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EDUCATION BY 3D PRINTING (3DP): A BIBLIOMETRIC OVERVIEW

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Abstract
Digital models produced by CAD software are used in 3D printing, an additive manufacturing technique, to manufacture products. Fused deposition modelling, selective laser sintering, and stereolithography are important technologies. Product development, the arts, customisation, component production, and education are just a few of the businesses that employ it. In the classroom, 3D printing creates engaging, dynamic learning environments that improve student comprehension of difficult subjects. The use of 3D printing in the classroom encourages collaboration between teachers and students as well as inclusive learning, creativity, and problem-solving. The number of publications on 3D printing in education has significantly increased since 2010, according to a bibliometric review, with China and the US leading the way.
Keywords: education, 3D printing, bibliometric review, scientometric.

1. INTRODUCTION

Three-dimensional objects are created by stacking materials, an additive manufacturing process also known as 3D printing (3DP) (Jadhav & Jadhav, 2022; Kharat et al., 2023). CAD software is used to produce a digital model of the object to be printed, which includes its dimensions and shape (Mobarak et al., 2023; Nesic et al., 2020). The 3D printer is then instructed to build the actual object layer by layer, slicing the model into thin cross-sectional sections (Luongo et al., 2020; Nomani et al., 2020). Plastics, metals, ceramics, and biological materials (Jandyal et al., 2022; Karakurt & Lin, 2020; Ranjan et al., 2022) might be used. The 3D printer next decodes the sliced design and begins layer-by-layer assembly of the item (Malik et al., 2023).

Stereolithography (SLA) (Daminabo et al., 2020), selective laser sintering (SLS) (Charoo et al., 2020), and fused deposition modelling (FDM) (Deshmane et al., 2021) are examples of 3DP technologies. Following printing, the object may undergo post-processing techniques to improve its functionality and appearance (Dizon et al., 2021). Many industries use 3DP, including product development (Prashar et al., 2023), customisation, component manufacturing (Novak, 2022), the arts (Jipa & Dillenburger, 2022), and education (Leinonen et al., 2020). It creates new potential in a variety of industries by enabling the rapid and accurate creation of complex and personalised items, revolutionising manufacturing processes.

According to Pearson and Dubé (2022), a number of sciences, including biology, chemistry, physics, geography, environmental science, engineering, and mathematics, are utilising 3D printers to create interactive, hands-on learning environments (Anđić et al., 2022; Monkovic et al., 2022; Pernaa, 2022; \İM\\İR et al., 2021). They may create complex physical, molecular, anatomical, and topographical models (Gharleghi et al., 2021). Additionally, in engineering, this technology can be utilised to swiftly prototype concepts, solids, and geometric designs (Wang et al., 2021). They are important because they boost student engagement, encourage deeper learning (Zhou et al., 2022), and get students ready for STEM jobs in the real world (Weng et al., 2022).

3D printers in schools can help students learn through hands-on experiences (Gunther et al., 2020), visualize abstract ideas (Lin et al., 2023), support interdisciplinary learning (Reymus et al., 2021), encourage creativity and problem-solving (Khasawneh & Darawsheh, 2023), customize instructional materials (Cheng et al., 2020), expose students to technologies used in different industries (Inoma et al., 2020), facilitate project-based learning (Unzueta & Eguren, 2023), improve teacher-student interaction (Kamat & Nasnodkar, 2021), promote the development of 21st-century skills (Coşkun & Deniz, 2022), and support inclusive education, among many other advantages. By creating real objects, students may engage with and with the models they create, gaining a deeper understanding of complex concepts. Visual aids may be made using 3DP, making abstract ideas more concrete and intelligible (Dickenson et al., 2020; ŞİMŞİR et al., 2021). In addition, it promotes transdisciplinary applications, allowing students to create models for a variety of academic areas. Overall, 3D printers benefit education by promoting hands-on learning, visualising abstract topics, cultivating creativity, and preparing students for the needs of today's workforce. They also encourage creativity and problem-solving skills, fostering an innovative atmosphere in the classroom. Meanwhile, the influence of 3DP on educational trends may be enhanced by scientometric research.

According to Yılmaz Özden et al. (2023), scientometrics can help educators understand how to adapt technology and implement successful teaching strategies. Furthermore, it may aid in resource allocation, determining learning objectives, and identifying knowledge gaps (Otto et al., 2021). To guarantee that the incorporation of 3DP is consistent with best practices and better prepares students for the future, educators may design

norms that promote the ethical and effective usage of 3DP by combining scientometric research. As a result, the need for a comprehensive study to identify trends, research hotspots, and active centres in the field of education using 3D printers has been recognised, and the objective of this research is defined appropriately.

2. LITERATURE REVIEW

In terms of the research's historical context, numerous articles about 3D printers have tackled topics like "Insights and Perspectives in 3DP" (Bai et al., 2021), "Fused Deposition Modelling" (Parvanda et al., 2024), "Additive Manufacturing" (Jemghili et al., 2021), "Technology Evolution Pathways for 3DP" (Ahmed et al., 2021), "The Environmental Effects of 3DP" (Nyika et al., 2022), "3-D Printing Technologies From Infancy to Recent Times" (Sood et al., 2024), and "Additive Manufacturing" (Dzogbewu et al., 2022). In the meantime, the research was close to the topic of the Mojica Herazo et al. (2024) research that highlights the substantial capacity of 3DP to improve both education and instruction. Therefore, the purpose of this article is to review the scientometrics of the articles published in "3DP and Education".

3. METHODOLOGY

3.1 Bibliometric analysis

A quantitative examination of academic publications, citations, and data is known as bibliometric research (Baas et al., 2020), and it is used to identify trends, patterns, and impacts within a subject (Goerlandt & Li, 2022; Zeb et al., 2021). In this method, research objectives are set, literature is reviewed, data is gathered, cleaned, and preprocessed, quantitative methods are applied, data is analyzed using metrics, collaborative networks are examined, visualizations are made, findings are interpreted, conclusions are drawn, a report is written (Carballo-Meilan et al., 2022; Miyashita & Sengoku, 2021; Moral-Muñoz et al., 2020).

3.2Search strategy and Data collection

Table 1: Keywords Searching

Retrieval Date	16/11/2024
Search Field	Title, Abstract, Keywords
Database	PubMed: 3698
Keyword	3D printing Education
inclusion criteria	"nursery education*" OR "Early childhood education*" OR "grade school*" OR "elementary school*" OR "lower school*" OR "primary school*" OR "grammar school*" OR "primary school*" OR "junior high school*" OR "Middle School*" OR "high school*" OR "secondary education*" OR "upper school" OR "senior high school*" "3 D printing" or "Three-dimensional printing" or "3 dimensional printing" or "3D Printable" or "3 D Printable" or "Three-dimensional Printable" or "3 dimensional Printable" or "3D print" or "3 D print" or "Three-dimensional Print" or "3 dimensional print" or "3D Printed" or "3 D Printed" or "Three-dimensional Printed" or "3 dimensional Printed" or "3D printing"
exclusion criteria	Adult*, universit*,

3DP's keywords Pattern taken from Bai et al., (2021).

3.3 Bibliographic mapping software

For this study, bibliometric analysis is used. Bibliometrics is the use of statistical methods to determine the content and quantity of books, papers, and other publications (Sweileh et al., 2017). It has been utilised in crisis analysis (Mukherjee et. Al, 2022) and information management (Du et al., 2017). In accordance with the theme, there is a shortage of published evidence in all issue areas. This study paper employs bibliometrics to examine works on 3D printing in education, providing data for co-citation analysis, co-occurrence analysis, and other pertinent investigations of previous literature. This paper presents a retrospective and descriptive bibliometric analysis of PubMed publications.

PubMed is favoured since it is a free search engine that allows users to access article databases. The programme utilised for bibliometric analysis is Bibliomatrix/Biblioshiny (Aria & Cuccurullo, 2017), which scans publications to categorise major ideas and varied fields of research. We've also used Vosviwer software. Reference co-citation analysis and the document's bibliometric mixture analysis were mapped using the "Visualisation of Science (VOS)" mapping tool. VOSviewer also has text mining capabilities, which may be used to generate and display co-occurrence networks of important phrases retrieved from scientific literature.

4. RESULTS AND DISCUSSION

The categories allocated to an article in Medline/PubMed indicate it's kind of publishing. Because an article might have more than one publishing type, a single publication may appear many times in the table below. It is apparent that the percentage of journal articles published is the greatest.

Figure 1 shows that academics studying 3D printing in education evaluated the following components or keywords for their publication.

Fig. 1 Word Cloud

Since 2010 people has seen a significant increase research on this field. From Figure 2, it is clear that number of publications is highest on 2023. It might be due to advancement of technology.

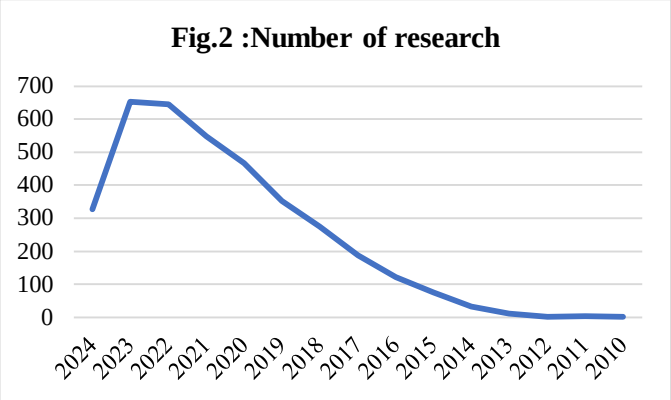

Fig.2: Number of research

4.1 Publications based on country

Based on data from the Pubmed database, Figure 4 shows the top nations that are actively publishing the most papers about '3D Printing in Education'. Figure 4 shows a collaborative map of nations that produce papers, with deeper colours indicating a higher frequency of article publication. The majority of writers and publications on '3D printing in education' are from China. In addition to the United States, India, South Korea, Malaysia, and the United Kingdom are among the countries with the most notable writers and publications.

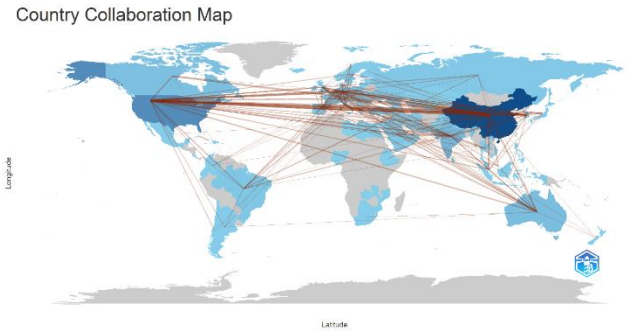

Fig.4 Country Collaboration Map

4.2 Processing data RStudio & Biblioshiny software

4.2.1 Most Relevant Words

(Figure 5) shows the top 10 relevant words available in the research on '3D printing in Education'. 'Printing three dimensional' and 'humans' are most relevant words amongst all.

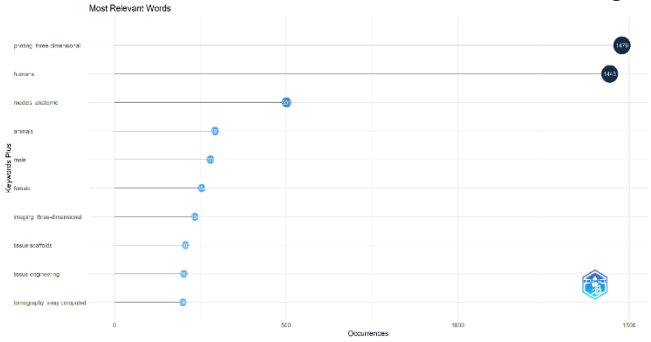

Fig. 5 Most relevant words

4.2.2 Trend Topics

In the context of "3D Printing in Education," Figure 6 shows a trending issues connected to keywords over time. In the years running up to 2010, most articles focused on 3D printing. However, in 2019, the focus was on male and female simulation training.

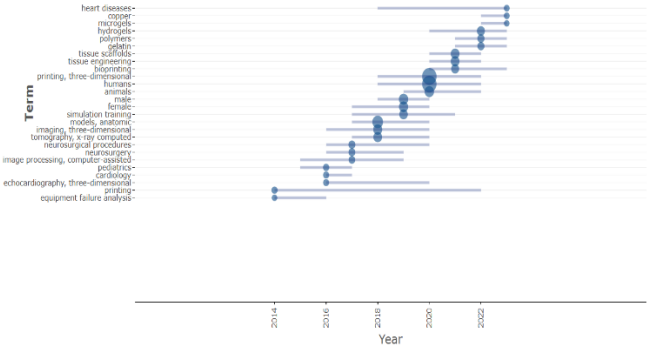

Fig.6 Trend Topics

4.2.3 Factorial Analysis topic dendrogram

A number of study categories that may be brought up in relation to "3D printing in Education" are shown in Figure 8, which also shows the analysis based on the subject dendrogram with the article's keyword field. The relationships of similarity between a set of things are represented by a branching diagram called a dendrogram. The term "clade" refers to each branch. Each clade's terminal end is referred to as a leaf. The order in which the clades are arranged indicates which leaves are most related to one another. The branch points' heights show how close or unlike they are to one another; the higher the height, the bigger the divergence. As long as we can gauge how similar two things are to one another, we may use a dendrogram to show the relationships between any type of entity.

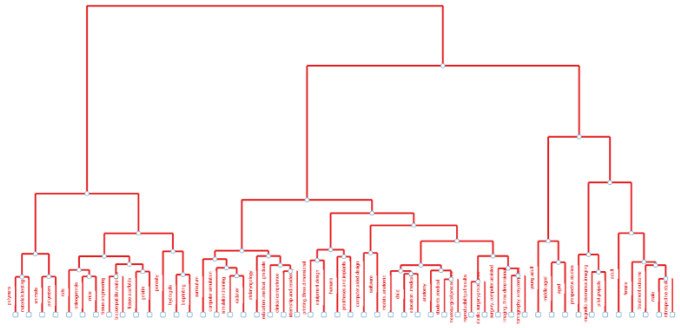

Fig.7 Dendrogram

4.2.4 TreeMap

The TreeMap in Figure 9 shows how frequently keywords are used. The term "three-dimensional printing" is used the most, 1479 times, followed by "humans," which appears 1443 times.

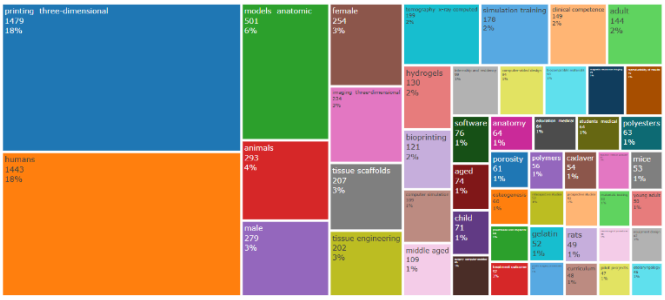

Fig.8 TreeMap

4.2.5 Co-Authorship Network Analysis

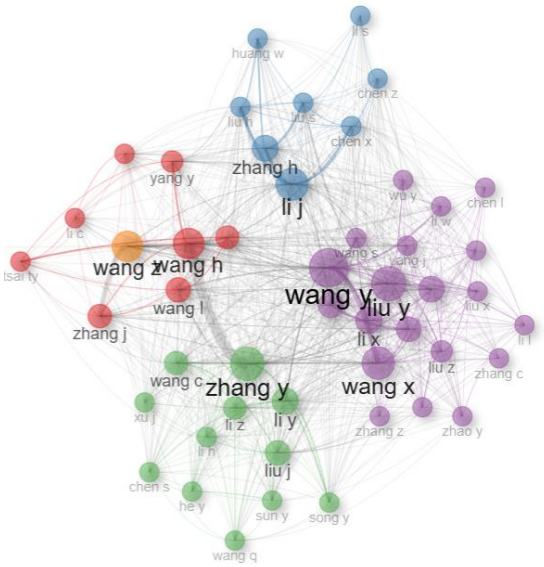

Fig. 9 Network visualization of Co-authorship

From the Fig. 9, 48 authors can be seen. They are differentiated into 4 categories. Among them Wang Z, Wang H, Wang y, Wang X, Liu Y, Zhang Y, Li J and Zhang H are most prominent ones. Same thing can be proven with Fig. 10.

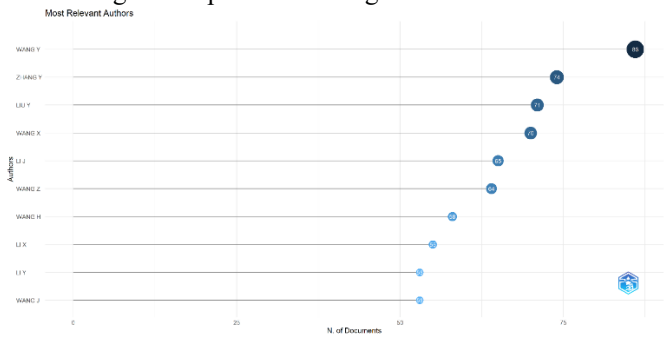

Fig. 10 Most Relevant Authors

4.3 Processing data with VOSviewer

The 'nibb' format was used for exporting the 3698 documents that were obtained from the PubMed database search. The data acquired from the PubMed database were then entered and bibliometrically analysed using VOSviewer to identify bibliometric networks. In the VOSviewer picture system (Figure 11), the darker the image, the longer the issue is explored in the research. The size of the circle in the VOSviewer network visualisation graphic represents the number of publications connected to the word in article titles, abstracts, and keywords; the bigger the circle, the more articles related to the phrase.

4.3.1 Co-occurrence Network Analysis

For this part we have selected only those paper who have minimum 2 documents in this field. After following these criteria 2488 article meet the criteria from 9615 keywords. The figure 11 shows that for printing three dimensional, there are 6 clusters. Printing, three dimensional is one of the mostly used keywords.

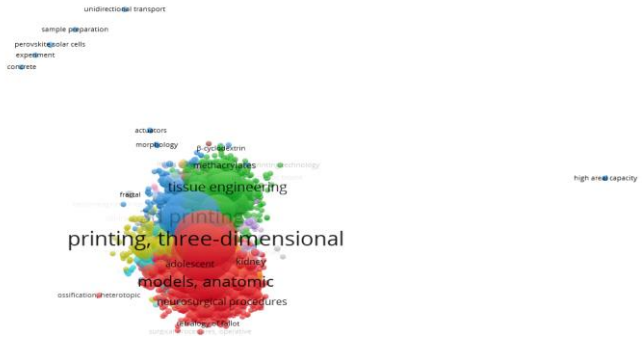

Fig. 11: Co-occurance Network Analysis

4.3.2 3.2.2. Co-authorship Network Analysis

For this part we have selected only those institution who have minimum 2 documents in this field. After following these criteria 2668 authors meet the criteria.

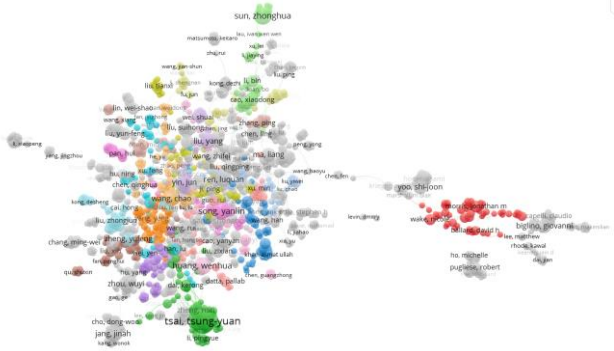

Fig. 12: Co-authorship Network Analysis

47 different cluster is available here (Fig. 12) and in there many authors are there. Among them, Tsai, Tsung-yuan is most prominent one. Apart from him, there is also Sun, Zhonghua; Jang, Jinah; Biglino, govanni, Song,Yanlin are also renowned in these field.

4.4 Discussion and Final Considerations

In order to better understand the link between 3D printing and education, this study aims to both investigate prior research on the topic and do a bibliographic survey of relevant scientific articles. Because this study also examines the evolution of research on 3D printing in education, bibliometric analysis is employed. Analysis of PubMed data is used to identify research trends and develop models for 3D printing in education. Bibliometric analysis with PubMed, RStudio, blilioshiny, and VOSviewer. According to the findings of bibliometric study, there has been a steady growth in research interest in 3D printing in education since 2010, and this trend is expected to continue in 2024 with over 300 article releases. Countries like China and the United States are the top publishers of research on 3D printing in education, according to this study's descriptive bibliometrics and visualisations. According to the 2019 trend topic picture, the most popular phrases for both men, women and simulation training are at the top. The most relevant words are '3D printing' and 'people'. The most popular keywords, people (18%) and 3D printing (18%), are displayed in TreeMap. The relationship between topics is shown in red, blue, and green in the VOSviewer bibliometric visualisation of trend mapping images, indicating that the topic has been widely used. In contrast, if the trend visualisation is purple, orange, and sky, it indicates that the topic is still rarely used in research. The phrase

"printing 3D dimensional" appears in red, indicating that there are currently few research on 3D printing.

5. CONCLUSION

The field of "3D printing in education" is new. Researchers are now working in this field. China and the United States are at the forefront of research into 3D printing in education. The terms "3D printing," "humans," "simulation training," "male," and "female" are the most pertinent.

One disadvantage of this analysis is that it only used the Pubmed study database. As a result, the author acknowledges that several keywords were not addressed, necessitating additional refining of study on '3D Printing in Education'. Subsequent inquiries are expected to look deeper into the matter. Future study should include comparison analysis with other databases and a broader scope, allowing for a more full understanding of the '3d printing in education' phenomena.

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