

# 3D printing as an educational tool for developing creative thinking: systematic review

## La impresión 3D como herramienta educativa para desarrollar el pensamiento creativo: revisión sistemática

<http://doi.org/10.32870/Ap.v15n2.2382>

Lorena Cabrera Frías\*

Diana Margarita Córdova Esparza\*\*

### ABSTRACT

#### Keywords

3D printing; educational tool; educational technology; creative thinking; industrial design

This systematic review explored how 3D printing as an educational tool favors learning and develops creative thinking in higher education students, particularly in the industrial design career. Furthermore, this tool potentiates specific educational and cognitive abilities in students. Therefore, we performed a literature analysis covering the years 2017 to 2022 on how 3D printing has been integrated into the educational area and where the work in the classroom is headed. In this context, we followed the inclusion, exclusion, and relevance criteria to search for articles, resulting in the analysis of 19 documents found in the Google Scholar, SciELO, Redalyc and Scopus databases. We divided the analysis into five steps: planning, selection, extraction, results, and conclusions. The results show that most authors agree that the use of 3D printing helps to develop creativity and generate motivation in students. Therefore, it is necessary to promote an intelligent curriculum with scientific and technological innovations that reinforce the path toward their professional development.

### RESUMEN

#### Palabras clave

Impresión 3D; herramienta educativa; tecnología educativa; pensamiento creativo; diseño industrial

La presente revisión sistemática exploró de qué manera el uso de la impresión 3D como recurso educativo favorece el aprendizaje y fomenta el desarrollo del pensamiento creativo en estudiantes de nivel superior, particularmente en aquellos que cursan la carrera de Diseño industrial. El uso de esta herramienta ofrece la oportunidad de potenciar diversas habilidades educativas y cognitivas en los estudiantes. Se realizó un análisis de la literatura académica publicada de 2017 a 2022, sobre la integración de la impresión 3D en el área educativa y las tendencias que determinan la dirección de este trabajo en las aulas. En este contexto, para la búsqueda de los artículos se siguieron los criterios de inclusión, exclusión y pertinencia, lo que dio como resultado el análisis de 19 documentos encontrados en las bases de datos de Google Académico, SciELO, Redalyc y Scopus. El análisis se dividió en cinco pasos: planeación, selección, extracción, resultados y conclusiones. Los resultados muestran que la mayoría de los autores coincide en que el uso de la impresión 3D favorece el desarrollo de la creatividad y genera motivación en los estudiantes, por lo que es necesario impulsar un currículo inteligente con innovaciones científicas y tecnológicas que refuercen el camino hacia su desarrollo profesional.

Received: March 21, 2023  
Accepted: September 6, 2023  
Online Published:  
September 30, 2023

\* Maestra en Diseño, Tecnología y Educación por la Universidad Autónoma Metropolitana, Unidad Xochimilco, México. ORCID: <https://orcid.org/0000-0001-7021-7297>, correo electrónico: [lorenacafri@gmail.com](mailto:lorenacafri@gmail.com) | \*\* Doctora en Tecnología Avanzada por el Instituto Politécnico Nacional. Profesora investigadora de la Universidad Autónoma de Querétaro, México. ORCID: <https://orcid.org/0000-0002-5657-7752>, correo electrónico: [diana.cordova@uaq.mx](mailto:diana.cordova@uaq.mx)

## INTRODUCTION

In education, as in different areas of knowledge, the use of technology is determined by stated objectives, just as López-Arenas (2009) mentions: "the setting of objectives must always be preceding to the use of technological resources and not the other way around [...] claim for it the place that corresponds to it at the time of decision-making"(p. 191), so it is not only the use of the tool itself, but the for what and how it will be used.

The 2018 Horizon Report for Higher Education describes various developments that employ educational technology as tools and resources aimed at improving teaching and learning. These developments are categorized into seven areas that are relevant to education and creative inquiry. In the report, 3D printing is considered to belong to visualization technologies, due to the fact that it seeks the brain's ability to quickly process visual information, identify patterns, explore dynamic processes, and simplify the complex (Adams *et al.*, 2018). Ortiz (2019) states as follows:

To create a 3D model, the first step is to design it with a 3D rendering software (CAD type). The model is saved in a stereolithography (.STL file). The printer software reinterprets the information in the .STL file and transforms it into 2D horizontal sections that will be printed by the printer in an additive way until the complete 3D object is formed (p. 1).

Berchon *et al.* (2014) mention that "this technique is called 'additive' manufacturing because it is carried out by adding material: the object takes shape as the layers solidify" (p. 3). Currently, 3D printing technology is used in multiple fields, including medicine, where it is used for "the development of medical devices [...] as various models of prostheses, implants and tissues have been manufactured by combining the use of different additive manufacturing techniques with the incorporation of cellular arrays, promoting the regeneration of biological structures" (Valenzuela-Villela *et al.*, 2020, p. 164). Results are even recorded in a research on the teaching of human anatomy that reports that students who made use of 3D printing showed greater accuracy in answering questions compared to students in conventional groups (Ye *et al.*, 2020).

In the construction industry, "the minimization of material use is not only an industrial demand and a need for feasibility, but also one of the greatest contributions of 3D printing technology" (Nadal *et al.*, 2017, p. 241). In the food area, its application is visualized due to the fact that "it has great potential to produce food with textures and geometric shapes that are complex to elaborate [...]; the contribution of this technology lies in its use [...] that highlights the most attractive characteristics of a food towards a consumer" (Almeida- Boderó *et al.*, 2021, p. 845). However, "the pedagogical use of 3D printing could change, once teachers and students become familiar with the makerspace culture [...]. The current state of pedagogical research and development remains unclear" (Perna and

Wiedmer, 2020, p. 2). Because of the above, it is important to use 3D printing optimally to support the teaching-learning process of students.

Using technological tools with a specific objective within the teaching-learning process favors innovation and creativity, as mentioned by Žujović *et al.* (2022), "understanding the effects of advanced technologies can guide future research, innovate design methods and improve education [...]. It can be used in the stages of the design process, from prototyping to the fabrication of full-scale structures" (p. 1).

Similarly, the use of 3D printing as an educational tool has been a latent trend and there has been a growing interest in incorporating it in the teaching-learning process, because "every revolutionary technology aims to multiply some of our natural abilities [...] and by multiplying our capabilities, new technologies always have a profound impact [...] on how they transform our work and personal relationships, our institutions and even our history" (Vazhnov, 2013, p. 3). Therefore, this systematic review shows how 3D printing has been analyzed educationally to develop creative thinking, as referred by Salomon (1992):

The cultivation of skills cannot be acquired except by direct experience [...]; the technology must demand of the individual a further development of the skills he already possesses at the time he is confronted with the technology [...]. Mere exposure and even some unconscious and poorly executed activity may not be enough (pp. 150-151).

Now, it is necessary to identify that "the competence of creative thinking is the mental behavior that generates processes of search and discovery of new and feasible solutions [...]. Related to the capacity for observation, problem solving and decision making, creativity, innovation and flexibility" (Hernández *et al.*, 2018, pp. 314-342). For this reason, it is essential to develop this competence in students so that they can find and propose original and innovative solutions to the new challenges of the working world.

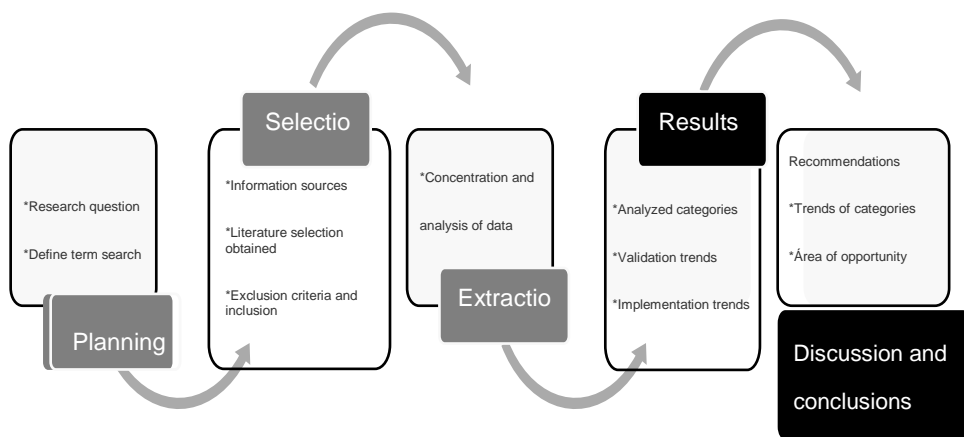
This research work carried out a review of the literature in a span that spans from 2017 to 2022, including the period prior to the pandemic caused by covid-19, since 3D printing was considered one of the trends in education; however, it is observed that its appropriation was interrupted before the contingency due to the confinement measures and the null access to the equipment in the institutional laboratories. It is worth mentioning that after this situation its use has been resumed in recent applications.

The present research consists of the following sections: the first section provides an introduction on 3D printing and its relationship with creative thinking; the second section determines the methodology used to carry out the systematic review, which is divided into planning, selection and extraction of information; the third section shows the results obtained; the

fourth section presents the discussion; and, finally, the fifth section outlines the conclusions derived from the research.

## METHODOLOGY

An exploratory systematic literature review was conducted with the aim of finding related studies on where or how 3D printing is used as an educational tool in design, specifically in industrial design. The procedure to select the articles to be analyzed consisted of five main stages, within which a total of twelve steps were included, as shown in Figure 1.



**Figure 1.** Stages and steps of the systematic review.  
Source: Selt elaboration with theoretical references from Mejia *et al.* (2022).

The following is a description of each of the stages and steps involved in the systematic review.

### *Planning*

#### Statement of the research question

While the development of creative thinking in basic education is developed on an ongoing basis, this does not happen with the same continuity and focus in higher education; therefore, the following research question arises: does the inclusion of 3D printing as an educational tool favor learning and develop creative thinking in industrial design students?

## Defining define the search term

To use the scientific databases, Boolean operators were used using the following strings in Spanish: (ab:(ti:(("3D printing" AND "educational technology" OR "industrial design")))), and in English: (ab:(ti:(("3D Printing" AND "educational technology" OR "industrial design")))), using quotation marks around each term to ensure an exact match. Scientific texts incorporating these terms in their titles or abstracts were selected. A six-year period (2017 to 2022) was established for the analysis, and scientific articles in Spanish and English were included.

## *Selection*

### Sources of information

Four databases were selected: Google Scholar, Redalyc, SciELO and Scopus, since these specialized information sources contain scientific research of a multidisciplinary nature.

### Selection of the literature obtained

The Boolean string formula for the search was configured in the four databases mentioned above, resulting in a total of 191 documents, of which 13 were obtained from Google Scholar, 32 from Redalyc, 62 from SciELO and 84 from Scopus. These documents were subjected to inclusion, exclusion and relevance criteria.

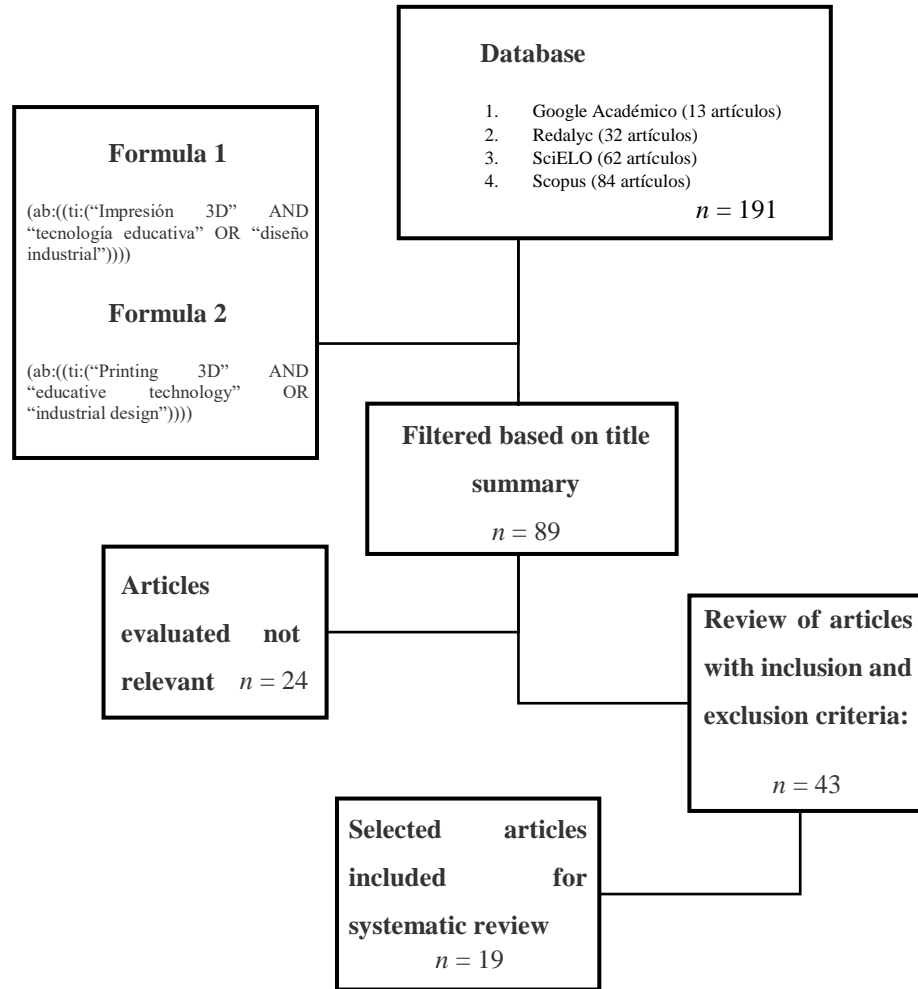
### Inclusion and exclusion criteria

As part of the inclusion and exclusion criteria, articles written in Spanish had to include in the title or abstract the terms: "3D printing", "educational technology" or "industrial design", while articles in English had to contain: "3D Printing", "educational technology" or "industrial design". Based on these criteria, only 89 articles were considered from the total sample: 12 from Google Scholar, 31 from Redalyc, 20 from SciELO and 26 from Scopus.

In the next step, the criterion of relevance was applied, i.e., those articles were discarded that, despite meeting the inclusion and exclusion criteria, were not relevant due to their scarce information on 3D printing or because they did not focus on the area of industrial design. As a result, a total of 32 articles were retained.

Subsequently, a review was conducted to ensure that the articles were within the period from 2017 to 2022. As a result, 19 articles were obtained,

distributed as follows: 2 from Google Scholar, 9 from Redalyc, 4 from SciELO and 4 from Scopus, as shown in Figure 2.



**Figure 2.** Selection process of scientific articles for systematic review.

### *Extracting*

#### Concentration and analysis of data

The most relevant data found in the selected articles were incorporated into a matrix of general aspects such as: year, author, title, categories, methodology used, premise and location, with the aim of showing

significant information from each of the documents and identifying the essential points of the research question (see table 1).

**Table 1.** Selection of articles in the databases

2017 Artículo de investigación Redalyc	Título: Educación y tecnología: pasado, presente y futuro de una relación compleja <a href="https://doi.org/10.46840/ec.2017.07.06">https://doi.org/10.46840/ec.2017.07.06</a>
Metodología: N/A	Categorías: educación, tecnología educativa, trabajo colaborativo, pensamiento de diseño, producción tecnológica, <i>makerspace</i> , apropiación creativa, tecnología transformadora y cambio educativo
Citaciones: 4	Premisa: la idea de que las personas puedan volver a apropiarse de la producción tecnológica no solo implica el desarrollo de conocimientos y habilidades técnicas, sino también una postura ética frente a la compleja relación entre los ciudadanos y el mundo tecnológico
2017 Artículo de investigación Redalyc	Título: Materiales digitales para fortalecer el aprendizaje disciplinar en educación media superior. Un estudio para comprender cómo se suscita el cambio educativo <a href="https://doi.org/10.15366/reice2017.15.2.005">https://doi.org/10.15366/reice2017.15.2.005</a>
	Categorías: innovación educativa, interactividad, creatividad, aula invertida, cambio, aprendizaje, educación formal y educación básica

Metodología: N/A	Premisa: la presencia de la tecnología en las aulas logra que los objetos de aprendizaje cobren un significado al ser usados como elementos de apoyo
Citaciones: 27	
2017 Artículo de investigación Redalyc	Título: Tecnologías de diseño y fabricación digital de bajo coste para el fomento de la competencia creativa <a href="http://dx.doi.org/10.5209/ARIS.51886">http://dx.doi.org/10.5209/ARIS.51886</a>
Metodología: N/A	Categorías: creatividad, competencias, diseño, tecnología educativa e impresión 3D
Citaciones: 19	Premisa: la competencia artística y creativa ha adquirido mayor relevancia y se ha convertido en una habilidad transversal en entornos educativos
2017 Artículo de investigación SciELO	Título: Impresión 3D como herramienta didáctica para la enseñanza de algunos conceptos de ingeniería y diseño <a href="https://doi.org/10.14483/23448393.12248">https://doi.org/10.14483/23448393.12248</a>
Metodología: Constructivismo	Categorías: enseñanza en ingeniería, creatividad, curiosidad y diseño
Citaciones: 14	Premisa: en las disciplinas de ingeniería y diseño, disponer de material didáctico para presentar a los estudiantes problemas y situaciones reales que puedan analizar y resolver, fortalece habilidades mecánico-espaciales y asociativas, además de fomentar la educación basada en problemas que es, a su vez, educación basada en el estudiante, lo que supera la unilateralidad de la información
2018 Artículo de investigación Redalyc	Título: La universidad 4.0 con currículo inteligente 1.0 en la cuarta revolución industrial <a href="https://doi.org/10.23913/ride.v8i17.377">https://doi.org/10.23913/ride.v8i17.377</a>
Metodología: N/A	Categorías: creatividad, innovación tecnológica, innovación científica, universidad innovadora e inteligencia
Citaciones: 56	Premisa: la transición entre el presente y el futuro de la enseñanza universitaria representa un espacio donde se generan innovaciones científicas y tecnológicas inteligentes
2018 Artículo de investigación Redalyc	Título: Retos de la formación profesional del diseñador industrial en la cuarta revolución industrial <a href="https://doi.org/10.23913/ride.v8i16.330">https://doi.org/10.23913/ride.v8i16.330</a>
Metodología: N/A	Categorías: aprendizaje imaginativo, aprendizaje creativo, comunidades de innovación, tecnologías convergentes y diseño industrial
Citaciones: 11	Premisa: el diseño industrial requiere una renovación profesional con nuevas tecnologías y materiales y de esta forma generar nuevos perfiles
2018 Artículo de investigación SciELO	Título: Propuesta metodológica para la mejora del aprendizaje de los alumnos a través de la utilización de las impresoras 3D como recurso educativo en el aprendizaje basado en proyectos <a href="https://doi.org/10.26864/pcs.v8.n1.8">https://doi.org/10.26864/pcs.v8.n1.8</a>
Metodología: Aprendizaje basado en proyectos	Categorías: ABP, tecnologías de la información y la comunicación (TIC), motivación, diseño instruccional, roles, fundamentos de diseño y educación secundaria
Citaciones: 20	Premisa: estudio de la motivación, aprendizaje y rendimiento académico; las TIC y su papel en la motivación y mejora del aprendizaje; las impresoras 3D con fines educativos y la aplicación del diseño 3D en la metodología ABP; diseño y optimización de estructuras y mecanismos

2018 Artículo de investigación Scopus	Título: Counterfeiting ancient Chinese Armour using 3D-printing technology / Recrear armaduras chinas antiguas usando tecnología de impresión 3D <a href="https://doi.org/10.1007/s11042-018-8462-y">https://doi.org/10.1007/s11042-018-8462-y</a>
Metodología: N/A	Categorías: diseño, arte, impresión 3D, cine, CAD, decoración y props
Citaciones: 7	Premisa: la impresión 3D presenta amplias aplicaciones en diversas áreas aún por explorar y puede producir diferentes oportunidades laborales al ser un tema emergente en el ámbito del diseño
2019 Artículo de investigación SciELO	Título: Preparando a los estudiantes para la generación Z: consideraciones sobre el currículo de impresión 3D <a href="http://dx.doi.org/10.20511/pyr2019.v7n2.280">http://dx.doi.org/10.20511/pyr2019.v7n2.280</a>
Metodología: Constructivismo	Categorías: trabajo colaborativo, impresión 3D, ingeniería, generación Z, desarrollo de habilidades, hábitos de estudio y pensamiento crítico
Citaciones: 19	Premisa: se considera necesario realizar modificaciones en el paradigma educativo requerido por los estudiantes de la generación Z; estos cambios indican el uso de herramientas de aprendizaje colaborativo y el desarrollo de mayor contenido creativo
2019 Artículo de investigación Scopus	Título: Invited review article: Where and how 3D printing is used in teaching and education / Revisión sistemática: dónde y cómo se utiliza la impresión 3D en la enseñanza y educación <a href="https://doi.org/10.1016/j.adidma.2018.10.028">https://doi.org/10.1016/j.adidma.2018.10.028</a>
Metodología: N/A	Categorías: impresión 3D, educación, aprendizaje, práctica docente y universidad
Citaciones: 326	Premisa: se abren nuevas oportunidades para las prácticas docentes mediante el uso de la impresión 3D como una tecnología de apoyo durante la enseñanza, especialmente en campos como la ingeniería y el diseño; sin embargo, se registra que su implementación puede crear vínculos con disciplinas STEM (por sus siglas en inglés, ciencia, tecnología, ingeniería y matemáticas)
2020 Artículo de investigación Google Académico	Título: La virtualidad en los procesos de formación educativa. Retos y oportunidades del sistema educativo ecuatoriano <a href="http://doi.org/10.23857/pc.v5i8.1629">http://doi.org/10.23857/pc.v5i8.1629</a>
Metodología: Constructivismo	Categorías: incorporación de tecnologías, apoyo didáctico y desarrollo de habilidades
Citaciones: 12	Premisa: la importancia de las TIC en el proceso de enseñanza-aprendizaje y el uso de tecnologías
2020 Artículo de investigación Scopus	Título: Leveraging design competitions to enhance learning goals and student motivation within a studio project / Aprovechar los concursos de diseño para mejorar los objetivos de aprendizaje y la motivación de los estudiantes dentro de un proyecto de estudio <a href="https://doi.org/10.1007/978-3-030-51194-4_34">https://doi.org/10.1007/978-3-030-51194-4_34</a>
Metodología: Aprendizaje experiencial	Categorías: diseño industrial, tecnologías digitales, concurso, competencia y motivación
Citaciones: 2	Premisa: los concursos pueden desempeñar un papel motivador en la educación universitaria en diseño y, de esta manera, el trabajo realizado contribuye a la mejora de proyectos futuros

2020 Artículo de investigación Scopus	Título: Innovation Strategy of 3D Printing in Industrial Design Based on Vision Sensor / Estrategia de innovación de la impresión 3D en diseño industrial basada en sensores de visión <a href="https://doi.org/10.1155/2021/9061110">https://doi.org/10.1155/2021/9061110</a>
Metodología: N/A	Categorías: impresión 3D, diseño industrial y diseño innovador
Citaciones: 2	Premisa: la impresión 3D tiene importantes ventajas en los procesos de fabricación de estructuras complejas y presenta un gran potencial en términos de desarrollo. El diseño libre y la creación rápida de prototipos pueden originar cambios revolucionarios en la fabricación de productos en el futuro
2021 Artículo de investigación Redalyc	Título: Combinando impresión 3D y electrónica como estrategia para mejorar la experiencia de aprendizaje <a href="https://doi.org/10.5944/ried.24.1.27596">https://doi.org/10.5944/ried.24.1.27596</a>
Metodología: Aprendizaje por Servicio	Categorías: aprendizaje, servicio e ingeniería mecánica
Citaciones: 4	Premisa: el aprendizaje-servicio es una propuesta educativa que combina los procesos de aprendizaje y el servicio a la comunidad en un proyecto unificado y bien estructurado, en el que los participantes se forman al involucrarse en las necesidades reales del entorno con el propósito de mejorarlo
2021 Artículo de investigación Redalyc	Título: Tecnologías avanzadas para afrontar el reto de la innovación educativa <a href="https://doi.org/10.5944/ried.24.1.28415">https://doi.org/10.5944/ried.24.1.28415</a>
Metodología: N/A	Categorías: nuevas tecnologías, TIC, medios de enseñanza y práctica pedagógica
Citaciones: 71	Premisa: la aplicación de tecnología en educación lleva a la comprensión y existencia de un proceso continuo de cambio
2022 Artículo de investigación Redalyc	Título: Juegos en tabletas digitales como introducción al modelado y la impresión 3D <a href="http://dx.doi.org/10.14201/eks2015162129140">http://dx.doi.org/10.14201/eks2015162129140</a>
Metodología: N/A	Categorías: adaptabilidad, flexibilidad, juego, apropiación natural, aprendizaje colaborativo, desarrollo y creatividad
Citaciones: 12	Premisa: la aplicación de tecnologías en contextos educativos genera interés de los alumnos en carreras de ciencia, arte y tecnología
2022 Artículo de investigación Redalyc	Título: Investigar en tecnología educativa: un viaje desde los medios hasta las TIC <a href="https://doi.org/10.15332/2422409X.6325">https://doi.org/10.15332/2422409X.6325</a>
Metodología: N/A	Categorías: tecnología educativa, investigación y teorías sobre aprendizaje con tecnologías TIC
Citaciones: 13	Premisa: las tecnologías como herramientas y objetos de estudio; entornos para aprendizaje colaborativo y para la evaluación del aprendizaje
2022 Artículo de investigación SciELO	Título: Integración de la impresión 3D en la educación tecnológica <a href="https://doi.org/10.23913/ride.v12i24.1170">https://doi.org/10.23913/ride.v12i24.1170</a>
	Categorías: niños, jóvenes y adultos

Metodología: Constructivismo Gamificación	Premisa: la finalidad del proyecto es la integración de la impresión 3D en la educación técnica y tecnológica para facilitar el acceso de los estudiantes al mundo laboral y del emprendimiento
Citaciones: 0	
2022 Artículo de investigación Google Académico	Título: La educación superior 4.0: retos y perspectivas <a href="https://publicaciones.uci.cu/index.php/serie/article/view/1058">https://publicaciones.uci.cu/index.php/serie/article/view/1058</a>
Metodología: N/A	Categorías: creatividad, pensamiento crítico y tecnología educativa
Citaciones: 0	Premisa: Las tecnologías deben utilizarse como herramientas cognitivas que fomenten el desarrollo del conocimiento de los alumnos, su pensamiento crítico y la capacidad de comunicación con sus pares

N/A: no aplica.  
Fuente: elaboración propia.

## RESULT

### *Categories analyzed*

The search for 3D printing as an educational technology and its application in the field of industrial design was carried out in four databases, from which 191 articles were obtained, which were reviewed applying the inclusion, exclusion and relevance criteria, which led to the selection of a total of 19 scientific research articles for analysis (see table 2).

**Tabla 2.** Articles included from the databases

<b>Datebase</b>	<b>Articles found</b>	<b>Items included</b>
Google Académico	13	2
Redalyc	32	9
SciELO	62	4
Scopus	84	4
<b>Total</b>	<b>191</b>	<b>19</b>

### *3D printing, educational technology and design*

The VOSviewer software was used in the databases of Google Scholar, SciELO, Redalyc and Scopus to analyze the bibliometric networks in order to identify links between the main categories during the period 2017-2022. Figure 3 identifies trends by interest in the topics covered.





**Figure 4.** Word cloud with the main categories found in the analyzed articles

### Validation trends

The method used to validate 3D printing as a technological tool that promotes learning in the area of industrial design was based on the analysis of the categories implicit in each of the articles. This included considering how students used it, or how teachers incorporate this tool into the teaching process.

The articles show that their implementation focuses mainly on the field of mathematics, its application as technology and the use of tangible materials; However, most authors agree that this tool encourages the development of creativity and generates motivation in students (see table 3).

**Table 3.** Implementation trends

Author / year	Main focus	Main category worked	Interest in development
2017 Pinto, L.	Technology	Design thinking	Cognitive
2017			

Gallardo, K.			
<b>2017</b> Bonet, A.	Tangible materials	Creativity	
<b>2017</b> Rúa, E.			
<b>2018</b> Pedroza, R.	Innovation		Cognitive and educational
<b>2018</b> Reyes, F.	Technology and innovation	Comprehensive thinking	Holistic
<b>2018</b> Blázquez, P.	Methodology	Motivation	Educational
<b>2018</b> Zhou, K	Technology	Creativity	Cognitive
<b>2019</b> Popescu, D.	Collective work  Study habits	Critical thinking	Holistic
<b>2019</b> Ford, S.	Methodology	Educative technology	Educational
<b>2020</b> Ayón, E.	Methodology	Training process	
<b>2020</b> Wilson, W.	Innovation Collective work	Motivation	
<b>2020</b> Sun, H.	Innovation	Design thinking	
<b>2021</b> Suardíaz, J.	Methodology	Service based learning	

<b>2021</b> Prendes, M.	Technology	Teaching aids	Cognitive and educational
<b>2022</b> Saorín, J.		Collaborative learning	Educational
<b>2022</b> Sánchez-Vera, M.		Educative technology	Cognitive and educational
<b>2022</b> Candia, F.		Technologic education	Cognitive
<b>2022</b> Vázquez, M.		Educative technology	Cognitive

## DISCUSSION

The information obtained shows that 3D printing as an educational tool offers a wide range of possibilities that have not yet been fully explored. The main methodology is constructivist approach, which allows students to create meanings and explore from their experience. While creative thinking is developed from basic levels, there are still important research opportunities in higher education. Beyond the simple use of the tool, the goal is to develop cognitive skills that contribute to the professional growth of students.

As shown in the bibliometric network (Figure 3), between 2017 and 2019, the period before the pandemic, 3D printing was used as an educational strategy with the aim of creating tangible objects, since at that time it was a tool that was being explored. However, during the confinement caused by covid-19, there were limitations in terms of access and use of equipment in institutions, which caused 3D printing to be done with home equipment. As a result, both the institutions and the teachers sought to incorporate 3D printing as part of their educational methodology, in view of the fact that the students were integrated back into the classrooms with different knowledge acquired autonomously.

The most recent articles, published from 2021 and 2022, present 3D printing with a main focus as educational technology and an interest in developing students not only educational but cognitive skills, "To facilitate access [...] to the world of work and entrepreneurship [...], the aim is to

promote the strengthening of the cognitive process [...] of students who demand quality instruction" (Candia, 2022, p. 4).

It has been observed that 3D printing has helped students in various areas to solve concepts more efficiently and with greater understanding, precision and integration in a shorter time, something that had not been achieved conventionally (Ye *et al.*, 2020). As a result, "teaching methods should also motivate students to study this technology in detail and help them develop their critical thinking and reasoning about 3D processes" (Popescu *et al.*, 2019, p. 243).

In this sense, we understand "the clear preferences of students towards more visual, interactive and practical learning activities [...], more tests of theoretical applications in practice" (Popescu *et al.*, 2019, p. 251). Therefore, it is important to follow this process and identify whether there is an improvement in the acquisition of knowledge as the required skill is planned and developed.

Something similar happened with the results provided by Candia (2022), who mentions that "for solving mathematical problems [...] the proposal is feasible with a high degree of applicability during collaborative repetition [...] involving 3D printed teaching material" (p. 24). Several of the articles analyzed agree on the need to boost creativity and develop an intelligent curriculum with scientific and technological innovations, referring to educational technology and the application of new tools in the teaching-learning process.

Based on recent trends, an opportunity for improvement is the application of 3D printing as an educational tool. This can be achieved through an instructional design that allows meeting objectives and goals to develop competencies or skills, and learning thematic content, as described by Blázquez *et al.* (2018): "an instructional design that is defined, defining roles and design foundations [...] solving real and contextualized problems for students [...] discovering aspects that arouse their curiosity" (p. 172). In this way, it will be possible to confirm if the didactic strategy in its design and implementation is viable to promote the development of creativity.

## CONCLUSIONS

According to the systematic review, it is important to note that institutions and teachers should implement more complex projects that lead students to investigate and work iteratively with this tool to encourage the development of creative thinking. An obvious strength is the opportunity to use 3D printing technology to improve the way students learn because it offers the advantage of interacting with real objects in flexible

environments and encourages the development of self-learning capabilities. This, in turn, gives rise to creativity and autonomy, which generates new forms of communication and promotes the development of creative thinking through collaborative work.

The possibility of developing creative thinking in industrial design students with the use of 3D printing is evident, because iteratively and seeks that they themselves manage to create a personalized process that allows them to better understand and create with innovation.

The importance of knowing how new generations learn will undoubtedly lead to greater use of a technology based on 3D printing as an educational tool. This will identify how students tend to appropriate this type of technology. The development of creative thinking can benefit if a process is organized from the conception, visualization, design and printing of the final object. This process will not only contribute to the educational competences, but also to the cognitive competences of the student.

It is suggested to create a didactic tool, as an educational strategy to build an object through a structured and organized process that contributes to the development of creative thinking. That is, a platform with a sequential guide that, following an organized process, will access combining theory with practice. This will allow students to develop their creativity and record how they manage to create and manipulate a 3D object.

Likewise, the need arises to develop creative thinking that is not limited to the use of a technological tool, but that optimally generates a comprehensive thinking when using educational technology to motivate and encourage creativity. The integration of 3D printing in the classroom aims to be perceived as a strategy that promotes teaching and collaborative learning by using it as a tool.



Mejía, M.; Escudero-Nahón, A. y Chaparro, R. (2022). Tendencias de game learning analytics: una revisión sistemática de la literatura especializada. *Sinéctica*, 58. [https://doi.org/10.31391/S2007-7033\(2022\)0058-006](https://doi.org/10.31391/S2007-7033(2022)0058-006)

Nadal, A.; Pavón, J. y Liébana, O. (2017). Perspectivas para la impresión 3D en la construcción. *Revista Europea de Investigación en Arquitectura: REIA*, 7-8, 231-244. <https://dialnet.unirioja.es/servlet/articulo?codigo=6303030>

Ortiz, A. (2019). Las impresoras 3D como herramientas científicas. *Encuentros Multidisciplinares*, 21(61). <https://dialnet.unirioja.es/servlet/articulo?codigo=6904251&info=resumen&idoma=SPA>

Pedroza, R. (2018). La universidad 4.0 con currículo inteligente 1.0 en la cuarta revolución industrial. *RIDE Revista Iberoamericana para la Investigación y el Desarrollo Educativo*, 9(17), 168- 194. <https://doi.org/10.23913/RIDE.V9I17.377>

Perna, J. & Wiedmer, S. (2020). A systematic review of 3D printing in chemistry education - Analysis of earlier research and educational use through technological pedagogical content knowledge framework. *Chemistry Teacher International*, 2(2). <https://doi.org/10.1515/cti-2019-0005>

Pinto, L. (2017). Educación y tecnología: pasado, presente y futuro de una relación compleja. *Economía Creativa*, (7). <https://www.redalyc.org/journal/5475/547569102006/547569102006.pdf>

Popescu, D.; Popa, D. M.; Cotet, B. G. y Popescu, D. (2019). Preparando a los estudiantes para la Generación Z: consideraciones sobre el currículo de impresión 3D. *Propósitos y Representaciones*, 7(2), 240-254. <https://doi.org/10.20511/PYR2019.V7N2.280>

Prendes, M. y Cerdán, F. (2021). Tecnologías avanzadas para afrontar el reto de la innovación educativa. *RIED. Revista Iberoamericana de Educación a Distancia*, 24(1). <https://www.redalyc.org/journal/3314/331464460002/331464460002.pdf>

Reyes, A. y Pedroza, R. (2018). Retos de la formación profesional del diseñador industrial en la Cuarta Revolución Industrial (4RI). *RIDE Revista Iberoamericana para la Investigación y el Desarrollo Educativo*, 8(16), 1-22. <https://www.redalyc.org/journal/4981/498159332001/498159332001.pdf>

Rúa, E.; Jiménez, F.; Gutiérrez, G. y Villamizar, N. (2018). Impresión 3D como herramienta didáctica para la enseñanza de algunos conceptos de ingeniería y diseño. *Ingeniería*, 23(1), 70. <https://doi.org/10.14483/23448393.12248>

Salomon, G. (1992). Las diversas influencias de la tecnología en el desarrollo de la mente. *Infancia y Aprendizaje*, 15(58), 143- 159. <https://doi.org/10.1080/02103702.1992.10822337>

Sánchez-Vera, M. y Prendes-Espinosa, M. (2022). Investigar en tecnología educativa: un viaje desde los medios hasta las TIC. *Hallazgos*, 19(37), 1-30. <https://www.redalyc.org/journal/4138/413870064009/413870064009.pdf>

Saorín, J.; Meier, C.; de la Torre, J.; Melian, D. y Trujillo, D. (2015). Juegos en tabletas digitales como introducción al modelado y la impresión 3D. *Education in the Knowledge Society*, 16(2), 129-140. <https://www.redalyc.org/pdf/5355/535554758009.pdf>

Suardíaz, J.; Pérez, M.; Cabrera, A. y Do Carmo Trolle, R. (2021). Combinando impresión 3D y electrónica como estrategia para mejorar la experiencia de aprendizaje. *RIED Revista Iberoamericana de Educación a Distancia*, 24(1), 115-135. <https://doi.org/10.5944/RIED.24.1.27596>

Sun, H. (2021). Innovation Strategy of 3D Printing in Industrial Design Based on Vision Sensor. *Journal of Sensors*, 2021. <https://doi.org/10.1155/2021/9061110>

Valenzuela-Villela, K. S.; Garda-Casillas, P. E. & Chapa-González, C. (2020). Progress of the 3D printing of medical devices. *Revista Mexicana de Ingeniería Biomédica*, 41(1), 151-166. <https://doi.org/10.17488/RMIB.41.1.12>

Vazhnov, A. (2013). Impresión 3D: cómo va a cambiar el mundo. Editorial Baikal. <https://docplayer.es/98245160-Impresion-3dcomo-va-a-cambiar-el-mundo-spanish-edition-kindle-edition-by-andrei-vazhnov.html>

Vázquez, M.; Martillo, I. y Castro, G. (2022). La educación superior 4.0: retos y perspectivas. *Serie Científica de la Universidad de las Ciencias Informáticas*, 15(4), 71-89. <https://dialnet.unirioja.es/servlet/articulo?codigo=8590696>

Wilson, W. & Choi, Y. M. (2020). Leveraging Design Competitions to Enhance Learning Goals and Student Motivation Within a Studio Project. *Advances in Intelligent Systems and Computing*, 1202, 255-260. [https://doi.org/10.1007/978-3-030-51194-4\\_34](https://doi.org/10.1007/978-3-030-51194-4_34)

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), 1-9. <https://doi.org/10.1186/s12909-020-02242-x>

Zhou, K.; Liao, J. & Zhou, X. (2019). Counterfeiting ancient Chinese Armour using 3D-printing technology. *Multimedia Tools and Applications*, 78(1), 1103-1116. <https://doi.org/10.1007/s11042-018-6462-y>

Žujović, M.; Obradović, R.; Rakonjac, I. & Milošević, J. (2022). 3D Printing Technologies in Architectural Design and Construction: A Systematic Literature Review. *Buildings*, 12(9). <https://doi.org/10.3390/buildings12091319>



### HOW TO CITE

Cabrera Frías, Lorena y Córdova Esparza, Diana Margarita. (2023). La impresión 3D como herramienta educativa para desarrollar el pensamiento creativo: revisión sistemática. *Apertura*, 15(2), 88-103. <http://dx.doi.org/10.32870/Ap.v15n2.2382>

