Chapter # 18

THE USE OF 3D PRINTING AS A DIDACTIC TOOL IN TECHNICAL DRAWING EDUCATION WITH AN EMPHASIS ON ECODESIGN

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ABSTRACT
This chapter explores the use of 3D printing as a didactic tool in the teaching of technical drawing, with an emphasis on ecodesign. 3D printing offers an innovative approach to education, enabling students to better understand complex geometric shapes and constructions through interactive and tangible models. At the same time, it provides hands-on experiences that significantly support the development of spatial imagination and technical skills. The chapter also highlights key aspects of ecodesign and sustainability in modern education. The use of ecological materials for 3D printing, such as biodegradable plastics, contributes to environmental protection and encourages sustainable practices. Furthermore, the efficient use of resources inherent to 3D printing can help reduce waste and material consumption compared to traditional production methods. Practical applications are illustrated through specific project examples in which 3D-printed models have been successfully integrated into technical drawing instruction. Feedback from students and teachers shows that this technology can enrich the learning process and increase interest in technical subjects. The chapter additionally provides an overview of essential software and hardware tools required for 3D printing, along with a discussion of challenges and possible solutions related to its implementation. Overall, the chapter offers a comprehensive view of the potential of 3D printing as a tool for modern and sustainable technical drawing education.

Keywords: 3D printing, didactic tool, technical drawing, ecodesign, sustainable education.

1. INTRODUCTION

In recent years, educational methods have undergone a significant transformation due to the integration of modern technologies into teaching across disciplines. One innovation that has found a firm place, especially in technical and engineering education, is 3D printing. This tool allows the conversion of digital designs into physical form, thereby opening up new possibilities for a better understanding of spatial relationships, geometric structures and design principles.

In the teaching of technical drawing, 3D printing brings a shift from theoretical diagrams to practical, interactive learning. This supports the development of spatial imagination, technical reasoning and problem-solving skills - skills crucial for future experts in technical professions. In addition, the inclusion of eco-design principles in projects leads students to a sustainable approach and responsible use of materials, which is increasingly important in the context of current environmental awareness.

This chapter focuses on the educational potential of 3D printing in the field of technical drawing, with an emphasis on sustainability and eco-design. It presents theoretical foundations, offers concrete examples from practice, and analyzes the benefits and challenges associated with implementing this technology in teaching.3D printing has become an important tool in education, especially in the field of technical drawing (Song, 2018; Pearson & Dubé, 2022; Abu Khurma, Ali, & Swe Khine, 2023; Anđić et al., 2023). This chapter focuses on the use of 3D printing as a didactic tool with an emphasis on ecodesign (Bravo-Díaz & Gutiérrez-Yurrita, 2015; Neto, 2019; Bedmar et al., 2024; Tomášková, Duda, Krotký, & Honzíková, 2024a; Tomášková, Duda, Krotký, & Honzíková, 2024b; Tomášková, Duda, Krotký, & Honzíková, 2025a; Tomášková, Duda, Krotký, & Honzíková, 2025b; Morales Méndez, del Cerro Pérez, & del Cerro Velázquez, 2024; Favi & Marconi, 2025). 3D printing brings an innovative approach that allows students to better understand complex geometric shapes and structures through interactive and tangible models.

2. DIDACTIC AIDS PRINTED ON A 3D PRINTER IN TECHNICAL DRAWING EDUCATION

The integration of 3D printing into the teaching of technical drawing represents a significant shift from traditional methods based on two-dimensional representations towards interactive and hands-on learning. This technology allows students to convert digital designs into physical models, opening up space for a deeper understanding of complex geometric structures, spatial relationships and design principles. The tangibility of 3D printing outputs brings a new dimension to teaching, which encourages active student engagement and the development of their technical thinking. From a pedagogical perspective, 3D printing has the potential to significantly enrich teaching strategies. It allows students to not only visualize but also physically manipulate objects, leading to a better understanding of abstract concepts. This form of learning supports the development of spatial imagination, which is key for technical disciplines, while also developing practical skills such as working with CAD (Computer-Aided Design) software, analyzing design solutions and the ability to iterative design.

Another significant benefit is the possibility of linking the teaching of technical drawing with the topics of sustainability and eco-design. Incorporating these concepts into teaching not only expands students' technical knowledge but also supports their environmental awareness and responsible behavior when designing products. The conference paper Ecodesign as a new possibility in teaching technical subjects in secondary schools (Tomášková, Duda, Krotký, & Honzíková, 2024b) presents ecodesign primarily as a new possibility to enrich the teaching of technical subjects with an environmental dimension. It emphasizes the basic principles of ecodesign and its importance for the development of sustainable thinking, while offering inspiring examples of integration into curricula. On the other hand, the book chapter Ecodesign as an innovative approach to teaching in secondary schools (Tomášková, Duda, Krotký, & Honzíková, 2025a) goes much deeper and shows ecodesign as a comprehensive innovative approach that connects technical drawing with practical projects, life cycle assessment (LCA) methodology and specific recommendations for teachers. It contains structured scenarios on how to implement project tasks, such as the design and production of teaching aids on a 3D printer, while assessing their ecological impacts. The conference paper Life cycle assessment of a product from 3D printer as a new tool for school (Tomášková, Duda, Krotký, & Honzíková, 2024a) focuses on the basic principles of LCA and its use as an educational tool, while the book chapter Innovative education and life cycle assessment of 3D printed products (Tomášková, Duda, Krotký,

& Honzíková, 2025b) develops this issue into practical methodological recommendations, including connections with innovative forms of teaching and project work. Thanks to this, technical drawing becomes not only a means for developing spatial imagination, but also a platform for integrating sustainability, critical thinking and digital competences.

From a didactic point of view, it is also important to reflect on the challenges associated with implementing 3D printing in teaching. These include, for example, the need for technical equipment, the time required to prepare models, the need to train teachers and integrate this technology into existing curricula. Nevertheless, it turns out that with appropriate methodological guidance, 3D printing can be a powerful tool for supporting active learning, project-based learning and interdisciplinary connection of technical and environmental topics. A few studies demonstrate that 3D printed products are used not only in the creation of teaching aids, but also in real experiments. For example, Krotký, Honzíková, & Moc (2016) investigated the deformation of PLA samples printed on a 3D printer at different substrate temperatures. Duda et al. (2019) used 3D printed models in experiments in fluid mechanics, which allowed for the visualization of flow and measurement of turbulence. Similarly, Duda, Yanovych, and Uruba (2022) applied printed components in rheoscopic experiments for teaching flow. The latest work by Duda et al. (2024) then shows how complex physical phenomena, such as time symmetry breaking in flow, can be didactically grasped through a device assembled from 3D printed elements.

Although the integration of 3D printing into technical drawing teaching brings a number of pedagogical benefits, it is also necessary to reflect on environmental and technological challenges. As Tomášková, Duda, Krotký, & Honzíková, 2024a; Tomášková, Duda, Krotký, & Honzíková, 2024b; Tomášková, Duda, Krotký, & Honzíková, 2025a; Tomášková, Duda, Krotký, & Honzíková, 2025b; state, the life cycle of a 3D printed tool includes all phases from the acquisition of raw materials and their processing, through production operations in the company including input and output control, to logistics, use and finally disposal or recycling. Energy consumption during printing itself is not negligible, especially for more complex models, and becomes an important factor in assessing the ecological footprint. Another aspect is the origin of materials, which often come from primary sources, which increases the environmental burden. Therefore, it is appropriate to include a discussion in the teaching about the possibilities of using recycled filaments and about the principles of ecodesign that minimize negative impacts on the environment. The recyclability of printed materials is crucial not only from a sustainability perspective, but also as a practical example for students of how to connect technical thinking with a responsible approach to natural resources. These challenges open up space for the application of the LCA (Life Cycle Assessment) methodology, which allows for a comprehensive assessment of the ecological impacts of a product and its integration into the educational process.

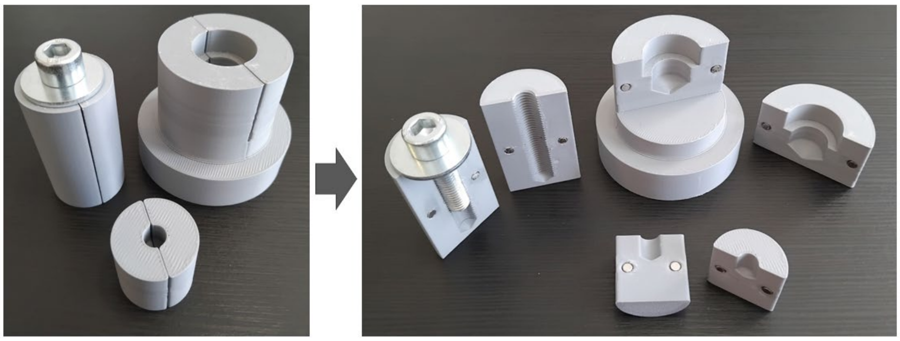
Another important aspect of implementing 3D technologies in education is the development of students' creativity. Fadrhonc, Honzíková, & Tomášková (2025) emphasize in their monograph that 3D modeling in elementary schools is not only a technical skill, but above all a means of supporting creative thinking and problem solving. The authors show that working with 3D models allows students to experiment with shapes, proportions and functionality of objects, which leads to a deeper understanding of the principles of design and technology. At the same time, it is confirmed that the inclusion of 3D modeling in teaching supports an interdisciplinary approach - it connects elements of mathematics, computer science, art education and technical education, i.e., areas covered by the STEM concept (Science, Technology, Engineering and Mathematics). This approach not only develops creativity, but also increases students' motivation for active learning and project work, which is in line with modern trends in STEM didactics.

2.1. Benefits of 3D Printing in Technical Drawing Teaching

3D printed models allow students to physically manipulate objects, which increases their engagement and interest in technical drawing, for example, models of machine components can be easily created and used in teaching, see Figure 1 (Fadrhonc, Honzíková, & Tomášková, 2025).

3D printing technology has become an integral part of modern technical education in recent years. Its application in the school environment allows students not only to master the principles of spatial design and technical drawing, but also to understand the properties of various materials, including ecological and recyclable ones. This opens up space for connecting technical skills with environmental aspects, which is in line with the requirements for sustainable development in education. One of the key benefits of 3D printing is the possibility of using a wide range of materials that differ not only in mechanical properties, but also in their ecological footprint. Among the most commonly used materials is PLA (polylactide), which is produced from renewable resources such as corn starch. Thanks to its biodegradability and low melting point (usually between 180–220 °C), PLA is ideal for educational purposes, especially when making models, prototypes and structural parts with lower demands on mechanical resistance. Another frequently used material is PETG, which combines good mechanical strength with chemical resistance. Its advantage is the possibility of recycling, which makes it suitable for projects focused on the circular economy. In more advanced stages of education, work with ABS can also be included, which is mechanically very resistant, but its printing requires higher temperatures (approx. 230–250 °C) and a controlled environment due to vapor emissions. A specific area that is developing dynamically is the use of filaments made from recycled materials - for example, from PET bottles, old CDs or electronic waste. These materials not only reduce teaching costs, but also allow students to reflect on the environmental impacts of technologies. As part of project education, students can design functional products, such as wall clocks from recycled printed circuit boards, thereby learning to apply the principles of eco-design in practice.

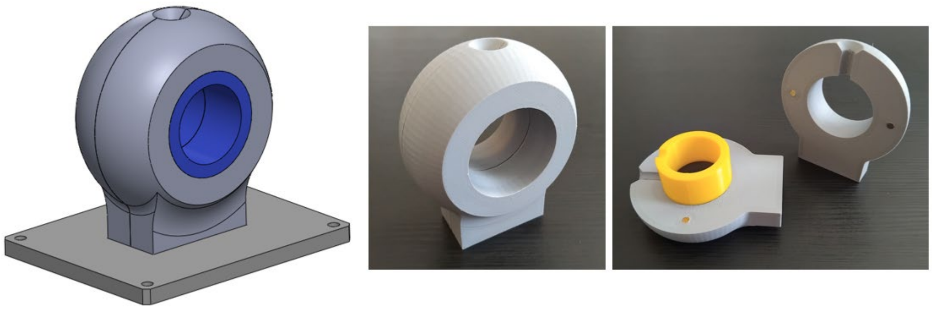
Figure 1.
Didactic aids printed on a 3D printer in technical drawing education.



From a technical point of view, it is important for students to understand the basic physical and chemical properties of individual materials. This includes, for example, tensile strength, elasticity, thermal conductivity, UV resistance and dimensional stability. These parameters have a direct impact on the quality of the resulting product and are key in the design of technical drawings, load calculations and structural optimization. The teaching should also include working with CAD software (e.g., Fusion 360, Tinkercad, SolidWorks), which allows for accurate modeling and preparation of data for printing. Students learn to convert technical drawings into digital form, work with tolerances, scale and structural elements. Subsequently, using a slicer (e.g., PrusaSlicer, Cura) they prepare print files, where they set parameters such as layer height, fill density, print speed or support.

Integrating 3D printing into teaching not only develops technical competencies, but also fosters creativity, critical thinking and environmental awareness. Students learn to make decisions based on technical and ecological criteria, which is important for their future professional orientation in the field of engineering, design and sustainable development. This approach also allows them to connect theoretical knowledge with practical application, which increases students' motivation to learn. Thanks to 3D printing, space is opened for interdisciplinary cooperation, for example between technical and artistic disciplines, and students adopt the principles of the circular economy, as they can use recyclable materials and minimize waste. The educational process becomes more interactive and attractive, which supports the active involvement of students and the development of their creativity. Students gain valuable practical experience in designing and manufacturing their own models, which they then print on a 3D printer, and this process supports technical skills important for future careers in engineering and technology (see Figure 2; Fadrhonc, Honzíková, & Tomášková, 2025). The integration of modern technologies, such as 3D printing, prepares students for the demands of the job market, where innovation and sustainability are key factors.

Figure 2.
Didactic aids printed on a 3D printer (modelling in SOLIDWORKS).

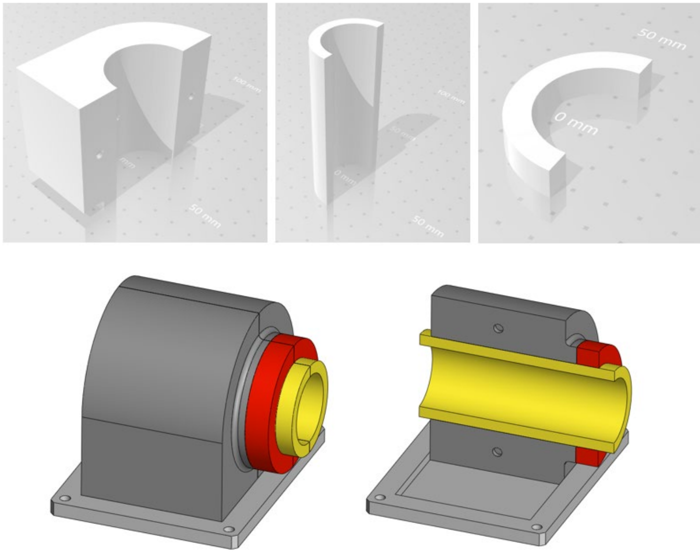


3D printed models of geometric shapes and structures can help students better understand abstract concepts and relationships between different shapes, see Figure 3.

Models of various machine components can be used to teach technical drawing and engineering, allowing students to study and understand their design and function in detail. Students can design and print their own technical drawings and models, providing them with hands-on experience in technical drawing and engineering processes, see Figure 4. The use of 3D models and visualizations allows you to connect theoretical knowledge with practical applications, which increases student motivation and engagement in the lesson.

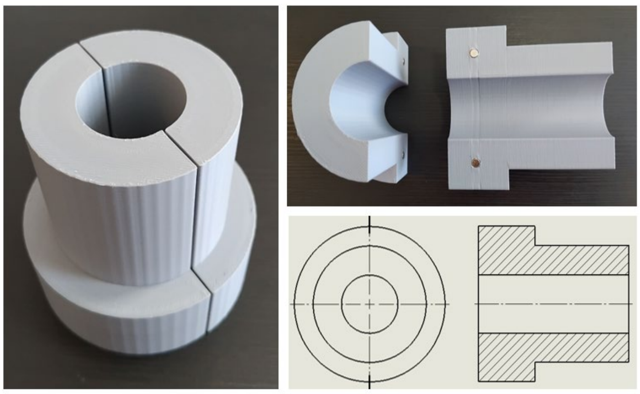
Part of the modern approach is the opportunity for students to design and print their own technical drawings and models. This process includes working with CAD software, creating drawing documentation and subsequent implementation using 3D printing. Students thus gain practical experience not only with technical drawing, but also with the entire engineering process from design to optimization to production. Such an activity develops their creativity, technical thinking and ability to solve real problems, which is key for their future professional application. As described by Fadrhonc, Honzíková, & Tomášková, 2025, connecting design with production through 3D printing allows students to better understand the relationships between design parameters, material properties and environmental impacts.

Figure 3.
Model of didactic aids (modelling in SOLIDWORKS).



The authors emphasize the importance of integrating life cycle assessment (LCA) methods and carbon footprint calculation, which leads to awareness of the ecological aspects of technical solutions. This approach supports not only technical competences, but also the development of responsible engineering oriented towards sustainability.

Figure 4.
Model of didactic aid and technical drawing.



3. FUTURE RESEARCH DIRECTIONS

Given the rapid technological development and increasing demands for sustainability, it is expected that the use of 3D printing in education will continue to expand and deepen. Several promising directions are opening up in the field of technical drawing, which can fundamentally influence both the content of education and its methodological approach. One of the key trends is the expansion of the material base with new types of ecological filaments, including composite materials with wood, metal particles or recycled polymers. These materials allow not only the expansion of technical teaching options, but also a deeper integration of environmental topics. Students can thus learn to evaluate materials not only in terms of their technical parameters, but also in terms of their impact on the environment, throughout the product's life cycle. Another direction is the personalization of teaching aids through parametric modeling. Using advanced CAD tools, students can create their own variants of models that correspond to their individual design solutions. This supports creativity, technical precision and the ability to iteratively improve the design. In combination with 3D printing, these designs can be quickly verified in practice, which significantly increases the effectiveness of teaching. From a pedagogical point of view, the development of project-oriented teaching that connects technical drawing, structural design, environmental analysis and digital manufacturing appears promising. Students can work on complex tasks that include the design of a functional product, the selection of suitable materials, the creation of technical documentation, printing a prototype and the subsequent evaluation of its functionality and ecological footprint. Such an approach supports interdisciplinarity and the development of key competencies for the 21st century. Last but not least, greater integration of simulation tools into teaching is expected, which will allow students to analyze the mechanical behavior of designed parts in advance, optimize their geometry and minimize material consumption. In combination with methods such as LCA (Life Cycle Assessment), technical drawing teaching can be enriched with systems thinking and the ability to comprehensively evaluate technical decisions. From an institutional development point of view, it is important to support the creation of open databases of teaching models that will be shared between schools and educational institutions. This will facilitate access to proven teaching aids and support collaboration between educators in the field of technical and environmental education. Overall, it can be stated that the future of 3D printing in technical drawing education lies in its deeper integration into teaching processes, the expansion of the ecological dimension and the connection with digital tools for design, simulation and evaluation. This technology has the potential to become not only a means for the development of technical skills, but also a tool for the formation of responsible and sustainably oriented technical thinking.

4. CONCLUSION/DISCUSSION

The integration of 3D printing into technical drawing education represents a significant step towards the modernization of technical education. This technology allows for the transformation of abstract geometric concepts into tangible form, thereby supporting the active involvement of students, the development of spatial imagination and technical skills. At the same time, it opens up space for connections with the principles of eco-design and sustainability, which is in line with current requirements for education oriented towards the responsible use of resources.

A key benefit is the possibility of connecting technical competencies with environmental thinking. Students learn not only to work with CAD tools and 3D printing technologies, but also to reflect on the choice of materials, the energy intensity of production and the impacts of the entire product life cycle. This makes technical drawing a platform for the development of systemic and critical thinking, interdisciplinary connections and digital skills.

From a sustainability perspective, it is essential to highlight the challenges that this technology brings: the need to optimize energy consumption, use recycled filaments, and incorporate environmental impact assessment methods (e.g., LCA) into the educational process. These aspects not only reduce the environmental burden but also provide students with a practical framework for applying the principles of the circular economy.

Based on simple studies and practical experience, we can conclude that without didactic aids, students achieved an average improvement in understanding and application of technical drawing of around 15%. When didactic aids printed on a 3D printer were used, students achieved an improvement in understanding and application of technical drawing by up to 35% due to the interactive and practical approach. If didactic aids are effectively integrated into the teaching and students have enough opportunities to use them, 3D printed models can significantly increase student engagement, their spatial imagination and technical skills, which leads to better learning outcomes. The percentage improvement values are based on a comparison of the pre-test and post-test results, which were carried out for the control and experimental groups. Students in both groups took a test before the start of the lesson (baseline), which verified their initial level of understanding of technical drawing. After the end of the lesson block, the same or equivalent test was administered, the results of which allowed to determine the level of improvement. The average improvement was calculated as the relative difference between the pre- and post-lesson scores, which provided an objective basis for the values of 15% and 35%.

Future research should focus on developing methodological approaches for effectively integrating 3D printing into the curriculum, verifying long-term impacts on learning, and finding ways to minimize the ecological footprint of this technology. Sharing open databases of models, using recycled materials, and integrating LCA into project-based learning are promising directions that connect technical education with sustainable development goals.

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