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The Digital Footprint: A Systematic Review of the Impact of 3D Printing in Art Education

La Huella Digital: Una Revisión Sistemática del Impacto de la Impresión 3D en la Enseñanza Artística

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Abstract

The use of 3D printing has the potential to contribute positively to art and education. This systematic review has been conducted to identify previous studies that address the benefits and challenges in the use of 3D printers in artistic education. The period of analysis of publications reviewed was between 2017 and 2024 to ensure the relevance and timeliness of the study. The initial results of the review yielded 220 results from which a second screening resulted in 113 records that were reviewed against inclusion and exclusion criteria. This third screening resulted in 10 articles that were analysed and compared. It is concluded that 3D printing serves as an effective pedagogical tool with certain challenges to overcome and at the same time it is identified that the use of printers of this type in the field of arts education is not yet sufficiently widespread and well known.

Keywords: 3D printing, education, art, innovation, creativity.

Resumen

El uso de la impresión 3D tiene el potencial de contribuir positivamente al arte y la educación. Esta revisión sistemática se ha realizado para identificar estudios previos que aborden los beneficios y desafíos en el uso de impresoras 3D en la educación artística. El periodo de análisis de las publicaciones revisadas fue entre 2017 y 2024 para asegurar la relevancia y actualidad del estudio. Los resultados iniciales arrojaron 220 resultados y el segundo cribado resultó en 113 registros que fueron revisados en función de los criterios de inclusión y exclusión. Este tercer cribado dio como resultado 10 artículos que fueron analizados y comparados. Se concluye que la impresión 3D sirve como herramienta pedagógica eficaz con ciertos retos a superar y del mismo modo, se ha identificado que el uso de impresoras de este tipo en el ámbito de la educación artística aún no está lo suficientemente extendido y conocido.

Palabras clave: Impresión 3D, educación, arte, innovación, creatividad.

1. Introduction

In the digital era we live in, three-dimensional (3D) printing emerges as a powerful tool with the potential to connect the digital world and the representation of reality in a creative and innovative way (González-Zamar & Abad-Segura, 2023). 3D printing has become a trend in art and, in turn, like innovation, has begun to be implemented in educational projects to improve learning processes.

Innovation and creativity are fundamental for humans, as they help them to develop innovative ideas, to adapt effectively to the ever-changing world, to find connections between different concepts, in short, to develop divergent thinking. Moreover, creativity should not be understood as a trait that only virtuous people possess; everyone should have access to it.

The term "digital footprint" in the title is used as a conceptual metaphor that alludes to the lasting and traceable impact that the incorporation of digital technologies, such as 3D printing, has on the educational environment, particularly in the field of art. It does not refer to the digital footprint in its computerized sense (digital identity), but rather to the transformative mark that these technologies leave on the teaching-learning process.

In terms of education, 3D printing can contribute significantly to flexible teaching-learning methodologies, as it requires good collaboration and creativity from both students and teachers (González-Zamar et al., 2023). However, with the saturation of technologies in contemporary society, concerns arise about their real contributions in these areas and the challenges they face. Therefore, this study seeks to identify previous studies that address the use of 3D printing in art and education.

1.1. Origin of 3D printing

Additive manufacturing or 3D printing is defined as production of 3D objects from a digital template. The manufacturing is done by additive layering using diverse types of materials such as plastic, metal, nylon and many others (Mpofu et al., 2014). 3D printing signifies a breakthrough for all of humankind and today it finds utility in multiple sectors. Its origins date back as far as the 1970s, however, the first 3D printing patent was granted to Hideo Kodama of Japanese origin in 1981. Kodama used a photosustainable resin that was polymerized by ultraviolet (UV) light. Nevertheless, his research publication did not have any significant impact, and his project was abandoned by the institution to which it was submitted (Wohlers et al., 2016; Brown, 2023)
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Three years later, in 1984, three French inventors, Le Mehauté, de Witte and André, filed a patent application for the industrial production of components through the curing of photosensitive polymers by UV radiation. However, they were unsuccessful and their application was rejected. In the same year, in the United States, Chuck Hull applied for a patent for the stereolithography process. The inventor used this word to define the creation of objects by hardening layers of their cross-section. He is also credited with significant contributions to the field of additive printing, as he created the STL (Standard Triangle Language) file format and methods for computing and breaking up models into layers to make them printable. The STL (stereolithography) format is widely used to export and share 3D models, particularly for 3D printing applications, as it encodes the surface geometry of an object using a mesh of triangles. However, STL files are not directly interpreted by 3D printers. Instead, they must first be processed by slicing software, which converts the geometric data into machine-readable instructions, typically in formats such as G-code, 3MF, or AMF. These formats contain the specific commands that control the printer's movements, layer height, and material extrusion during the printing process. Therefore, while STL is essential in the design and preparation stage, it must undergo preprocessing before fabrication. Hull obtained the patent in 1986 and created the

VOL 16, NRO 2
doi: 10.18537/mskn.16.02.04

company 3D Systems Corporation to introduce the first 3D printer for commercial use, the SLA-1 (Stereo Lithography Apparatus) (Wohleres et al., 2016; Ochoa Guevara, 2023).

After Hull's significant contribution, new innovations have been presented in the field of additive manufacturing, thanks to which the market has been opening with new methods, materials and patents, among which Fused Deposition Modeling (FDM), invented and patented by Scott Crump in 1989, stands out. This method consists of passing a wire of thermoplastic material through a hot nozzle that melts the material and creates layers of the part to be printed. It is currently the most popular method among the public. The early 1990s were marked by a great development of the technology and several 3D printing companies started to appear (Brown, 2023).

In 2004, Adrian Bowyer created the RepRap project, whose name is an abbreviation of Replicating Rapid-prototyper. Its purpose is to create affordable printers that can replicate themselves (Heredia and Franco, 2014; Dixit, 2022). This project had significant impact among the public thanks to its free use and easy production. As a result, multiple commercial 3D printing companies were subsequently born, among which we can find: Ultimaker, Makerbot, Creality, Prusa, etc. These companies have been growing in the market to become leaders in the distribution of 3D printers with utility in multiple fields, from engineering, biotechnological applications such as organ and tissue printing, to construction and sports industries, etc. (Ochoa Guevara, 2023; Dixit, 2022; Siemiński, 2021).

1.2. Educational and artistic use of 3D printing

The rapid evolution of technology in the field of 3D printing has transformed many different sectors, as we saw at the end of the previous chapter. Its contribution to the area of education has been equally important, thanks to the speed with which it has developed into a versatile and easily accessible technology. 3D printing is an innovative form of plastic expression that allows students to explore different artistic practices and offers new possibilities for interaction. One such case is the use of 3D printing itself (González-Zamar, 2024).

3D printers have opened up new possibilities and learning tools for educators and students that serve to develop the STEAM pedagogical approach whose abbreviation stands for Science, Technology, Engineering, Art, and Mathematics (Wendt et al., 2020). This approach is gaining more importance in the educational environment due to its goal which is to cultivate creative skills and train problem-solving skills, indispensable competences in today's society where creative imagination turns out to be more important than theoretical knowledge. Therefore, this approach uses innovative tools such as coding, robots, drones, virtual reality and 3D printing (Chun, 2021).

It may give the impression that 3D design programs are intended only for professionals, but in recent years free tools have been developed and they are available to everyone, they are free and easy to use, such as, for example, Tinkercard. Also, the prices of 3D printers have been decreasing and they are becoming more and more accessible in educational environments (Farnicka & Serrano, 2019).

To understand how far the educational use of 3D printers can go, here are some of the fields in which they are finding their usefulness: historical artifacts can be printed to examine them, design and engineering students can print their works to examine a real world. In relation to geographical topics, it is interesting to print maps to visualize geographic data, chemistry students can print models of molecules for better analysis, in the field of biology it is very useful to print the shapes of cells, viruses, organs and other biological elements for further study, etc. (Assante et al., 2020).

3D printing marks a major step forward in terms of innovation in education, and among the many benefits offered by its use, the following stand out: the engagement and emotion that this technology generates among students who can actively participate in all stages, from design to the creation of objects; the active participation of students that fosters their motivation in the learning process; new learning possibilities thanks to the direct manipulation of 3D models of objects discussed in classes that would normally be difficult to access and their 2D form would not provide the same level of information; the development of problem-solving skills by overcoming various difficulties of the used 3D printing technology. In addition, the use of 3D printers proves to be especially useful as a support tool to improve the learning process of students with difficulties, such as people with visual impairment (Assante et al., 2020).

It can be observed that 3D printing can have an infinite number of contributions in the educational system. In fact, the technologies have begun to gain great importance and indispensability in the daily life of students, and there is evidence of the impact of 3D printing at all educational levels due to its important benefits in terms of stimulation of imagination and creativity, creation of 3D art, development of spatial perception and many other aspects. However, regarding the relevance of 3D printing in education, it is essential to highlight the importance of teacher training in this area to maximize the benefits in the integral development of students (Chun, 2021).

Despite the immense importance of 3D printing in education, teachers are confronted with two major challenges when integrating technologies into teaching: the time constraints due to curricula and the lack of experience and training in these areas. It is important to understand the relevance of the interdisciplinary nature that these technologies allow to work on and to develop several skills in students at the same time. Therefore, it is essential to provide professional development opportunities for teachers to improve the entire teaching-learning process, to connect learning with the world outside of the classroom (Wisdom & Novak, 2020).

The teacher is responsible for ensuring that the use of innovative technologies is in line with the learning objectives. It is necessary to have the competences to be developed very well defined, to have a solid knowledge base in terms of cognitive education and, finally, to master the tools to be used, as in this case would be 3D printing. The teacher becomes the guide during the process and the students' learning will depend on the scaffolding that the teacher can offer (Sullivan, 2020).

It is important to distinguish between digital modeling and 3D printing. Digital modeling refers to the computer-assisted three-dimensional design process, using specialized software such as Tinkercad, Fusion 360, or Blender, in which virtual representations of objects are created. 3D printing, on the other hand, is the physical process by which these digital models are materialized using a printer that deposits layers of material, usually plastic (such as PLA or ABS), until a tangible object is formed. The two processes are complementary, but not synonymous.

In addition to its instrumental value, 3D printing in art education raises new questions about the relationship between the creative process and the final object. The use of digital tools transforms the notion of authorship and authenticity in art. This debate becomes relevant in educational settings, where digital reproduction can challenge learning based on individual expression and manual technique.

Finally, it is essential to remember that visual and plastic expression are key educational domains that goes beyond mere artistic creativity. When effectively integrated into the educational environment, 3D printing enriches the learning process, caters to diverse learning modalities and contributes to the holistic development of students. This holistic approach positions visual expression as an essential component in educational training, demonstrating that technology can and should be used responsibly and beneficially for everyday life and academic development (González-Zamar, 2024).

VOL 16, NRO 2
doi: 10.18537/mskn.16.02.04

2. Materials and methods

For the analysis and interpretation of data, the methodology of a qualitative systematic review has been selected, and its general objective is to identify previous studies that deal with the use of 3D printing in art and education. The following research question is posed: Is the use of 3D printers in artistic education beneficial?

2.1. Systematic review

This section contextualizes the database searches that have been carried out to identify studies relevant to the topic under discussion and then presents the data obtained in the process together with the criteria taken into account. In this sense, the review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach, using Scopus as the primary database. Inclusion criteria were: peer-reviewed articles published between 2010 and 2024, in English or Spanish, and specifically addressing the use of 3D printing in art teaching contexts. Opinion pieces, theses, non-indexed documents, or those with no direct link to the main topic were excluded. A thematic approach was used for the qualitative analysis of the results.

2.1.1. Database

For this systematic review, Scopus was selected as the database of choice. Scopus is a large, multidisciplinary database that provides access to bibliographic information, including abstracts and citations. This database was launched by the academic publisher Elsevier and its tools help to identify relevant information, follow research trends, track new published research and identify experts in the field. In this context, the Scopus database was chosen due to its high editorial quality standards, its international multidisciplinary coverage, and its reliability in obtaining up-to-date and relevant scientific publications. It is recognized that future research could expand the search scope to databases such as Web of Science, ERIC, or Google Scholar, in order to complement the findings presented. The main Boolean operators used were: AND and OR, linking the following descriptors: "3d print" OR "additive manufacturing" AND art OR education.

In the first search with the formula mentioned above, 3,729 results were obtained, where the year of publication ranges from the year 2005 to 2025. Next, the search was filtered by subject area (limited to Social Sciences and Arts and Humanities), by document type (limited to Article) and by language (limited to English). After this selection, the number of results decreased to 113 results, where all the year of publication ranges from 2013 to 2024. To obtain even more precise results it was necessary to exclude other research areas with little relevance to the topic (Agricultural and Biological Sciences; Chemical Engineering; Decision Sciences; Earth and Planetary Sciences; Health Professions; Bussines, Management and Accounting; Economics, Econometrics and Finance; Material Science; Psychology; Physics and Astronomy; Mathematics; Chemistry; Dentistry; Energy; Environmental Science; Medicine; Computer Science; Engineering). After this last filter, the total of results was 26 articles.

The table 1 shows the results of the research with the respective search formulas used, the results of the first screening, the filters applied with the successive results and the result after exclusion of non-relevant areas.

Table 1: Initial database search (2005-2025)
Source: Own elaboration, (2025)

Database	Search formula	Initial number of results	Filters	Number of results
Scopus	"3d print" OR "additive manufacturing" AND art OR education	3,729	**Subject areas limited to:** Arts and Humanities, Social Sciences **Document type:** Article **Language:** English	113
			Excluded areas: Agricultural and Biological Sciences; Chemical Engineering; Decision Sciences; Earth and Planetary Sciences; Health Professions; Bussines, Management and Accounting; Economics, Econometrics and Finance; Material Science; Psychology; Physics and Astronomy; Mathematics; Chemistry; Dentistry; Energy; Environmental Science; Medicine; Computer Science; Engineering	26

It is recognized that limiting the search exclusively to the Scopus database could restrict the diversity of approaches included in this review. Future research suggests incorporating other complementary academic databases, such as Web of Science, ERIC, or Google Scholar, to enhance the variety and representativeness of the sources.

2.1.2 Inclusion and exclusion criteria

To reduce the substantial number of results that the first search yielded, the following screening has used inclusion criteria, which are filters used in article searches and should meet the following requirements:

- Papers that relate the use of 3D printing to education or art within the area of Arts and Humanities or Social Sciences.
- Article-type papers
- Documents in English language
- Availability of full text

On the other hand, articles that meet the following criteria would not be included in the literature review (exclusion criteria):

- Papers related to research area other than Social Sciences or Arts and Humanities.
- Papers related to the subject other than Education or Art

For the present study, only the Scopus database has been selected as a source to extract the necessary documents for the study. In the first

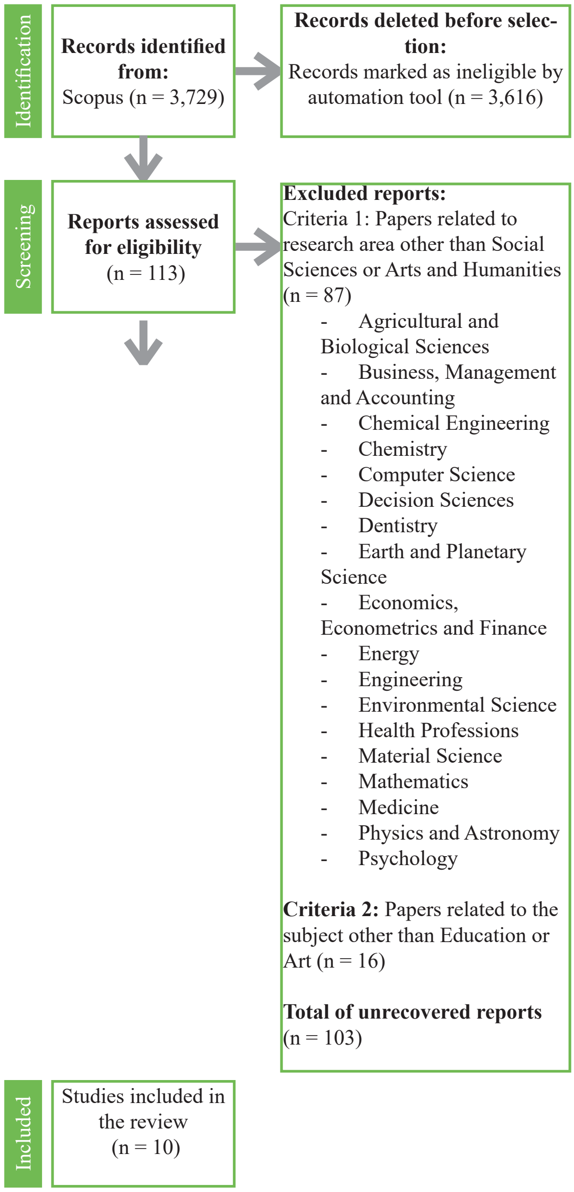

Figure 1: Flow chart of the record selection process (2005-2025)
Source: Own elaboration, (2025)

VOL 16, NRO 2
doi: 10.18537/mskn.16.02.04

"Identification" phase, 3,729 entries were displayed. Then, the documents that were marked as ineligible using the automation tool, i.e. after the application of the filters, 3,616 papers were eliminated, resulting in 113 documents suitable for retrieval. In the next "Screening" phase we started from a base of 113 entries to which the above-mentioned exclusion criteria were applied. This process resulted in 10 articles that have been used for the preparation of this study, which meet the inclusion criteria described above (Figure 1).

3. Results

This section shows the most relevant and outstanding characteristics of the 10 articles that were selected through the screening described above, which form the basis of this systematic review (Table 2).

Table 2: Studies included in the review (2005-2025)
Source: Own elaboration, (2025)

Authors	Coun-tryww	Design	Relation to Art/ Education	Educatio-nal context	Conclusions
Khyzhynskyi et al. (2024)	Ukraine	A scoping review	Artistic ceramics	General public and artists	This study emphasizes the growing role of additive technologies in artistic ceramics, highlighting their potential to innovate traditional practices and support educational development by expanding knowledge of materials, techniques, and the creative possibilities of 3D printing with ceramics.
Malinka et al. (2024)	Czech Republic	Quantitative research approach	Education including art education	Secondary Education	The paper presents the results of two experiments demonstrating high student acceptance of 3D technology and positive impacts on student performance, and deals with the issue of incorporating 3D printing into the curriculum.
Adler (2023)	United States	Descriptive article	Art authenticity	General public	The authenticity of works of art is questioned in a view of 3D printing which can make an exact copy of the art object. This Article explores the norm of authenticity of art, and shows why it is essential to understanding both the art market and the NFT phenomenon.
Wargo et al. (2022)	United States	Case study	Art expression	Preservice teachers	This paper illustrates how integrating 3D printing with arts-based literacy practices can enrich educational experiences, enabling preservice teachers to critically engage with texts, explore social issues, and expand their understanding through multimodal expression.
Alhonkoski et al. (2021)	Finland	A scoping review	Education	Secondary and Higher Education	This scoping review describes the use of 3D technology to support teaching and learning in health care education. The findings describe positive effects on student learning related to skills, knowledge, students' perceptions and emotions.
Horton (2021)	United States	Quantitative research approach	Art accessibility	Higher Education	This paper analyses 3D printing program at an academic library that was used for educational or research purposes. The departments that have used the 3D printer the most have been: Mechanical Engineering and Energy Processes, Library Affairs, Architecture, Industrial Design, Curriculum and Instruction, Computer Science, Mass Communication and Media Arts and Geology.
Jordan et al. (2021)	United States	Mixed-methods approach	Art education	and general public	In this work, mobile makerspaces like MAKE 3D integrate 3D printing into art education. Through interdisciplinary learning that bridges art, design, and technology, MAKE 3D fosters kinaesthetic experiences that encourage artistic expression, problem-solving, and technical skills, expanding access to STEAM education in diverse, place-based contexts.

Reilly and Dawson (2021)	United Kingdom	Research Article	Art and Archaeology	General public	This paper describes human creative responses to a surface assemblage (a scatter) of lithic artefacts via the use of 3D printed replicas made with certain modifications in terms of colour and scale.
Ye et al. (2020)	China	A systematic review and meta-analysis	Education	Secondary and Higher Education	The review shows that in teaching the human body using 3D printed models, the test results are not inferior to that of the conventional teaching group. Compared with the cadaver or 2D group, the 3D group had higher test scores. Compared with the conventional group, students in the 3D group had higher test accuracy, and the students found the 3D model more useful.
Turner et al. (2017)	Canada	Descriptive article - collaborative research	Art accessibility	Elementary and Secondary Education, Museum	This article describes a research project about how children learn to 3D print in a museum, evaluating their technical understanding and interest in the cultural history of shoemaking. The use of 3D printing technologies in museum contexts encourages creative participation which helps engagement and enthusiasm with museum content and digital technologies.

In the screening process, certain criteria were established that helped to derive the presented selection of articles, the main objective of which was to search for articles that identified the use of 3D printing in education and art. All the authors start from the key element of additive manufacturing and the utilities that this technology finds in the aforementioned areas and the benefits they bring.

The dates of the publications have shown that the existing literature and studies about this research are very recent, from which it can be deduced that the object of study is current and important. The publications range from 2017 to 2024, where most of them were published in the period from 2021 onwards.

Regarding the educational context, differences were observed in the educational levels addressed in the studies. Some papers focused on secondary education, such as Malinka et al. (2024), while others covered both secondary and higher education, such as Alhonkoski et al. (2021) and Ye et al. (2020). Jordan et al. (2021) and Horton (2021) worked in the higher education setting, with the latter also covering the general population. Wargo et al. (2022) focused their study on trainee teachers, while Turner et al. (2017) included both primary and secondary education in their research on museums. Finally, some studies targeted the public, such as Khyzhynskyi et al. (2024), Adler (2023), and Reilly and Dawson (2021).

After the analysis of the selected articles, the use of 3D printing in education brings multiple benefits that have been demonstrated by several studies. Within the field of art education, various thematic approaches were found. Some research studied the use of 3d printing in education in general, such as those of Alhonkoski et al. (2021) and Ye et al. (2020). Others focused specifically on art education, such as Malinka et al. (2024) and Jordan et al. (2021) or Wargo et al. (2022) who explored artistic expression in future teachers. In terms of accessibility to art, Horton (2021) and Turner et al. (2017) stand out. On the other hand, some studies approached art from different perspectives with an indirect relationship with education, such as the work of Khyzhynskyi et al. (2024) on the teaching of artistic ceramics, the study of Adler (2023) on authenticity in art and the analysis of Reilly and Dawson (2021) around art and archeology.

Regarding the incorporation of 3D printing in education as a pedagogical tool, authors such as Malinka, et al. (2024), Wargo et al. (2022), Jordan et al. (2021) and Horton (2021) justify the great benefits that 3D printing brings. Malinka et al. (2024) present research in secondary education that summarises the benefits that this technology brings to education such as increased student motivation, greater interactivity and attractiveness, improvement of students' observation and concentration, creativity and spatial imagination, and statistically significant drop, in students' boredom. This general

VOL 16, NRO 2
doi: 10.18537/mskn.16.02.04

approach also encompasses art education. Apart from the benefits there are also certain problems that the educational system must face, such as low correspondence of existing materials with the educational framework, lack of a broader set of teaching materials and teachers' lack of knowledge often leads to a decision not to purchase equipment.

Wargo et al. (2022) explore how 13 teacher trainees used 3D printing to transform sociocultural values and practices into 3D artifacts, enabling a construction of meaning that transcended the representational into the abstract. The process involved both design collaboration and critique and exhibition of the creations, fostering reflection and engagement with art education. On the other hand, Jordan et al. (2021) highlight the potential of 3D printing in art education through interdisciplinary approaches in STEAM projects. Their MAKE 3D initiative merges art, design, and STEM, promoting experiential learning and skill development in digital fabrication. Results show that participation in MAKE 3D improved awareness of the intersection between art and engineering, although differences in interest persisted between students from both disciplines. The study underscores that 3D printing not only facilitates artistic experimentation, but also fosters convergence between different fields of knowledge.

Horton (2021) is another author who justifies the relevance of 3D printing in the educational field, however, he operates in the university environment, where a long-term project has been carried out during which data has been collected and analyzed in relation to the introduction of 3D printers in the academic library. Through credit courses, library workshops, and more traditional outreach type events, the teaching-learning processes have been improved, as the printers were made available to the entire university community. On the other hand, the technology has also been made available to the public which expands the technology collection, perform outreach to certain groups, or market to specific departments. The author demonstrates that 3D printing can significantly help with the needs of teaching and research and demonstrates the potential to expand in the future due to its positive results.

Another key area from the perspective of arts education, is the use of 3D printing in museum and heritage contexts is observed in multiple studies as Turner et al. (2017) and Khyzhynskyi et al. (2024). The study by Turner et al. (2017) demonstrated in a museum space that 3D printing can enhance the learning environment and make it more fruitful. It especially highlights the benefits that 3D printing has when used as a directed workshop in combination with museum-specific pedagogical tools. The author points out the fusion of technical-digital and cultural literacies that engages children with objects with historical-cultural value through a 3D design process. The findings affirm engagement and enthusiasm with both the content of the museum in which the research took place and with digital technologies, and further underline their better understanding.

Khyzhynskyi et al. (2024) explore the impact of 3D printing in artistic ceramics, highlighting its potential to transform both teaching and creative practice. Unlike printing with plastic or metal, 3D printed ceramics require an additional drying and firing process, which introduces unique challenges but also new possibilities for artists. The precision of this technology allows the creation of complex shapes and innovative textures, pushing the boundaries of traditional ceramic design. Despite some technical problems, such as deformation of models before firing, the research highlights the growing interest in clay 3D printing and its integration into art education, including collaborations with artist and ceramic 3D printing teachers to optimize its applications. The impact of 3D printing on the authenticity of art is a key topic in some research. We find new possibilities and contributions: Adler (2023) and Reilly and Dawson (2021) are the only authors who were selected in the process of the systematic review and who are concerned by the topic of 3D printing in art. The study by Reilly and Dawson (2021) highlights the properties of the most used material in 3D printing, PLA, such as biodegradability and biocompatibility with the human body. They created projects whose purposes were replicas of lithic artefacts that were found in a cornfield. These replicas were made with certain modifications in terms of colour and scale. These are the great benefits of 3D printing, which makes it possible to replicate artefacts and for better analysis to enlarge them and even turn them into art through their colour modifications that add new meaning. The replicated and modified artefacts were introduced into the environment where the original elements were found to be rediscovered and to create new contexts.

Adler (2023) offers a unique perspective on the use of 3D printing that challenges a sensitive area of the authenticity of works. As can be seen in the previous study (Reilly & Dawson, 2021), highly advanced technologies can reproduce any object. As a result, art works and their authenticity are threatened by this technological advance. Building on this concern, Adler (2023) warns about the elimination of the visual distinction between copies and originals. Questions are raised about the value of art, whether in the future we will all be able to have the Mona Lisa at home and not have to travel to the Louvre to see it.

Regarding the topic of education, there are authors who have studied the contributions of 3D printing in relation to a better knowledge of the human body, enriching students in health care education (Alhonkoski et al., 2021; Ye et al, 2020). Alhonkoski et al. (2021) use a scoping review to demonstrate the positive effects of the use of 3D printing. This study of different research has demonstrated the usefulness of this technology especially in the field of teaching of anatomy. The authors also point out positive results from the perspective of learning outcomes and outcomes that supported learning for example students' motivation. They highlight the benefits in multiple areas and includes improved skills, knowledge and empathic concerns which are in line with studies in medical education.

Likewise, Ye et al. (2020) discuss 3D print utility, where 3D printed models were found to be more useful than conventional models. After analyzing the selected studies in a systematic review, the authors show that most studies confirm that students who use 3D printing were more satisfied than the conventional group. Only one article does not show a statistical difference between the two groups. The study also highlights the speed with which students answer questions on certain medical topics, showing that the 3D printing groups took less time to answer questions compared to the conventional groups.

4. Discussion

This systematic review has shown that the use of 3D printers in artistic education is beneficial, since it has been possible to see its multiple applications in various educational contexts. Smith (2014) and Menano et al. (2019) concur that the integration of 3D printing in arts education has been demonstrated to engender creativity, critical thinking and active learning. The two studies highlight that this process, based on iterative design, allows students to define criteria, generate solutions, create digital prototypes and receive feedback. The reports also emphasize that 3D printing does not replace traditional techniques, but complements them and expands creative possibilities. Furthermore, both studies emphasize the pivotal role of teacher training in facilitating effective integration of 3D printing in arts education, as well as the significant contribution of contemporary artists in inspiring students. However, the two studies diverge in their approach to implementation. Smith (2014) emphasizes the need for a clearly defined curriculum structure for 3D printing to have a significant impact on learning, while Menano et al. (2019) place more emphasis on interdisciplinary collaboration as key to its success. Likewise, Menano et al. (2019) further highlight the potential of 3D printing to generate

VOL 16, NRO 2
doi: 10.18537/mskn.16.02.04

new educational perspectives by integrating art and technology, while Smith focuses more on its practical application within traditional art education.

Zhang's (2024) study demonstrates how 3D printing can enhance creativity and innovation in art education by facilitating the creation of intricate forms that are challenging to achieve manually. Digital tools such as Sculpt GL facilitate students' experimentation, iteration of designs, and exploration of novel concepts beyond the limitations imposed by traditional materials. The study also emphasizes the interdisciplinary benefits of integrating art, design, and engineering, promoting both functionality and aesthetics. Nevertheless, Zhang (2024) aligns with Smith (2014) and Menano et al. (2019) in underscoring the necessity for adequate teacher training, systematic curriculum integration, and effective resource management. While the transformative potential of 3D printing in the domain of art education is indisputable, its success is predicated on the successful navigation of two significant challenges: the technical and the pedagogical. To ensure a harmonious balance between traditional and digital skills, it is essential to maintain a nuanced approach to the integration of 3D printing in art education.

While creativity and innovation have been widely highlighted as competencies promoted by the use of 3D printing in arts education contexts, the literature reviewed also demonstrates benefits in the development of spatial thinking, problem-solving, digital literacy, collaborative work, and project planning. These skills are fundamental in the context of 21st-century education, aligned with frameworks such as the Digital Competencies for Teachers (DigCompEdu) framework.

Following the contributions of Assante et al. (2020), the study by Chen and Chang (2018) also highlights the potential of 3D printing in art education for students with visual impairments, overcoming challenges such as the lack of specialized teachers and appropriate materials. Through interviews and experimentation with the ARCS (Attention, Relevance, Confidence, and Satisfaction) motivational model, the authors conclude that 3D printing facilitates the teaching of the concept of space in art, allowing students to perceive and create compositions with different depths (foreground, middle ground, and background). The utilization of 3D replicas of renowned paintings served to stimulate curiosity and enhance spatial understanding through tactile engagement. Additionally, the study emphasizes the importance of fostering students' confidence in their artistic abilities and facilitating greater access to cultural spaces, such as museums and galleries, which serve to enrich learning and promote development in the visual arts. Museums were also highlighted as key areas from the perspective of arts education in relation to 3D printing by Turner et al. (2017) and Khyzhynskyi et al. (2024).

Furthermore, there are studies that analyse the advantages and disadvantages of using 3D printing in art education. Meng's (2022) study examines the integration of 3D printing in secondary art education, highlighting its ability to enhance spatial understanding, creativity, and student interaction with art. Virtual modelling enables students to navigate 3D environments, engage with their artwork through simulations and virtual reality, and cultivate teamwork skills. Furthermore, the utilisation of 3D software has been shown to foster autonomy and motivation. However, the study also identifies challenges such as potential technology addiction, the time required to learn the software, and the risk of limiting creativity when over-relying on digital tools. To address these concerns, the author proposes a balanced integration of traditional and digital methods in art education.

5. Conclusions

Following a comprehensive analysis of the 10 selected articles, it can be concluded that 3D printing, used in different contexts (i.e. schools, educational institutions, universities and museums), acts as a versatile tool in the teaching-learning process in art education. It has been demonstrated that this technology can be employed to develop skills related to problem-solving, enhance subject matter comprehension, and stimulate students' motivation and interest in learning, thereby fostering their commitment and enthusiasm. The usefulness and versatility of 3D printing in art have also been demonstrated, as it allows objects to be replicated with great precision and modified in aspects such as scale and colours, giving them new meaning. The ability to transform abstract concepts into tangible objects has been demonstrated to enhance spatial reasoning and artistic expression, broadening students' perspectives on art and technology. However, concerns and controversies have been raised regarding the authenticity of artworks, which may be challenged by these technologies. The successful integration of 3D printing in art education is contingent on the provision of adequate teacher training, as educators must develop the necessary digital and pedagogical skills to guide students effectively and maximize the potential of this technology in the learning process.

The integration of 3D printing in artistic and educational environments offers significant potential to enrich learning and stimulate creativity. However, the studies reviewed reveal several areas that require further attention. Critical issues such as the question of possible weaponization and how to avoid it, licensing issues related to making replicas of certain objects and the lack of research on the contribution of 3D printing in art are not adequately addressed. There is also no mention of the technical challenges of 3D printers, such as the difficulty of printing minute details, the manufacturing of large objects, long printing times, the solidity of the material or its toxicity, especially relevant when the material comes into contact with children. These factors are the limitations not encountered in the selected studies and serve as a motivation for further research. It is also necessary to go deeper into the subject of art, as there have not been enough studies to analyze it.

The review shows that disciplines such as sculpture, industrial design, architecture, and digital art benefit most from the integration of 3D printing, due to their focus on three-dimensionality and prototyping. Regarding educational levels, the impact is especially significant in secondary and higher education, where students have greater technical and cognitive skills to harness the potential of these technologies. However, positive experiences are also recorded at elementary levels through adaptive approaches geared toward creative exploration.

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VOL 16, NRO 2
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7. Bibliographical references

Adler, A. (2023). Artificial Authenticity. *New York University Law Review, 98*(3), 706-769.

Alhonkoski, M., Salminen, L., Pakarinen, A. & Veermans, M. (2021). 3D technology to support teaching and learning in health care education – A scoping review. *International Journal of Educational Research, 105*. https://doi.org/10.1016/j.ijer.2020.101699

Assante, D., Cennamo, G.M. & Placidi, L. (2020). 3D Printing in Education: an European perspective. In 2020 *IEEE Global Engineering Education Conference (EDUCON)* (pp. 1133-1138). Institute of Electrical and Electronics Engineers (IEEE). https://doi.org/10.1109/EDUCON45650.2020.9125311

Brown, M. (2023). *A brief history of 3D printing*. Cad Crowd.

Chen, Y. H., & Chang, P. L. (2018). 3D printing assisted in art education: Study on the effectiveness of visually impaired students in space learning. In 2018 *IEEE International Conference on Applied System Invention (ICASI)* (pp. 803-806). Institute of Electrical and Electronics Engineers (IEEE). http://dx.doi.org/10.1109/ICASI.2018.8394384

Chun, H. (2021). A Study on the Impact of 3D Printing and Artificial Intelligence on Education and Learning Process. Scientific Programming, 2021. https://doi.org/10.1155/2021/2247346

Dixit, U. S. (2022). Evolution of Manufacturing. In V. Sharma and P.M. Pandey (Eds.), *Additive and Subtractive Manufacturing Processes: Principles and Applications* (pp.1-30). CRC Press. https://doi.org/10.1201/9781003327394-1

Farnicka, M. & Serrano Diaz, N (2019). 3D printing skills as a resource for the development of creativity in middle childhood. *Rocznik Lubuski, 45*(1), 123–134. https://doi.org/10.34768/rl.2019.v451.07

González-Zamar, M.-D. (2024). *Expresión plástica y visual: un espacio creativo y didáctico de aprendizaje.* Universidad Almería.

González-Zamar, M.-D., & Abad-Segura, E. (2023). Aproximación al aprendizaje artístico-visual y digital en la Educación Superior. *Maskana, 14*(1), 66-77. https://doi.org/10.18537/mskn.14.01.05

González-Zamar, M.-D., Abad-Segura, E., &Ademar Ferreyra, H. (2023). Alfabetización visual en la Educación Artística en contextos universitarios. *International Journal of Educational Research and Innovation*, (19), 1-16. https://doi.org/10.46661/ijeri.5735

Heredia Martínez, C. A. & Franco Rubio, J. P. (2014). Tecnologías de fabricación aditiva. La impresora 3D, antecedentes y funcionamiento. *Ignis,* (7), 24-30. https://doi.org/10.52143/2711-029X.92

Horton, J. (2021). Assessment of the first 1000 3D prints requests at an academic library. *Public Services Quarterly, 17*(1), 1-11. https://doi.org/10.1080/15228959.2020.1857320

Jordan, A., Knochel, A.D., Meisel, N., Reiger, K. & Sinha, S. (2021). Making on the Move: Mobility, Makerspaces, and Art Education. *The International Journal of Art y Design Education, 40*(1), 52-65. https://doi.org/10.1111/jade.12333

Khyzhynskyi, V., Lampeka, M., & Strilets, V. (2024). The history of the development of 3D printing technologies and their use in world artistic ceramics. *History of Science and Technology, 14*(1), 152-183. https://doi.org/10.32703/2415-7422-2024-14-1-152-183

Malinka, K., Vodová, L., Jancová, M., Sobková L. & Schindler, V. (2024). Evaluation of the Pedagogical Impact of the Educational Usage of 3D Printing in Czech Lower Secondary and Grammar Schools. *European Journal of*

Educational Research, 13(2), 631-649. https://doi.org/10.12973/eu-jer.13.2.631

Menano, L., Fidalgo, P., Santos, I. M., & Thormann, J. (2019). Integration of 3D Printing in Art Education: A Multidisciplinary Approach. *Computers in the Schools, 36*(3), 222–236. https://doi.org/10.1080/07380569.2019.1643442

Meng, C. (2022). Introduce 3D Modelling and Virtual Technology to High School Art Education. Advances in Social Science, *Education and Humanities Research, 637*, 767-770. https://doi.org/10.2991/assehr.k.220131.139

Mpofu, T.P., Mawere, C. & Mukosera, M. (2012). The Impact and Application of 3D Printing Technology. *International Journal of Science and Research, 3*(6), 2148-2152.

Ochoa Guevara, A. (2023). Origen y avance de la impresión 3D. *+Ciencia. Revista de la Facultad de Ingeniería,* (33), 24-28.

Reilly, P. & Dawson, I. (2021). Track and Trace, and Other Collaborative Art/Archaeology Bubbles in the Phygital Pandemic. *Open Archaeology, 7*(1), 291-313. https://doi.org/10.1515/opar-2020-0137

Siemiński, P. (2021). Introduction to fused deposition modeling. In J. Pou, A. Riveiro and J.P. Davim (Eds.), *Additive Manufacturing* (pp. 217-275). Elsevier. https://doi.org/10.1016/B978-0-12-818411-0.00008-2

Smith, S. (2014). 3D Printing: where art and technology collide. *TRENDS, The Journal of the Texas Art Education Association*, 17-23.

Sullivan, P. (2020). 3D Printing in Early Childhood Classrooms: Teacher Considerations and Decisions. In N. Ali, and M.S. Khine (Eds.), *Integrating 3D printing into teaching and learning* (1a ed., Vol. 13, pp. 15-31). BRILL. https://doi.org/10.1163/9789004415133

Turner, H., Resch, G., Southwick, D., McEwen, R., Dubé, A.K. & Record, I. (2017). Using 3D Printing to Enhance Understanding and Engagement with Young Audiences: Lessons from Workshops in a Museum. *Curator, 60*(3), 311-333. https://doi.org/10.1111/cura.12224

Wargo, J. M., Morales, M., & Corbitt, A. (2022). Fabricating response: Preservice elementary teachers remediating response to The Circuit through 3D printing and design. *Curriculum Inquiry, 52*(5), 544¬-570. https://doi.org/10.1080/03626784.2022.2149028

Wendt, J., Beach J. & Wendt, S. (2020). 3D Printing: Practical Applications for K-16 Education. In N. Ali, and M.S. Khine (Eds.), *Integrating 3D printing into teaching and learning* (1a ed., Vol. 13, pp. 1-14). BRILL. https://doi.org/10.1163/9789004415133

Wisdom, S. & Novak, E. (2020). Using 3D Printing to Enhance STEM Teaching and Learning: Recommendations for Designing 3D Printing Projects. In N. Ali, and M.S. Khine (Eds.), *Integrating 3D printing into teaching and learning* (1a ed., Vol. 13, pp. 189-205). BRILL. https://doi.org/10.1163/9789004415133

Wohlers, T., Gornet, T., Mostow, N., Campbell, I., Diegel, O., Kowen, J., Huff, R., Stucker, B., Fidan, I., Doukas, A., Drab, B., Drstvenšek, I., Eitsert, N., Espalin, D., Feldhausen, T., Ghany, K.A., Gillett-Crooks, M., Guo, D., Held, A., Hargovan, S., Holmegaard, L., Jeng, J.Y., Jurrens, K., Keating, B., Ksy, A., Kircher, R., de Beer, D., Brandt, M., Vasco, J., Khorasani, M., Overy, C., Park, K., Chen, S., Pearce, N. & Peels, J. (2016). History of Additive Manufacturing. *Wohlers Report 2016-2022*. http://dx.doi.org/10.2139/ssrn.4474824

Ye, Z., Dun, A., Jiang, H., Nie, C., Zhao, S., Wang, T. & Zhai, J. (2020). The role of 3D printed models in the teaching of human anatomy: A systematic review and meta-analysis. *BMC Medical Education, 20*(1) , 335 https://doi.org/10.1186/s12909-020-02242-x

Zhang, H. Y. (2024). Investigating the Use of 3D Printing in Fine Arts Education: A Case Study on Student Artistic Development. *Art and Design Review, 12*, 284-299. https://doi.org/10.4236/adr.2024.124020