stack layers of soil and form structures. The study delimits its area of application in the development of sustainable methods for civil construction.

The fourth selected article, developed by Siqueira et al. (2024), deals with the application of 3D printing in the development of sustainable composite filaments, specifically PLA reinforced with marble waste. The study aims to improve the mechanical properties of PLA and reduce the environmental impact caused by the disposal of marble waste. The technology used was FDM (Fused Deposition Modeling) 3D printing, where the PLA/marble composite was obtained through high-energy grinding and mixing with solvents, resulting in a material suitable for future extrusion and application in 3D printing. The study delimits its area of application in sustainable civil construction.

The analysis of the articles reveals a growing trend in the Brazilian scenario to integrate 3D printing in the development of sustainable solutions for civil construction, with a focus on alternative materials and innovative technologies. Research points to the predominant use of Fused Deposition Modeling (FDM) and extrusion techniques for cementitious and composite materials, such as PLA reinforced with wood or marble waste. These studies demonstrate a strong commitment to sustainability, by seeking alternatives that reduce environmental impact and optimize the construction process, promoting the reuse of industrial waste and efficiency in the construction of buildings. In addition, the application of 3D printing with natural materials, such as soil, reinforces the feasibility of new ecological approaches to construction, combining low cost and thermal comfort. Thus, the development of products aimed at civil construction through additive manufacturing signals a promising path, in which technological innovation and sustainability are consolidated as fundamental pillars in the sector.

PRODUCT DEVELOPMENT IN ASSISTIVE TECHNOLOGIES

As previously mentioned, a total of 15 studies were analyzed in this subsection, 7 of which were discarded. The application area focuses on the development of products and methodologies aimed at assistive technologies. Although this field may share some characteristics with the health and education area, the main focus is on demonstrating how additive manufacturing can be used as an innovative tool to solve problems related to physical disabilities and other assistive needs. These studies explored the creation of technological solutions aimed at improving the quality of life of people with disabilities, as well as the development of innovative equipment that can be applied both in academic contexts and in other practical situations. The contributions of this research area can be seen in Table 5.

Table 5 – Product development - assistive technologies

Assistive Technology Area		
Name	Author	Technology and material
Wearable optical device for assistance of the visually impaired in the classroom	(Borges et al., 2020)	Fused Deposition Modeling (FDM) - PLA
The development of a assistive technology/orthoprosthesis for the rehabilitation of patients with leprosy and the presence of a claw hand and/or bone resorption	(Júnior et al., 2021)	Not specified - fiberglass, natural leather and galvanized sheets
Digitization of biological structures in the Tactile instructional material design for visually impaired people	(Junior et al., 2023)	FDM (Fused Deposition Modeling) - PLA
Rapid prototyping in development Prototype of a writing adapter	(Serra et al., 2020)	Fused Filament Fabrication (FFF) - ABS
Combining: a material for teaching Combinatorial analysis of blind students	(Basniak; Dombrowski, 2023)	Fused Deposition Modeling (FDM) - PLA
Rapid Prototyping: A Footrest Ergonomic to Aid Venous Return	(Pereira; Santos, 2021)	Fused Deposition Modeling (FDM) - PLA e ABS
Using the displacement map in creation of auxiliary resources to inclusive education for People with Visual Impairment	(Monteiro; Garcia, 2022)	Fused Deposition Modeling (FDM) - Not specified
Teaching Geography and Gender Disorder Autism Spectrum: 3D Material Proposition	(Silva; Silva, 2023)	FDM (Fused Deposition Modeling) - ABS

Source: Prepared by the authors

The first selected article, developed by Borges et al. (2020), deals with the application of 3D printing in the development of a wearable optical device to help the visually impaired in classrooms. The technology was used to create the structural parts of the device through Fused Deposition Modeling (FDM), using ABS Plus. The device allows you to capture images and transmit them to smartphones, where they are magnified and

Revista ARACÊ
ISSN: 2358-2472

filtered to improve visibility. The study delimits its area of application in the development of products aimed at education and assistive technology, promoting inclusion in the school environment.

The second selected article, developed by Júnior et al. (2021), deals with the development of an assistive technology device for the rehabilitation of leprosy patients who have hand deformities, such as claw hand and bone resorption. The device aims to improve the manual function of these patients. Although the article compares the orthoprosthesis developed with traditional 3D printing methods, the manufacture was made with low-cost alternative materials, such as fiberglass, natural leather and galvanized sheets, with the aim of keeping the cost affordable. The study delimits its area of application in rehabilitation and assistive technology.

The third selected article, developed by Junior et al. (2023), deals with the application of 3D printing in the development of tactile teaching materials for people with visual impairments. The study focuses on creating models of biological structures, such as snake skulls, heads, scales, and tails, with the aim of making science education more accessible through touch. The technology used was FDM (Fused Deposition Modeling) 3D printing, with the use of PLA due to its ease of use and cost-effectiveness. The digital models were generated by 3D scanning with the EinScan-SE Scanner, edited in GOM Inspect and printed on a BIQU B1. The study delimits its area of application in the development of assistive technology for inclusive education.

The fourth selected article, developed by Serra et al. (2020), deals with the application of 3D printing in the development of assistive products, focusing on the construction of a writing adapter for children with motor restrictions in their hands. The technology used was Fused Filament Fabrication (FFF), employing an Ultimaker 2 3D printer with ABS filament. The process included CAD modeling and prototyping of two models, with adjustments made after the first print test to optimize the design.

The fifth selected article, developed by Basniak and Dombrowski (2023), applies 3D printing in inclusive mathematics education, focusing on the development of pedagogical material for teaching Combinatorial Analysis (Fundamental Principle of Counting) aimed at blind students. The study promotes accessibility by making math learning more interactive and manipulable. The technology used was FDM (Fused Deposition Modeling) 3D printing, with materials such as PLA, chosen for its biodegradability and resistance. The material was modeled in the Blender software and printed on a Cliever CL1 - Black Edition printer.

Revista ARACÊ
ISSN: 2358-2472

The sixth selected article, developed by Pereira and Santos (2021), applies 3D printing to ergonomic design, focusing on the development of a footrest with active movement to improve venous return of the lower limbs of people who spend long periods of sitting. The technology used was FDM (Fused Deposition Modeling) 3D printing, employing materials such as ABS for the base, PLA for the pedal and nylon for the textured layer, chosen for their resistance and grip properties. The study delimits its area of application in ergonomics and occupational health.

The seventh selected article, developed by Monteiro and Garcia (2022), applies 3D printing in inclusive education, focusing on the development of tactile educational resources for people with visual impairment (POS). The study explores the use of the displacement map technique to convert 2D images into 3D models, creating accessible materials that facilitate learning for visually impaired students through touch. The technology used was FDM (Fused Deposition Modeling) 3D printing, with an SETHI3D S4X printer to produce the three-dimensional models from vector images, allowing a tactile understanding of symbols and shapes.

The eighth selected article, developed by Silva e Silva (2023), applies 3D printing in the teaching of geography to students with Autism Spectrum Disorder (ASD). The study focuses on the development of 3D printed didactic resources to facilitate the learning of geomorphology and cartography, promoting school inclusion and assisting in the spatial understanding of the themes. The technology used was FDM (Fused Deposition Modeling) 3D printing, with ABS filaments, and the three-dimensional models were obtained from platforms such as Thingiverse and MyMiniFactory, providing a differentiated and interactive didactic approach.

The analysis of the articles reveals a strong tendency in the Brazilian scenario to use **3D printing** as a key tool for the development of assistive technologies, with emphasis on inclusive education, rehabilitation and ergonomics. The research focuses on the creation of personalized and accessible devices, such as tactile materials, orthoses, adapters and optical devices, aiming to improve the inclusion of people with disabilities in school and professional environments. Fused Deposition Modeling (FDM) technology, using mainly PLA and ABS, appears as the most used technique due to its versatility, cost-benefit and mechanical properties. In addition, there is a growing integration of 3D modeling software and scanning tools for the customization of devices, allowing the adaptation of specific solutions for each user. This movement highlights a promising path

Revista ARACÊ
ISSN: 2358-2472

for Brazil, where technological innovation is being applied to promote greater accessibility and inclusion, expanding access to quality assistive products, with a focus on sustainable and low-cost solutions.

PRODUCT DEVELOPMENT IN INDUSTRIAL TECHNOLOGIES

As previously mentioned, a total of 18 studies were analyzed in this subsection, 7 of which were discarded. The application area focuses on the development of products and methodologies aimed at technologies applicable to the industry. The main focus is on demonstrating how additive manufacturing can be used as an innovative tool to solve specific problems in various industrial fields. These studies explored the creation of technological solutions aimed at improving industrial processes and developing innovative equipment, applicable both in academic contexts and in practical industrial operations. The contributions of this research area can be seen in Table 6.

Table 6 – Product development in industrial areas

Metal-Mechanics and Industrial Technologies Areas		
Name	Article	Technology and material
Study of the Feasibility of the Use of Rapid 3D Prototyping in Production Processes in Rural Areas	(Zucca et al., 2018)	Fused Deposition Modeling (FDM) - Not specified
Poka Yoke Artifact Crafting by 3D Printing for Inspection of Diameter Along the Length of Circular Section Pipes	(Dias; Galhardi, 2023)	Fused Deposition Modeling (FDM) - PETG
Between the Virtual and the Tangible: Parametry of Furniture to Promote Collaborative Processes in Social Housing Contexts	(Silva; Nunes; Medvedovsky, 2021)	Not specified
Design, Ergonomics and 3D Printing: One Practical Design Exercise for Outlet Protectors	(Sousa et al., 2022)	Fused Deposition Modeling (FDM) - ABS
Personal Protective Equipment 3D Printed by Federal Educational Institutions to Confront COVID-19	(Santos et al., 2020)	Fused Deposition Modeling (FDM) - for face shields and plastic filaments
The importance of 4.0 methodologies in Development of a small company: Case study on the use of 3D printing in a Metallurgical company	(Morais; Saints; Morais, 2021)	Fused Deposition Modeling (FDM) - Not specified
Rapid prototyping process like Alternative to the re-design of equipment components: case study of a 3D printed air exhaust fan propeller	(Mergener; Silva, 2021)	Fused Deposition Modeling (FDM) - PLA
Use of Reengineering, Combined with Prototyping, in the Maintenance of Laboratory Equipment at UNESP – Guaratinguetá Campus	(Mattos et al., 2023)	Fused Deposition Modeling (FDM) - ABS
3D Printed Trims for Small Fashion Brands	(Hornburg et al., 2022)	Filament Manufacturing - Cast (FFF) - PLA, PETG, TPU and ABS

Revista ARACÊ
ISSN: 2358-2472

3D printing for clothing: new design and consumption paradigms	(Gomes et al., 2020)	Fused Deposition Modeling (FDM) - PLA e FilaFlex
Development of a low-grade greenhouse cost for 3D printer filaments	(Baêta; Silva, 2023)	Not specified

Source: Prepared by the authors

The first selected article, developed by Zucca et al. (2018), deals with the application of 3D printing in rural areas, with a focus on the development of spare parts and prototypes for agricultural machinery. The study addresses how rapid prototyping can be used to solve parts manufacturing problems on rural properties, optimizing production processes and reducing costs and time. The technology used was 3D printing by Fused Deposition Modeling (FDM), allowing the production of customized mechanical parts quickly and efficiently. The study delimits its area of application in the development of technologies aimed at the agricultural and rural industry.

The second selected article, developed by Dias and Galhardi (2023), deals with the application of 3D printing in the metal-mechanic industry, focusing on the creation of Poka Yoke artifacts for the inspection of steel pipe diameters. The technology used was FDM (Fused Deposition Modeling) 3D printing, with PETG filament, chosen for its mechanical, chemical and thermal resistance, ideal for functional prototypes.

The third selected article, developed by Silva, Nunes, and Medvedovski (2021), applies digital technologies, such as 3D printing and parametric design, in the development of solutions for social housing (HIS). The study focuses on the creation of customized furniture and the adaptation of housing spaces, promoting collaborative processes between technicians and residents for the requalification of housing. Digital fabrication by 3D printing was combined with tangible interfaces and the use of parametric design tools, such as Grasshopper software, to generate furniture adapted to the needs of HIS.

The fourth selected article, developed by Sousa et al. (2022), deals with the application of 3D printing in product design and ergonomics, with a focus on the development of outlet protectors for domestic environments, aiming to increase safety and prevent electrical accidents, especially with children. The technology used was FDM (Fused Deposition Modeling) 3D printing, using the ABS material, chosen for its mechanical resistance and safety in contact with the power grid.

The fifth selected article, developed by Santos et al. (2020), deals with the application of 3D printing in public health, with a focus on the development of personal protective equipment (PPE) during the COVID-19 pandemic. Federal educational

Revista ARACÊ
ISSN: 2358-2472

institutions in Brazil have used 3D printers to manufacture face shields, masks similar to the N-95 model, and other protective devices for health workers. The technology used was FDM (Fused Deposition Modeling) 3D printing, using materials such as acetate and plastic filaments, following open-source standards, such as the model developed by Prusa Research.

The sixth selected article, developed by Morais, Santos, and Morais (2021), deals with the application of 3D printing in the metallurgical sector, focusing on the implementation of Industry 4.0 technologies in a small company. The technology used was FDM (Fused Deposition Modeling) 3D printing, with the manufacture of simple parts, such as washers and alignment supports, complementing traditional machining methods.

The seventh selected article, developed by Mergener and Silva (2021), deals with the application of 3D printing in the ventilation and exhaust industry, with a focus on the redesign of propellers for air exhaust fans in adhesive application booths. The technology used was FDM (Fused Deposition Modeling) 3D printing, with PLA filament, and the propeller prototype was compared to metal models to evaluate its efficiency.

The eighth selected article, developed by Mattos et al. (2023), deals with the application of 3D printing in the maintenance of laboratory equipment, focusing on the recovery of voltage regulator activation buttons for UNESP's Physics laboratories. The technology used was FDM (Fused Deposition Modeling) 3D printing, with ABS filament, chosen for its mechanical resistance. The process involved modeling in SolidWorks and preparation for printing in Simplify3D, resulting in the fabrication of 120 buttons.

The ninth selected article, developed by Hornburg et al. (2022), deals with the application of 3D printing in the fashion industry, with a focus on the creation of personalized trims, such as buttons, plaques and rings, for small fashion brands. The technology used was Fused Filament Fabrication (FFF), with printing on materials such as PLA, PETG, TPU and ABS. The process was carried out with the Cliever CL1 Black Edition and Systemprime Delta printers, allowing the creation of trims with different levels of detail and resistance.

The tenth selected article, developed by Gomes et al. (2020), deals with the application of 3D printing in the fashion industry, with a focus on the development of garments, accessories and footwear. The technology used was Fused Deposition Modeling (FDM), employing thermoplastics such as PLA and Filaflex to create flexible and customized parts.

Revista ARACÊ
ISSN: 2358-2472

The eleventh selected article, developed by Baêta and Silva (2023), deals with the application of 3D printing in the preservation of filaments used in FDM (Fused Deposition Modeling) printers. The study develops a low-cost greenhouse to improve the durability and quality of filaments, keeping them dry and ready for use. The technology used was a prototype greenhouse with a PID control system to regulate the temperature, using accessible components such as H4 lamps, Arduino Uno boards, LM35 sensors, and thermal insulation with styrofoam and aluminum foil. The study delimits its area of application in optimizing the use of filaments in 3D printing.

The analysis of the articles reveals a growing trend in the Brazilian scenario to use 3D printing as a strategic tool for the development of industrial technologies, with a focus on process modernization, cost reduction and product customization. Research shows the predominance of the Fused Deposition Modeling (FDM) technique, with the application of materials such as PLA, ABS and PETG, which offer good mechanical resistance and versatility for various industries. The use of 3D printing ranges from the manufacture of spare parts and prototypes for the agricultural and metallurgical sector to the development of ergonomic solutions, trims for fashion and filament preservation. The studies also highlight the incorporation of Industry 4.0 technologies, demonstrating the potential of 3D printing to optimize production processes in small and large companies, promoting innovation and sustainability. This scenario shows that Brazil is adopting additive manufacturing as an ally in the search for efficiency and flexibility in the most varied industrial sectors.

PRODUCT DEVELOPMENT IN VARIOUS AREAS

As previously mentioned, a total of 17 studies were analyzed in this subsection, 11 of which were discarded. The application area focuses on the development of products and methodologies aimed at technologies applicable to various areas. The main focus is on demonstrating how additive manufacturing can be used as an innovative and versatile tool to solve specific problems in various fields. These studies explored the creation of technological solutions aimed at improving processes and developing innovative equipment, applicable in various academic contexts and practical operations. The contributions of this research area can be seen in Table 7.

Revista ARACÊ
ISSN: 2358-2472

Table 7 – Product development in various areas

Varied Areas		
Name	Article	Technology and material
3D Printing in the Field of Cartographic representations	(Graça et al., 2021)	Fused Deposition Modeling (FDM) - PLA
Development of a Project for Multi-Material 3D Printing Using a Dual Extruder Module for Personal Printing	(Prado et al., 2020)	Fused Deposition Modeling (FDM) - PLA e ABS
Application of additive manufacturing in Forensic Sciences: new technologies at the service of justice and society	(Matos et al., 2023)	Not specified
Use of additive manufacturing (3D printing) in the treatment of vertebral osteosarcoma in a dog submitted to lumbar vertebrectomy: Case report	(Santos; See; Thizen, 2022)	(FDM) Fused Deposition Modeling - PETG
Thermal imaging camera evaluation of Implantation of co-polyamide associated with thermoplastic elastomer in rabbit trachea	(Bini et al., 2021)	(FDM) Fused Deposition Modeling - PCTPE
Approach to Specification Requirements for 3D Modeling of the Otto Robot for Therapy Sessions with Autistic Children	(Rebouças et al., 2024)	(FDM) Fused Deposition Modeling - PLA

Source: Prepared by the authors

The first selected article, developed by Graça et al. (2021), deals with the application of 3D printing in the field of cartography, with a focus on the creation of three-dimensional models of maps. The technology was used to generate physical representations of terrain and other spatial data, making it easier to view and understand maps, especially in educational and accessibility contexts, such as the creation of tactile maps for the visually impaired. The technology used was Fused Deposition Modeling (FDM), using filaments such as PLA to print maps in relief. The study delimits its area of application in the development of products aimed at various technologies and applications.

The second selected article, developed by Prado et al. (2020), deals with the application of 3D printing in the development of extrusion systems for personal 3D printers, with a focus on multi-material printing. The project aims to expand the capabilities of low-cost 3D printers by allowing the simultaneous printing of two different materials, such as structural and soluble plastics. The technology used was Fused Deposition Modeling (FDM), with the development of a double extruder module, allowing greater precision and versatility in printing. The study delimits its area of application in the improvement of personal 3D printers for multi-material use.

The third selected article, developed by Matos et al. (2023), deals with the application of 3D printing in Forensic Sciences, with a focus on human identification and the recreation of evidence, such as bones, teeth, and projectile trajectories. The technology is used to produce accurate replicas of forensic evidence from scans, making it easier for jurors to view and reducing the need to handle the original evidence. While the article explores various 3D printing techniques, it does not specify a single method in detail. The study delimits its area of application in the development of new technologies to assist justice and society.

The fourth selected article, developed by Santos, Siqueira and Thizen (2022), deals with the application of 3D printing in the field of veterinary medicine, with a focus on the treatment of vertebral osteosarcoma in dogs. The technology was used to manufacture a 3D-printed vertebral spacer, which was inserted during a vertebrectomy surgery to stabilize the dog's spine after a tumor was removed. The Fused Deposition Modeling (FDM) technique was employed, using the PETG material, which offers high resistance, biocompatibility and low cost. The study delimits its area of application in the use of 3D printing for advanced veterinary treatments.

The fifth selected article, developed by Bini et al. (2021), deals with the application of 3D printing in veterinary medicine, focusing on the use of tracheal prostheses in rabbits. The study aims to evaluate the biocompatibility and inflammatory processes in tracheal reconstruction using 3D printed implants. The technology used was Fused Deposition Modeling (FDM), using nylon associated with PCTPE thermoplastic elastomer. Printing was performed with a Prusa i3 printer, and biocompatibility was evaluated by means of thermographic images. The study delimits its area of application in the use of additive manufacturing for veterinary surgical interventions.

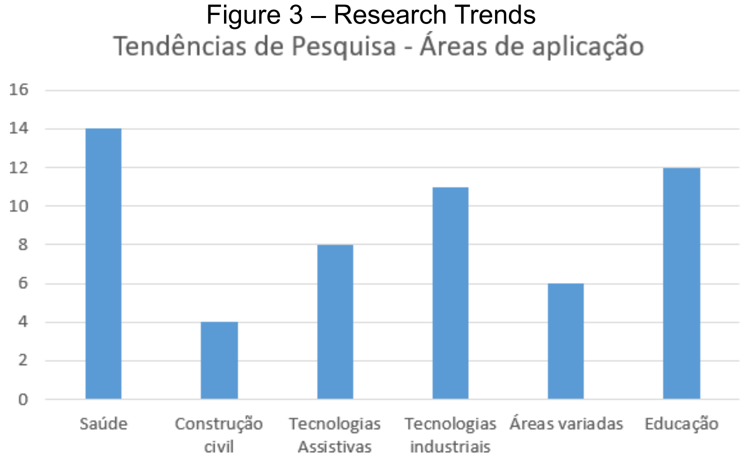
The sixth selected article, developed by Rebouças et al. (2024), deals with the application of 3D printing in robot-assisted therapy, focusing on the treatment of children with Autism Spectrum Disorder (ASD). The study presents the development of the Otto robot, designed to facilitate social interaction and communication during therapeutic sessions. The technology used was FDM (Fused Deposition Modeling) 3D printing, with PLA filaments, aiming to create a robust, accessible and low-cost therapeutic toy, with a simplified and playful design. The study delimits its area of application in the use of robots in therapies for children with ASD.

Analysis of the studies reveals a growing use of 3D printing as a versatile tool for product development in a variety of areas, including cartography, forensics, veterinary medicine, and robot-assisted therapies. The Fused Deposition Modeling (FDM) technique appears as the most used, with materials such as PLA, PETG and nylon, which stand out for their resistance, biocompatibility and cost-effectiveness. 3D printing has been applied to create solutions that facilitate the visualization of complex data, promote accessibility, and offer advances in the medical and technological fields. The Brazilian scenario has adopted this technology to solve specific problems in various fields, from the improvement of personal 3D printers to the creation of therapeutic and support tools in veterinary medicine, highlighting its fundamental role in innovation and adaptation to different industrial, educational and social needs.

NATIONAL CONTEXT OF ADDITIVE MANUFACTURING

The national scenario related to additive manufacturing has shown an expressive growth since 2020, considering that only 7 of the 55 articles analyzed are prior to that date. Regarding research trends, the national context presents a varied distribution among different areas of application. About 25.45% of the research is focused on the health area, 21.81% is focused on the educational area, 7.27% on civil construction, 14.54% on the development of assistive technologies, 20% is focused on the development of industrial technologies, and 10.9% cover various areas, including from veterinary medicine to forensic medicine, applied to the resolution of criminal cases. This diversity reflects the versatility and broad applicability of additive processes, as can be seen in Figure 3.

Figure 3 – Research Trends



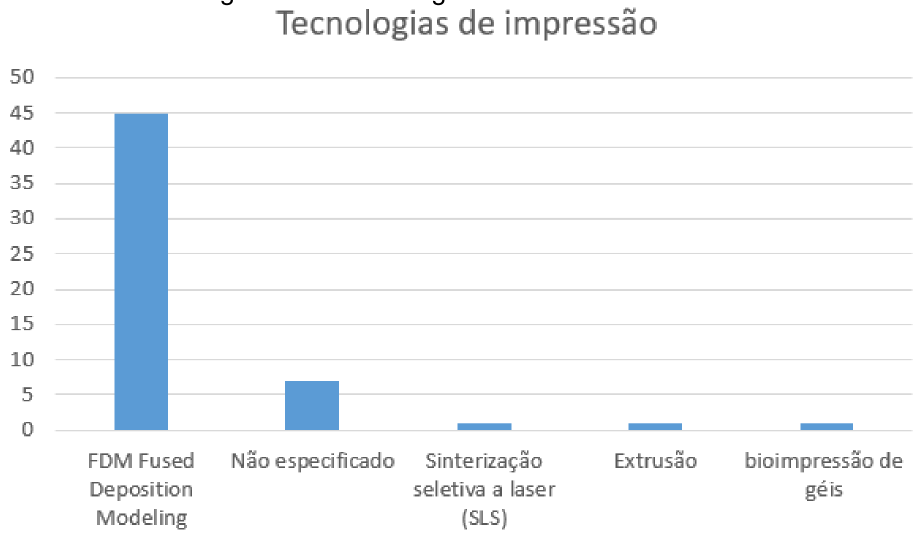
Source: Prepared by the authors

Despite this advance, Brazil is still largely restricted to the most consolidated additive manufacturing technologies in the market. Approximately 82% of the studies analyzed use FDM (Fused Deposition Modeling) or FFF (Fused Filament Fabrication) technology, which are equivalent. The scarcity of research employing less conventional

Revista ARACÊ
ISSN: 2358-2472

technologies highlights a challenge in the national context. Although additive manufacturing is seen as a low-cost manufacturing process, less widespread technologies require higher investments and specialized labor, which limits its use and study. The most used technologies in Brazil can be seen in Figure 4.

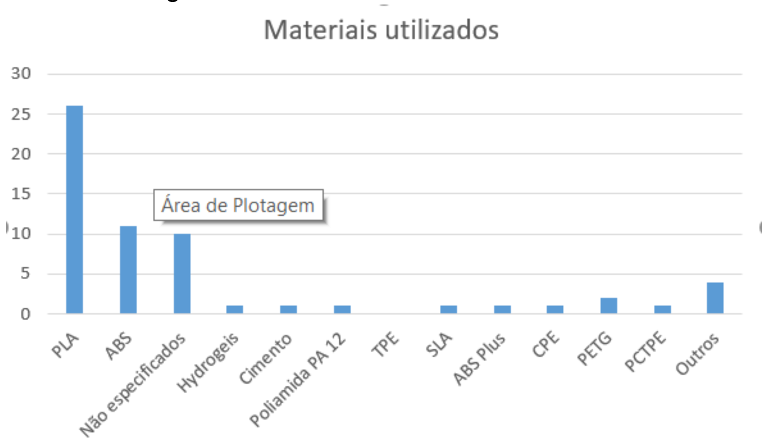
Figure 4 – Technologies Used in the Studies



Source: Prepared by the authors

Another relevant obstacle is the lack of skilled labor and investments needed to explore different types of materials. Conventional materials, such as PLA (polylactic acid) and ABS (Acrylonitrile Butadiene Styrene), dominate the studies, being used in about 32 of the 55 articles analyzed. The predominance of these materials limits the development of research that could explore more advanced or specific materials for certain applications. The distribution of the materials used in the research can be seen in Figure 5.

Figure 5 – Materials Used in the Studies



Source: Prepared by the authors

Revista ARACÊ
ISSN: 2358-2472

In summary, although Brazil has shown remarkable growth in research related to additive manufacturing, the country still faces significant limitations in terms of printing technologies and materials used. This scenario stems from the fact that additive manufacturing is a relatively new process in the country and the initial investment, although not exorbitant, continues to be a barrier to further research, especially in less conventional technologies.

CONCLUSION

This systematic study reviewed the use of additive manufacturing (AM) in Brazil, with the objective of identifying the products developed, the emerging research trends, the most used technologies and materials, in addition to the methodologies applied in the national scenario. The analysis revealed a significant growth in searches related to additive manufacturing in Brazil from 2020 onwards, with most studies concentrated in sectors such as health, education, and industry.

The most widely used 3D printing technologies in Brazil are Fused Deposition Modeling (FDM) and selective laser sintering (SLS). FDM was the predominant technology, being used in approximately 82% of the studies reviewed. The preference for this technology reflects its affordable cost and wide availability in the market, but it also highlights a limitation in the use of more advanced and less conventional technologies, which require greater investment and skilled labor. In the health sector, 14 articles were analyzed, with emphasis on the use of 3D printers in the creation of personalized prostheses, anatomical biomodels and diagnostic tools, evidencing the growing adoption of technology in the hospital environment.

In the educational area, 12 studies addressed the use of additive manufacturing to improve basic and higher education, with the development of three-dimensional models aimed at innovative pedagogical practices. In the industrial sector, 11 studies stood out in the modernization of processes and the development of sustainable products. In addition, 8 studies focused on assistive technologies, aiming to make life easier for people with disabilities. Various areas, including civil construction, were represented in 10 articles, demonstrating the versatility of additive manufacturing in the national context.

In terms of materials, PLA (polylactic acid), ABS (Acrylonitrile Butadiene Styrene) and PETG were widely used, appearing in 32 of the 55 articles reviewed. The predominance of conventional materials, such as PLA and ABS, and the scarcity of

Revista ARACÊ
ISSN: 2358-2472

research exploring more advanced alternatives reflect a significant limitation in the development of new materials in Brazil.

Therefore, although the country has shown significant growth in the use of additive manufacturing, its progress is limited by factors such as lack of investment and lack of skilled labor. Overcoming these challenges involves expanding the use of innovative materials, adopting advanced manufacturing techniques, and investing in professional training. The methodology applied in the reviewed studies was varied, ranging from experimental studies to the application of computer simulations, showing an advance in research practices in the Brazilian scenario.

For additive manufacturing to become a competitive and sustainable alternative in Brazil, it is essential that the academic and industrial sectors expand their efforts in the adoption of emerging technologies and in the training of trained professionals, ensuring that the country keeps up with the global evolution of this technology.

Revista ARACÊ
ISSN: 2358-2472

REFERENCES

1. Abrantes, J. C., Turque, F., Demier, B. F., Neves, D. G., Yahiro, D. S., Kubo, T. T. A., Canale, L., & Mesquita, C. T. (2024). 3D printing in the evaluation of constrictive pericarditis. Arquivos Brasileiros de Cardiologia, 121(2), Article e20220866. https://doi.org/10.36660/abc.20220866

2. Aguiar, S. L., Tavares, F. R. M., Mendonça, F. J. S. F., Cassiano, C. E. M., & Duarte, A. K. G. (2023, October). Study on the use of rapid prototyping in 3D printing applied to product development: A systematic literature review. In XLIII Encontro Nacional de Engenharia de Produção, Fortaleza, Ceará, Brazil. https://www.abepro.org.br/publicacoes/artigo.asp?e=enegepa=2023c=46123

3. Alkunte, S., Fidan, I., Naikwadi, V., Gudavasov, S., Ali, M. A., Mahmudov, M., Hasanov, S., & Cheepu, M. (2024). Advancements and challenges in additively manufactured functionally graded materials: A comprehensive review. Journal of Manufacturing and Materials Processing, 8(1), Article 23. https://www.mdpi.com/2504-4494/8/1/23

4. Andrade, M. A. B., Silva, C., Cella, J. V. S., & Savi, M. B. M. (2020). 3D printing of face shields for the protection of healthcare professionals against COVID-19 infection. Revista Tecnologia e Sociedade, 16(44), 59–66. https://periodicos.utfpr.edu.br/rts/article/view/12207

5. Assad, D. A. B., Elui, V. M. C., Wong, V., & Fortulan, C. A. (2017). 3D printed shoulder orthosis: A case report. Acta Fisiátrica, 24(3), 154–159. https://doi.org/10.5935/0104-7795.20170029

6. Basniak, M. I., & Dombrowski, A. F. (2023). Combining: A material for teaching combinatorial analysis to blind students. ACTIO: Revista de Extensão e Cultura, 8(1), 1–23. https://periodicos.utfpr.edu.br/actio

7. Baumfeld, T., Rezende, R. F., Araújo, L. H. O., Andrade, M. A. P., Baumfeld, D., & Huebner, R. (2021). Preoperative planning for the correction of supramalleolar deformities using 3D printing: A case report. Medicina (Ribeirão Preto), 54(3), Article e172832. https://doi.org/10.11606/issn.2176-7262.rmrp.2021.172832

8. Baêta, C. F., & Silva, E. V. C. (2023). Development of a low-cost dryer for 3D printer filaments. Research, Society and Development, 12(6), Article e1912641857. https://doi.org/10.33448/rsd-v12i6.41857

9. Belgiu, G., Turc, C. G., & Carausu, C. (2020). Selection of subtractive manufacturing technology versus additive manufacturing technology for rapid prototyping of a polymeric product. Mater. Plast., 57(4), 343–352. https://doi.org/10.37358/MP.20.4.5434

10. Belloti, J. C., Alves, B. V. P., Archetti, N., Nakachima, L. R., Faloppa, F., & Tamaoki, M. J. S. (2021). Treatment of distal radius malunion: Corrective osteotomy with planning using 3D printing prototyping. Revista Brasileira de Ortopedia, 56(3), 384–389. https://doi.org/10.1055/s-0040-1718510

11. Bertti, J. V. P., Silveira, E. E., & Assis Neto, A. C. (2020). Reconstruction and 3D printing of a dog's neurocranium using computed tomography as a tool to assist in teaching veterinary anatomy. Arquivos Brasileiros de Medicina Veterinária e Zootecnia, 72(5), 1653–1658. https://doi.org/10.1590/1678-4162-11209

12. Bettega, A. L., Brunello, L. F. S., Nazar, G. A., Enomoto de-Luca, G. Y., Sarquis, L. M., Wiederkehr, H. A., Foggiatto, J. A., & Pimentel, S. K. (2019). Chest drain simulator: Development of a low-cost model for training doctors and medical students. Revista do Colégio Brasileiro de Cirurgiões, 46(1), Article e2011. https://doi.org/10.1590/0100-6991e-20192011

13. Bini, I. F. B., Yamashiro, L. M., Ido, C. K., Ribeiro, J. O., Montanhim, G. L., Pazzini, J. M., Rocha, T. A. S. S., Dias, L. G. G., & Moraes, P. C. (2021). Thermographic camera evaluation of a co-polyamide and thermoplastic elastomer implant in a rabbit trachea. Veterinária e Zootecnia, 28, 001–011.

14. Bona, C., Camozzato, T. S., Silva, C., Dorow, P. F., & Savi, M. B. (2020). Learning human vertebral anatomy using 2D and 3D lumbar vertebral models. Revista Novas Tecnologias na Educação, 18(1), 1–20. https://jems.sbc.org.br/jems2/index.php?r=person/view&id=236138

15. Borges, A. F., Santos Junior, J. F., Sousa, L. O., Souza, R. C., Galvão, R. C. D., Ribeiro, V. C. T., Greati, V. R., Silva, I. M. D., & Pinheiro, F. I. (2020). Wearable optical device to assist visually impaired individuals in the classroom. Research, Society and Development, 9(9), Article e930997623. http://dx.doi.org/10.33448/rsd-v9i9.7623

16. Capeloto, O. A., Rodrigues, C. N., Guilherme, A. P., & Yamaguchi, K. K. L. (2023). Application of 3D printing models as a tool for experimental practical activities in physics education. Revista de Ciências e Tecnologia, 6(6), 710–722. https://doi.org/10.12345/rct.v6i6.2023

17. Carbonari, L. T., Toralles, B. M., Silva, L. F., Librelotto, L. I., & Giglio, T. G. F. (2023). 3D printing with cementitious materials: A comparative analysis of residential projects. Mix Sustentável, 9(4), 27–39. https://doi.org/10.29183/2447-3073.MIX2023.v9.n4.27-39

18. Cecchel, S., & Cornacchia, G. (2024). Additive manufacturing for rapid sand casting: Mechanical and microstructural investigation of aluminum alloy automotive prototypes. Metals, 14(4), Article 459. https://www.mdpi.com/2075-4701/14/4/459

19. ChatGPT. (2024). Article analyst conversation. Retrieved July 16, 2024, from https://chatgpt.com/g/g-JwYhftH3M-article-analyst/c/df568dde-25f4-45b8-8474-75d762b60fd3

20. Dias, L. A., & Galhardi, A. C. (2023). Creation of a poka yoke artifact by 3D printing for inspecting the diameter along the length of circular section tubes. Revista Foco, 16(2), Article e1040. https://doi.org/10.54751/revistafoco.v16n2-133

21. Duan, J., Shao, H., Wu, J., Liu, H., Wang, S., & Lin, T. (2022). Effect of SiO2 in situ cross-linked CS/PVA on SrFe12O19 scaffolds prepared by 3D gel printing for targeting. Ceramics International, 48(20), 30307–30316. https://www.sciencedirect.com/science/article/pii/S0272884222023379

22. Ferreira, C. C., & Freitas-Gutierres, L. F. (2022). Active learning through rapid prototyping in an undergraduate energy engineering course. Revista Thema, 21(3), 776–795. https://doi.org/10.15536/thema.V21.2022.776-795.2197

23. Gade, S., Vagge, S., & Rathod, M. (2023). A review on additive manufacturing – methods, materials, and its associated failures. Advances in Science and Technology Research Journal, 17(3), 40–63. https://doi.org/10.12913/22998624/163001

24. Garofalo, J., Shah, R., Thomas, G., Shirvani, K., Marian, M., & Rosenkranz, A. (2024). Additive manufacturing in the maritime industry: A perspective on current trends and future needs. Journal of Ship Production and Design, 40(1), 36–43. https://doi.org/10.5957/JSPD.05230005

25. Gil, A. C. (2022). Como fazer pesquisa qualitativa [How to conduct qualitative research] (1st ed.). Barueri, SP: Atlas.

26. Gomes, J. N., Gomes, S. H. A., Costa, S. M., & Costa, S. A. (2020). 3D printing for clothing: New paradigms in design and consumption. ModaPalavra e-periódico, 13(29), 136–156. https://doi.org/10.5965/1982615x13292020136

27. Graça, A. J. S., Fosse, J. M., Veiga, L. A. K., & Botelho, M. F. (2021). 3D printing in the context of cartographic representations. Revista Brasileira de Cartografia, 73(3), 809–826. https://doi.org/10.14393/rbcv73n3-56659

28. Guidolin, L. R., Müller, A. F., Tonetto, M. S., Furlanetto, A. P., Puricelli, E., Quevedo, A. S., & Ponzoni, D. (2022). Free software navigation and 3D printing: Basic principles and simulations in oral and maxillofacial surgery and traumatology. Research, Society and Development, 11(1), Article e57811125324. http://dx.doi.org/10.33448/rsd-v11i1.25324

29. Hornburg, L. E., Sobral, J. E. C., Silva, D. C., & Ribeiro, R. B. (2022). 3D printed trims for small fashion brands. DATJournal, 7(4), 319–333. https://www.datjournal.univille.br

30. Junior, M. I. A., Ambrósio, L. C., Mota, L. S. L. S., Medola, F. O., & Paschoarelli, L. C. (2023). Digitization of biological structures in the design of tactile instructional material for people with visual impairment. DATJournal, 8(4), 100–123.

31. Júnior, J. L. R., Santos Júnior, H. C. F., Silva, E. C., Rodrigues Neto, J. L., Miranda, A. P., Sá, N. M. C. M., & Xavier, M. B. (2021). Development of an assistive technology device/orthoprosthesis for the rehabilitation of leprosy patients with claw hand and/or bone resorption. Research, Society and Development, 10(16), Article e449101623742. http://dx.doi.org/10.33448/rsd-v10i16.23742

32. Kocovic, P. (2017). History of additive manufacturing. In 3D printing and its impact on the production of fully functional components: Emerging research and opportunities (pp. 1–24). IGI Global. https://doi.org/10.4018/978-1-5225-2289-8.ch001

33. Maia, L., Ladeia, K. T., Althoff, B. F., Marchetto, A., Meneghel, D., & Baldo, G. V. (2024). Partial shoulder arthroplasty guided by three-dimensional prototyping. Revista Brasileira de Ortopedia, 59(S1), e73–e77. https://doi.org/10.1055/s-0042-1749625

34. Martins, K. Y. N., Branco, R. R. C., Andrade, K. D., Silva, J. B., & Oliveira, M. L. F. (2017). Development of a vaginal educator through the additive manufacturing process (3D printing). Revista Pesquisa em Fisioterapia, 7(1), 20–23. https://doi.org/10.17267/2238-2704rpf.v7i1.1239

35. Matos, I. A. F., Costa, V. B., Godoi, M. A., Fernandes, C. M. S., & Serra, M. C. (2023). Application of additive manufacturing in forensic sciences: New technologies in service of justice and society. Research, Society and Development, 12(1), Article e28412139725. http://dx.doi.org/10.33448/rsd-v12i1.39725

36. Mattos, V. O., Ferraz, R. A. S., Fukai, R. I., Sousa, D. G. L. C., Laguna, J. P. M., Marques, L. R., Pedro, H. A. A., Sampaio, D. J. B. S., & Martins, M. S. (2023). Use of reengineering allied with prototyping in the maintenance of laboratory equipment at UNESP – Guaratinguetá campus. Revista Foco, 16(1), Article e793. https://doi.org/10.54751/revistafoco.v16n1-083

37. Mendonça, C. J. A., Gasoto, S. C., Belo, I. M., Setti, J. A. P., Soni, J. F., & Schneider Júnior, B. (2022). Application of 3D printing technology in the treatment of pseudarthrosis of a Hoffa fracture. Revista Brasileira de Ortopedia, 58(2), 303–312. https://doi.org/10.1055/s-0042-1750760

38. Mergener, D., & Silva, F. P. (2021). Rapid prototyping process as an alternative for redesigning equipment components: A case study of a 3D-printed air exhaust fan propeller. Projética, 12(1), 88–113. https://doi.org/10.5433/2236-2207.2021v12n1p88

39. Mohamed, M. Y., & Surmen, H. K. (2024). Fostering cross-industry sustainability with intelligent technologies. In B. K. Mishra (Ed.), Fostering cross-industry sustainability with intelligent technologies (pp. 499–520). IGI Global. https://doi.org/10.4018/979-8-3693-1638-2.ch030

40. Monteiro, H. M. S., & Garcia, L. J. (2022). Use of displacement maps in creating auxiliary resources for inclusive education for people with visual impairment. Revista Design & Tecnologia, 12(25), 1–17. https://www.pgdesign.ufrgs.br/det2022iss25pp01-17

41. Morais, M. O., Santos, O. S., & Morais, G. A. (2021). The importance of 4.0 methodologies in the development of a small business: A case study on the use of 3D printing in a metallurgical company. Research, Society and Development, 10(1), Article e56710112218. https://doi.org/10.33448/rsd-v10i1.12218

42. Oliveira, C. R. A., Ferreira, C. C., & Martins, C. S. L. (2022). Didactic model for science education, constructed through 3D printing: Analysis and evaluation in the teaching-learning process. Revista Iberoamericana de Tecnología en Educación y Educación en Tecnología, 32, 44–53. https://doi.org/10.24215/18509959.32.e5

43. Onisaki, H. H. C., & Vieira, R. M. B. (2019). 3D printing and the development of educational products. Educitec, 5(10), 128–137.

44. Palaio, S. C. S., Almeida, M. V. L., & Patreze, C. M. (2018). Development of 3D printed models for science education. Ensino de Ciências e Tecnologia em Revista, 8(3), 70–82.

45. Pant, M., Pidge, P., Nagdeve, L., & Kumar, H. (2021). A review of additive manufacturing in aerospace application. Revue des Composites et des Matériaux Avancés-Journal of Composite and Advanced Materials, 31(2), 109–115. https://doi.org/10.18280/rcma.310206

46. Peng, X., Kong, L., Fuh, J. Y. H., & Wang, H. (2021). A review of post-processing technologies in additive manufacturing. Journal of Manufacturing and Materials Processing, 5(2), Article 38. https://www.mdpi.com/2504-4494/5/2/38

47. Pereira, J. F., & Santos, J. E. G. (2021). Rapid prototyping: An ergonomic footrest to assist venous return. Revista Conhecimento Online, 13(2), 114–129. https://doi.org/10.25112/rco.v2i0.2543

48. Prado, V. J., Freitas, L. C., Jesuíno, F. M., & Ornellas Filho, E. B. (2020). Development of a multimaterial 3D printing project using a dual extruder module for personal prints. Research, Society and Development, 9(4), Article e62942853. http://dx.doi.org/10.33448/rsd-v9i4.2853

49. Priarone, P. C., Catalano, A. R., & Settineri, L. (2023). Additive manufacturing for the automotive industry: On the life-cycle environmental implications of material substitution and lightweighting through re-design. Progress in Additive Manufacturing, 8(6), 1229–1240. https://doi.org/10.1007/s40964-023-00395-x

50. Ramos, C. M. C., Lopes, J. R., & Teixeira, R. B. (2023). Development of mask design as personal protective equipment through 3D printing. Revista Design & Tecnologia, 13(26), 183–193. https://www.pgdesign.ufrgs.br

51. Rebouças, G. R. B. S., Kempner, T. R., Borges, L. C. L. F., & Nunes, E. P. S. (2024). Requirements specification approach for 3D modeling of the Otto robot for therapy sessions with autistic children. Projética, 15(1), 1–24. https://doi.org/10.5433/2236-2207.2024.v15.n1.48223

Revista ARACÊ
ISSN: 2358-2472

52. Rodrigues, R. A., & Stocco, T. D. (2020). Use of prosthetic limbs manufactured through 3D printing for amputees. Archives of Health Sciences, 27(1), 65–69. https://doi.org/10.17696/2318-3691.27.1.2020.1640

53. Rodrigues, R. B. L., Torriani, E. A. A. C., Giacomini, G. O., Dotto, G. N., & Liedke, G. S. (2020). Multidetector computed tomography with ultra-low radiation dose and 3D printing as aids for guided surgery in implantology. RFO UPF, 25(2), 241–246. http://dx.doi.org/10.5335/rfo.v25i2.9579

54. Santos, A. F., Ramos, I. S., Santos, A. C. S., Borges, G. F., Silva, I. O., & Guimarães, J. M. M. (2020). 3D printed personal protective equipment by federal educational institutions to combat COVID-19. Cadernos de Prospecção, 13(5), 1237–1250. https://doi.org/10.9771/cp.v13i5.38373

55. Santos, C. A. R., Siqueira, E. G. M., & Thizen, G. (2022). Use of additive manufacturing (3D printing) in the treatment of vertebral osteosarcoma in a dog undergoing lumbar vertebrectomy: A case report. Veterinária e Zootecnia, 29, 001–006. https://doi.org/10.1016/j.wneu.2018.01.078

56. Santos, J. T. G., & Andrade, A. F. (2020). 3D printing as a resource for developing didactic material: Linking maker culture to problem-solving. Revista Novas Tecnologias na Educação, 18(1), 1–15. https://doi.org/10.1000/renote2020

57. Serra, M. C., Maia, A. L. D. M., Araujo Filho, P. M., & Pinheiro, E. M. (2020). Rapid prototyping in product development: Construction of a writing adapter prototype. Projética, 11(1), 108–133. https://doi.org/10.5433/2236-2207.2020v11n1p108

58. Silva, A. B. A., Nunes, C. S., & Medvedovski, N. S. (2021). Between the virtual and the tangible: Furniture parametrization to promote collaborative processes in social housing contexts. Revista Pixo, 17(5), 195–211.

59. Silva, J. L., Szydloski, V. M., Puricelli, E., & Ponzoni, D. (2023). Free software navigation and 3D printing applied to the treatment of mandibular osteoma. Research, Society and Development, 12(14), Article e33121444507. https://doi.org/10.33448/rsd-v12i14.44507

60. Silva-Neto, H. A., Duarte-Junior, G. F., Bazílio, G. S., Parente-Rocha, J. A., Colugnati, D. B., Borges, C. L., & Coltro, W. K. T. (2023). 3D printing of a magnetic separator: An accessible approach for sample preparation in COVID-19 diagnosis. Química Nova, 46(5), 476–481. https://doi.org/10.21577/0100-4042.20230023

61. Silva, R. G., Santos, A. L., Silva, M. L., & Carvalho, Y. K. (2023). Three-dimensional representation of mammal teeth and its use as a didactic resource in the training of science and biology teachers. ENCITEC - Ensino de Ciências e Tecnologia em Revista, 13(1), 78–97. https://doi.org/10.31512/encitec.v13i1.796

62. Silva, S. S., & Silva, E. S. O. (2023). Geography education and autism spectrum disorder: Proposal of a 3D material. Revista Ensino de Geografia (Recife), 6(1), 115–129. https://doi.org/10.51359/2594-9616.2023.256876

63. Siqueira, V. C. R., Sousa, M. B. M., Ferreira, J. S. S., Cunha, E. R., Nicolini, J. V., & Borges, S. P. T. (2024). Use of marble residue as a filler for PLA filaments for 3D printing applications. The Journal of Engineering and Exact Sciences (jCEC), 10(1), 171–184. https://doi.org/10.18540/jcecvl10iss1pp17140

64. Sonkamble, V., & Phafat, N. (2023). A current review on electron beam assisted additive manufacturing technology: Recent trends and advances in materials design. Discover Mechanical Engineering, 2(1), Article 1. https://doi.org/10.1007/s44245-022-00008-x

65. Sousa, F., Gatinho, N., Demaison, A., & Campos, L. F. (2022). Design, ergonomics, and 3D printing: A practical project exercise for socket protectors. Revista de Design e Ergonomia, 5, 168–179.

66. Spohr, D. L., Sánchez, F. A. L., & Marques, A. C. (2021). Feasibility study of manufacturing sustainable composite filament for 3D printing from a PLA matrix reinforced with wood fiber waste. Mix Sustentável, 7(4), 115–126. https://doi.org/10.29183/2447-3073.MIX2021.v7.n4.115-126

67. Taparello, G. I. K. (2016). Industrialization of earth construction through 3D printing. Mix Sustentável, Revista de Arquitetura, 87–92. https://doi.org/10.12345/impressao3d-construcao-terra

68. Vafadar, A., Guzzomi, F., Rassau, A., & Hayward, K. (2021). Advances in metal additive manufacturing: A review of common processes, industrial applications, and current challenges. Applied Sciences, 11(3), Article 1213. https://www.mdpi.com/2076-3417/11/3/1213

69. Wiltgen, F., & Lopes, M. (2022). Additive and subtractive manufacturing in the construction of hybrid mechanical molds for application in formative manufacturing. Revista de Tecnología, 15, 45–63.

70. Wohlers, T. T., & Caffrey, T. (2013). Wohlers report 2013: Additive manufacturing and 3D printing state of the industry: Annual worldwide progress report. Semantic Scholar. https://api.semanticscholar.org/CorpusID:108186451

71. Wu, F., & El-Refaie, A. M. (2020). Toward additively manufactured electrical machines: Opportunities and challenges. IEEE Transactions on Industry Applications, 56(2), 1306–1320.

72. Wustro, L., Silva, J. L. V., Moura, B. A. B., Schoenberger, H. S., Takito, D., & D'Agostini, J. C. H. (2024). Use of three-dimensional printing for diagnostic and therapeutic assistance in tibial pilon fractures. Revista Brasileira de Ortopedia, 59(3), e456–e461. https://doi.org/10.1055/s-0044-1785514

73. Zhang, X., Guo, Z., Chen, C., & Yang, W. (2018). Additive manufacturing of WC-20Co components by 3D gel-printing. International Journal of Refractory Metals and Hard Materials, 70, 215–223.

74. Zucca, R., Santos, R. C., Lovatto, J., Lovatto, F., & Sanches, A. C. (2018). Feasibility study of using rapid 3D prototyping in rural production processes. Enciclopédia Biosfera, 15(28), 517–532. https://doi.org/10.18677/EnciBio_2018B45

75. É, G. N., Peduti, G. P., Carvalho, A. M. L., Rabelo, A. S., & Diniz, M. C. (2020). 3D bioprinting of tissues and organs: A technological prospection. Cadernos de Prospecção, 13(5), 1383–1393. http://dx.doi.org/10.9771/cp.v13i5.33571

76. Society of Petroleum Engineers. (2022, November 1). Additive manufacturing bearing design for performance improvement and carbon footprint reduction. In Abu Dhabi International Petroleum Exhibition and Conference (Day 2, D022S158R004). https://doi.org/10.2118/211837-MS