Applications of 3D Printing in Science Education

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Abstract. The development of technology has implications for learning technology, such as using 3D printing technology in education as a learning medium. 3D printing has become one of the media that helps students actively develop visualization skills, improve their understanding of learning concepts, and acquire skills through knowledge. Based on the results of science-based learning research, learning will be more effective with authentic learning. 3D printing can be used to provide authentic learning for students. To find out more about how 3D printing is effective in science learning, it is necessary to review and analyze research publications that discuss 3D printing in science education. The purpose of this study is to find out the research trends in 3D printing in science education and the new research opportunities in 3D printing in science education. The research method is biometric analysis using the Vos viewer application. The results of the analysis of meta-data obtained from Scopus show an increase in the trend of 3D printing research in science education. Research trends with the latest publications on 3D printing are found in applied science education, namely medical education, the field of medicine, and anatomy. Based on Vos viewer's visualization, keywords that are very weakly connected to 3D printing and related to science learning include critical thinking, experimentation, physics, and chemistry. This indicates that 3D printing research with these keywords can be follow-up research that is useful for science education.

Keywords: Applications, Education, 3D Printing, Science

1 Introduction

1.1 Background

3D printing is one of the technological products that has been adopted in educa-tion as a learning medium, but it is not without limitations, so it is very important to pay attention to the learning context when applying new things [1]. Learning with 3D printing has been implemented in schools, universities, libraries, and for children with special needs. The use of 3D printing in education includes teaching students about 3D printing, teaching educators about 3D printing, as an assistive technology during

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teaching, producing artifacts that aid learning, and creating assistive technology. Although these five things have been done, the implementation is still not perfect. Schools are looking for new breakthroughs to develop more innovative ways of learning by utilizing 3D printing technology [2], so intensive research is needed as a source of recommendations for further research and future education policy [3]. 3D printing can be used as an aid to support additional teaching, improve technical communication skills using visual aids, and enable repeated experimentation in re-search. The challenge of incorporating this 3D printing technology into the regular curriculum in academic institutions takes a long time, so the socialization carried out is to provide short courses on the use of 3DP by increasing student engagement, developing skills, and gaining knowledge [4].

3D printing has also been used in modern chemistry laboratories. This technology provides chemists with the ability to design, prototype, and print functional devices that integrate catalytic and/or analytical functions and even print common laboratory hardware and teaching aids. Although access to 3D printing has greatly improved, several design principles and materials need to be considered before using the technology in chemical laboratories [5].

Based on this presentation, it can be explained that further research on the use of 3D printing is still needed. This is stated by Ford and Minshall, who state that the application of 3D printing is not perfect, meaning that it is still looking for the most efficient formula for learning and in terms of preparing school curricula for the use of 3D printing, thus still expecting further research. Based on research on the advantages of 3D printing that has been known, namely the use of the 3DP model in STEM education, the results can increase student knowledge, motivation, and participation in the learning process. However, implementation in schools is still low. Numerous studies of teachers in secondary schools and colleges show that teachers' perceptions of 3D model printing are one of the key factors for their successful use [6]. Teachers became an important factor in the development of 3D printing in educational institutions. Research on elementary school teachers' perceptions of using 3D printing models in STEM learning has not been widely researched, while research on science teachers and math teachers shows mastery of 3D printing models is advanced. 3D printing models can be adopted by teachers in research-based learning. Thus, further research is expected to explore the concept of using 3D printing models more effectively [7].

Based on the explanation above, it can be concluded that there are still many new research opportunities for the use of 3D printing in education. For this reason, the author argues, it is important to explore the studies that have been carried out related to 3D printing, especially in science education, so that a map of existing studies can be obtained as a recommendation for further research on the use of 3D printing in science education. The formulation of the problem in this study is: what are the trends in 3DP re-search in science education, and what are the new research opportunities for 3DP in science education?

2 Literature review

3D printing is a tool that can create real objects based on digital designs. This tool can produce various forms of objects, such as implantable medical devices, artificial teeth, and other shapes. 3D printing in education can help students present ideas in concrete form, then printed objects can be utilized and even produced [8]. In applied sciences such as medicine, 3D printing technology that prints parts of living things is called bioprinting. This 3D printing technology is closely related to the interests of biologists and medicine; it is an alternative way to form artificial tissue and living organs from a person's cells for further transplantation. The idea has already started at an experimental level with the help of computer-aided bioadaptive manufacturing, a process that stores living cells in a suitable scaffold to produce 3D tissues and organs. This cell printing technology is called 3D bioprinting. Bioprinting can be used for many different applications, such as spraying cells in situ for tissue regeneration. This will be very important in the treatment of skin burns [9]. In the field of veterinary medicine, 3DP is used in general surgical learning, with the main application being to develop silicone models from 3DP to learn how to suture in surgery, providing learning tools close to textures from living creature models and reusable objects for student training and support in clinical skills [10].

The use of 3D printing in teaching has the advantage of being able to print 3D artifacts better than virtual screen-based artifacts. Students are trained to have the ability to perform independent construction, increase their capacity for independent work, and observe physical artifacts that have been carefully made. Eisenberg notes that fabrication is accessible to children, which can be useful as a counterweight to technology culture. In their application, innovative design activities in 3DP involve the following five challenges: expanding the range of physical media available for printing, incorporating ideas derived from the "pick and place" mechanism into 3D printing, exploring methods for making printing devices portable, making tools for hand customization and the finishing stages of real printed objects, designing soft-ware techniques to define, transform, and combine 3D elements in the context of printing [11].

A research project examining the extent to which the technological capabilities of 3D printing can function as a means of learning and communication. The learning theory of constructionism is used as a theoretical framework for creating experimental educational scenarios that focus on 3D design and printing. In a three-month project run at two secondary schools in Ioannina, Greece. The 33 students had the task of designing and producing creative artifacts collaboratively with the help of 3D printers and 3D design platforms. Most artifacts carry messages in Braille. The goal of the project is to deliver goods and products to blind children, implementing new ways of communication and collaboration among blind and non-blind students. The results are positive. 3D printing and design can stimulate children's literacy and creativity skills, which are interconnected in collaboration with information-based activities[12]. If students are already enthusiastic about learning, it will have an impact on how actively they participate in finishing teacher-given homework [13]. Here are the steps for using 3DP in schools, according to Kostalis.

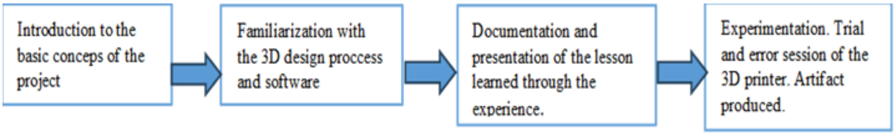

Fig. 1. Basic steps of the project at schools (Kostakis, et.al., (2015).

The application of 3D printing in high school education has prepared students for a career in technology. For geoscience education, there are not many examples found in the literature about using 3D printing in the curriculum or in short courses [4]. How teaching fossil models and mineral crystals can complement digital models with 3D perception and better features. In the field of geosciences, 3D printing, used mainly in paleontological research, geomorphology, porous rocks, and geomechanics' [3].

3 Method

The method used in this study is biometric analysis. Before doing a literature search, first determine keywords, which are references in research, namely the words "3D printing," "education," and "science." Then a literature search was carried out according to keywords selected from Scopus as initial data. By choosing data-based Scopus, it is expected to get good data and quality articles. With the keywords 3D printing, education, and science, we obtained 339 articles for all subject areas from 1996 to 2023. The data obtained is then collected in RIS data format and converted into a CSV file. The RIS format is then entered into the Mendeley reference management software for reading, and the CSV files are converted into XLSX format to be processed according to analysis needs. The RIS data was then analyzed with Vos viewer to see data visualization in terms of networking, overlay years of research, and research density.

Then, to find out the trends of research in the last ten years about 3D printing in the field of science, researchers carried out the data filtering stage by taking Scopus data with a choice of subjects in the areas of biochemistry, genetic and molecular biology, chemistry, earth and planetary science, environmental science, immunology and microbiology, and agriculture and biological science from 2014–2023. We obtained as many as 48 articles. The data is analyzed biometrically using the Vos viewer software application. According to [14], Vos viewer can compile publication, author, and journal maps. The following are the steps for carrying out the bibliometric analysis method.

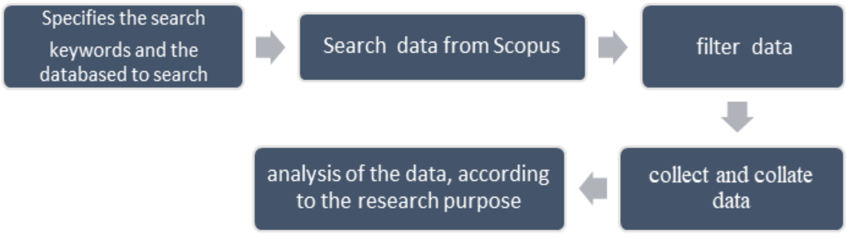

Fig. 2. Steps of the Bibliometric analysis method.

4 Result and Discussion

4.1 Research Growth and Trend

The Scopus database's search results for publications with information about 3D printing using the keywords "3D printing," "education," and "science" The following chart displays the resulting data.

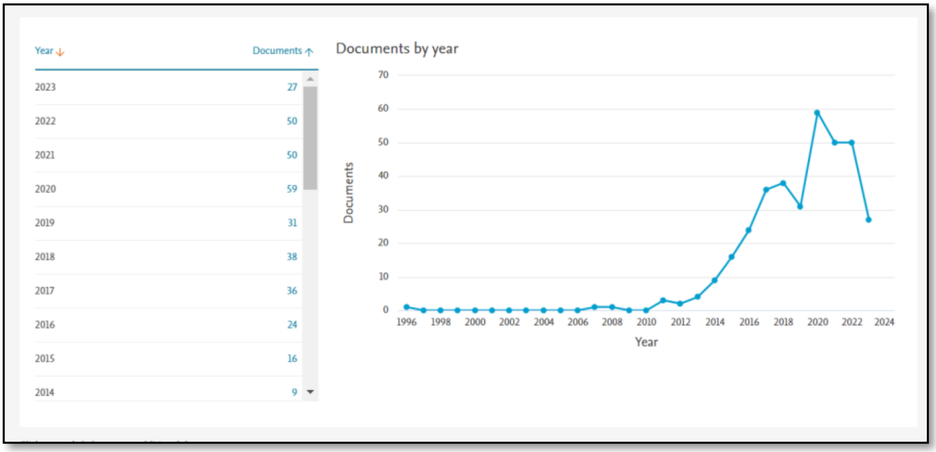

Fig. 3. Graph of increased research on 3DP

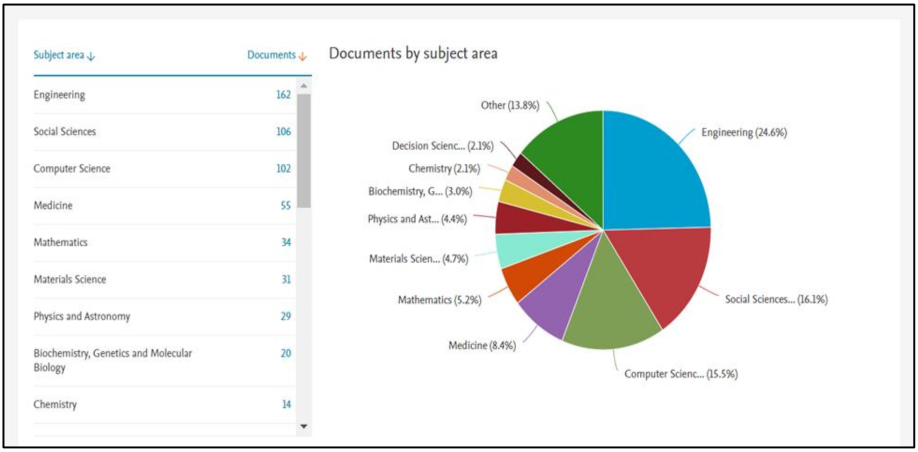

Fig. 4. 3DP research, in various subject areas

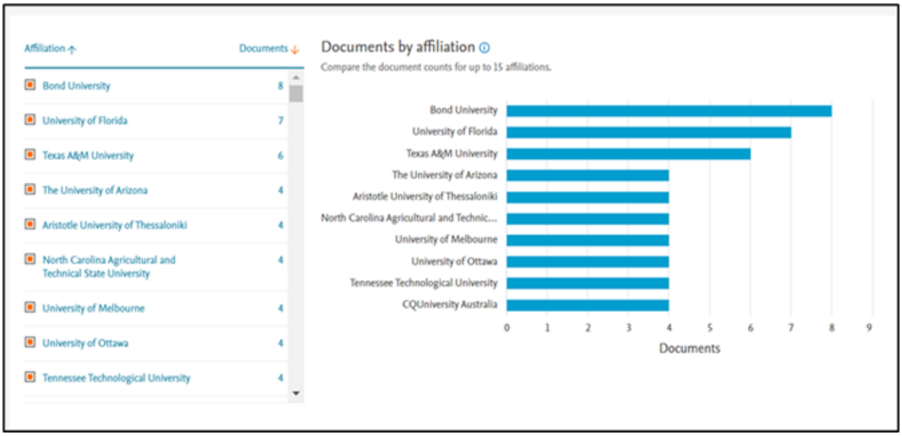

Fig. 5. Affiliation in 3DP research

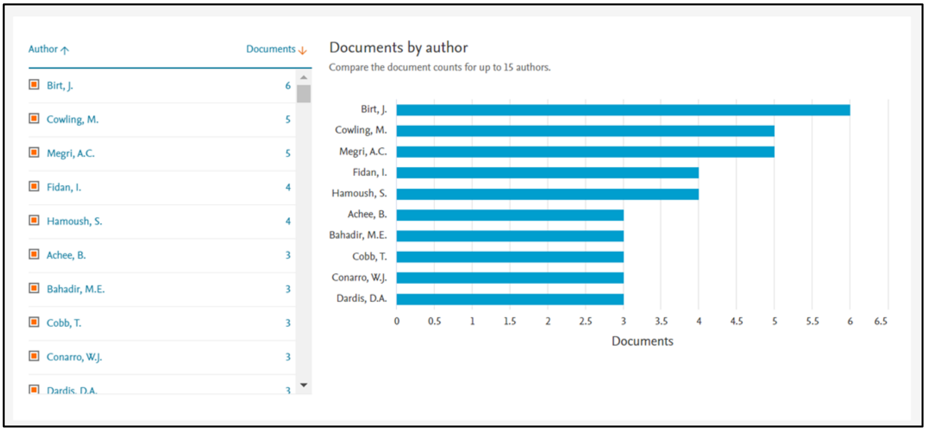

Fig. 6. The names of the 3DP research authors

Based on Fig. 3, the maximum publication rate for 3DP occurred in 2021, and publishing rates improved following 2014. Chemistry has the lowest percentage of publications of any topic (Fig. 4). In comparison to the fields of engineering and social sciences, natural science still has a low percentage of publications. As a result, there is a gap in 3DP research in the science field as compared to other subject areas. Universities in the United States dominate the publishing affiliation (fig. 5), while James Birt is the most prolific author of 3DP articles (fig. 6). The following image is a Vos viewer visualization related to 3D printing data.

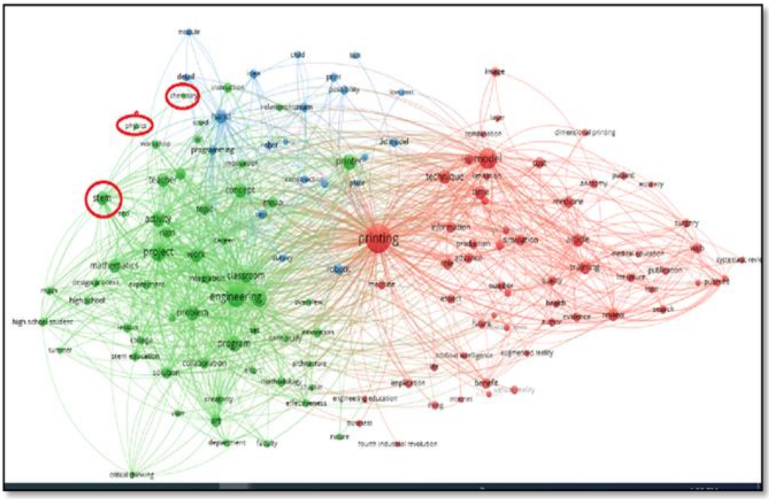

Fig. 7. Network data visualization with Vos viewer

Fig. 7's visualization of Vos viewer results reveals that according to data from Scopus.com, the fields of science such as chemistry and physics are still small and occupy a remote position with printing as a keyword. The small circle visualization shows that there are still a few publications in the chemistry and physics areas related to 3DP. Therefore, there are still opportunities for further scientific research on 3DP.

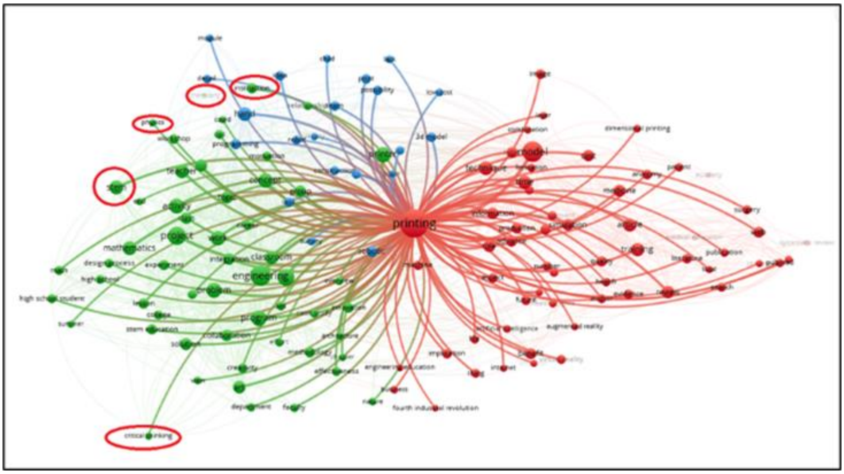

Fig. 8. Visualization of keywords related to 3D printing and words related to science education.

According to Fig. 8, it is evident that the crucial terms highlighted in red circle are related to the concept of printing and include words such as chemistry, physics, education, and critical thinking. With visualization, it is possible to observe that there are still numerous avenues for scientific research using 3D printing, especially in natural science.

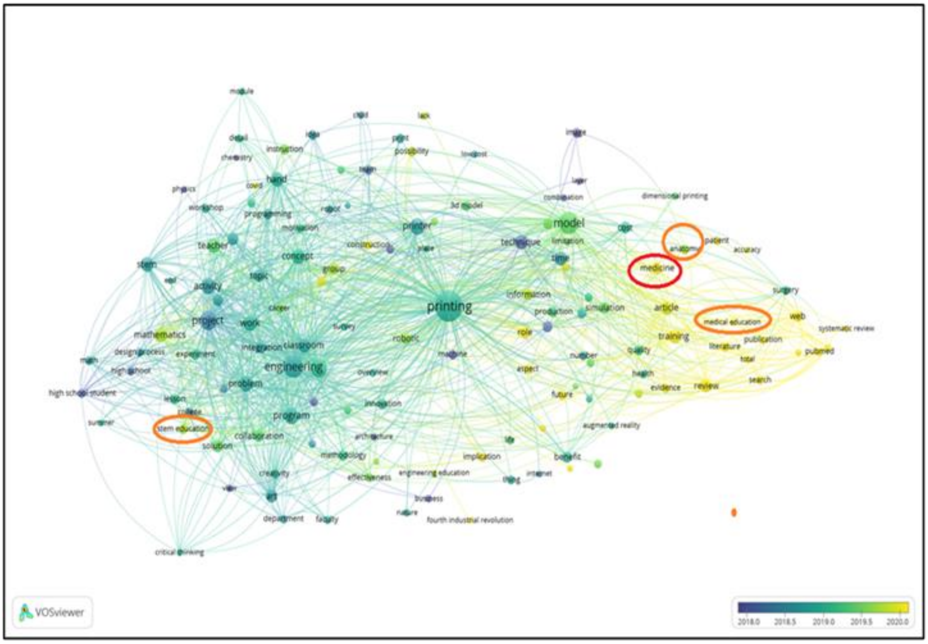

Fig. 9. Vosviewer Visualization Overlay by year of publication.

Based on the visualization in Fig.9, the latest publications are shown in yellow color in applied science fields such as education in medicine, surgery, anatomy, and health. This shows an increase in the use of 3DP in the fields of medicine, health, and biological sciences, especially in anatomy. Further research studies are possible based on previous research recommendations in this area.

To analyze the development of publications in the last ten years in 3D printing, from 2014 to 2023, we took data from Scopus by limiting the year and subject area to the same keywords, namely 3D printing, education, and science. The subject areas whose data were collected included the following areas: (1) biochemistry, genetics, and molecular biology; (2) chemistry; (3) earth and planetary science; (4) environmental science; (5) immunology and microbiology; and (6) agriculture and biological science. Based on these restrictions, 48 articles were produced. researcher analyzes the data more specifically because, since 2014, there has been an amazingly fast increase in publications about 3DP (Fig. 10).

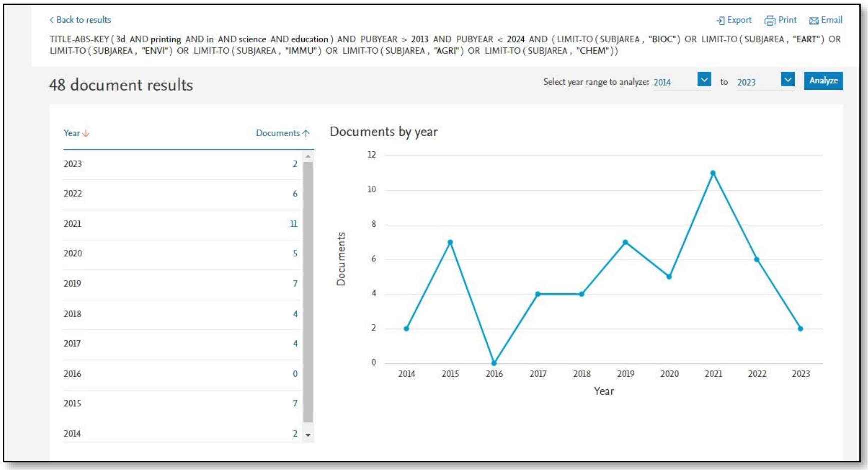

Fig. 10. Publications based on Scopus 2014-2023

Based on data from the publication of 3DP research in science education in 2014–2023, although there has been an increase, it is still relatively low. Publications published related to 3D printing in ten years are still small, with the highest number in 2021 but declining in 2023. This is an interesting phenomenon to research. With the advancement of 3D printing technology, the use of 3D printing has become one of the learning media that helps students produce creative ideas and realize them in concrete form. The trend in educational research is the use of 3D printing, which is very effectively applied to STEM learning. 3D printing technology is a powerful learning tool that can involve students actively in learning, developing design thinking, and problem-solving. Learning provides opportunities to integrate STEM with other disciplines [15]. For further research, this gap can be filled so that the development of science learning with 3D printing has a broad influence on improving the quality of science learning. Recent research is more focused on medicine, so basic science research related to the use of 3D printing is still wide open, especially examining the impact of the use of 3D printing on student learning outcomes holistically in the cognitive, psychomotor, and affective domains.

5 Conclusion

The research trend of 3DP printing in science education, based on data from Scopus.com 2014-2023, is medical education, and anatomy. Based on data visualization, words connected to 3D printing that are very weakly connected, namely critical thinking, experiment, physics, and chemistry, indicate that this field has a wonderful opportunity for new research because there are still few publications. Learning with STEM is also still research that can be further developed. The results of the research that has been conducted so far show that the use of 3D printing in science learning means that students can develop design thinking and problem-solving skills and could integrate STEM with other disciplines. However, further research is still needed on the holistic impact of 3D printing on student learning outcomes.

References

1. U. A. Chaeruman, B. Wibawa, and Z. Syahrial, "Development of an instructional system design model as a guideline for lecturers in creating a course using blended learning approach," *International Journal of Interactive Mobile Technologies*, vol. 14, no. 14, pp. 164–181, 2020, doi: 10.3991/ijim. v14i14.14411.
2. L. Pebriantika, B. Wibawa, and M. Paristiowati, "Adoption of Mobile Learning: The Influence and Opportunities for Learning During the Covid-19 Pandemic," *Int. J. Interact. ("Mobile Gramabot: Development of a Chatbot App for Interactive German Grammar Learning") Mob. Technol.*, vol. 15, no. 5, pp. 222–230, 2021, doi: 10.3991/ijim. v15i05.21067.
3. S. Ford and T. Minshall, "Invited review article: Where and how 3D printing is used in teaching and education," *Addit Manuf*, vol. 25, no. October, pp. 131–150, 2019, doi: 10.1016/j.addma.2018.10.028.
4. S. Ishutov, K. Hodder, R. Chalaturnyk, and G. Zambrano-Narvaez, "A 3D printing Short Course: A Case Study for Applications in the Geoscience Teaching and Communication for Specialists and Non-experts," *Front Earth Sci (Lausanne)*, vol. 9, no. May, pp. 1–12, 2021, doi: 10.3389/feart.2021.601530.
5. A. J. Capel, R. P. Rimington, M. P. Lewis, and S. D. R. Christie, "3D printing for chemical, pharmaceutical and biological applications," *Nature Reviews Chemistry*, vol. 2, no. 12. Nature Publishing Group, pp. 422–436, Dec. 01, 2018. doi: 10.1038/s41570-018-0058-y.
6. M. Derya Gurer, E. Tekinarslan Bolu Abant, I. Kocaayak, and S. Gonultas, "Development and validation of an attitude assessment scale for the use of 3D printing in education," 2019.
7. B. Anđić, "A Phenomenography Study of STEM Teachers' Conceptions of Using Three-Dimensional Modeling and Printing (3DMP) in Teaching," *J Sci Educ Technol*, vol. 32, no. 1, pp. 45–60, 2023, doi: 10.1007/s10956-022-10005-0.
8. Budinski, N.,et.al "Opportunities for 3D printing in Hybrid Education _ Overview of research on 3d printing in education - Open Knowledge Maps.pdf." pp. 339–344, 2022. doi: https://doi.org/10.1515/edu-2022-0175.
9. C. Fonda, E. Canessa, and M. Zennaro, *Low-Cost 3D Printing for Science, Education and Sustainable Development*. 2013.
10. N. O. et. al Marouf, "3d In Veterany medicine.pdf." Veterinarska Stanica, 2023.
11. M. Eisenberg, "3D printing for children: What to build next?" *Int J Child Comput Interact*, vol. 1, no. 1, pp. 7–13, 2013, doi: 10.1016/j.ijcci.2012.08.004.
12. V. Kostakis, V. Niaros, and C. Giotitsas, "Open-source 3D printing as a means of learning: An educational experiment in two high schools in Greece," *Telematics and Informatics*, vol. 32, no. 1, pp. 118–128, 2015, doi: 10.1016/j.tele.2014.05.001.
13. A. S. Ningrum, S. Muslim, and E. Siregar, "Multimedia Simulation Model on Basic Electrical and Electronics Subjects for Vocational Secondary School," *Journal of Education Research and Evaluation*, vol. 6, no. 1, pp. 72–79, Feb. 2022, doi: 10.23887/Jere. v6i1.38783.
14. W. van Eck, "Vos viewer Manual." Leiden University, 2023.
15. N. Ali and M. S. Khine, "Integrating 3D Printing into Teaching and Learning," *Integrating 3D Printing into Teaching and Learning*, no. May 2019, doi: 10.1163/9789004415133.