The Use of a 3D Pen in Teaching Solid Geometry to Visually Impaired Students

Introduction

Vision is widely regarded as the most important sensory modality for acquiring information, as approximately 80% of information from the external environment is perceived visually. Consequently, living with a visual impairment presents numerous challenges in everyday life. Education is no exception, as it plays a crucial role in providing individuals with visual impairments with equal access to social and professional opportunities.

Solid geometry represents a particularly challenging area of mathematics, as spatial visualization is essential for understanding geometric concepts. However, the lack of appropriately adapted teaching aids, their high cost, and inadequate instructional design can significantly hinder students' understanding of the subject matter. Therefore, the aim of this study is to design and develop affordable and pedagogically effective teaching aids using 3D pen technology.

3D Pen Tool and Its Application in Education

A 3D pen is an innovative educational tool that enables the creation of three-dimensional objects through the extrusion of molten thermoplastic material. In recent years, the use of 3D pens in geometry education has attracted increasing attention in international research, highlighting their considerable pedagogical potential. A particularly relevant contribution is the research presented in [3], which demonstrates that integrating 3D pens into mathematics education supports the process of learning through making. Working with this technology encourages students to develop creativity and explore alternative problem-solving strategies, for example when investigating cross-sections of three-dimensional solids [2]. The study by [4] highlights the potential of 3D pens for creating raised tactile drawings by individuals with visual impairments. The findings showed that 3D pens enable continuous tactile exploration of drawn lines and the creation of reference points, potentially supporting tactile perception and communication between teachers and students.

Model Development Process

When designing the templates and constructing the models, emphasis was placed on appropriate dimensions and maximizing tactile accessibility for students with visual impairments. The design followed expert recommendations and established principles of tactile perception [1]. The models were constructed with heights exceeding 10 cm to facilitate tactile exploration.

Tactile clarity guided each design choice. Essential geometric elements, such as right triangles, solid heights, and base diagonals, were incorporated into the models to support the understanding of spatial relationships. All elements were designed to be easily accessible and distinguishable by touch. The construction process is illustrated in Figure 1.

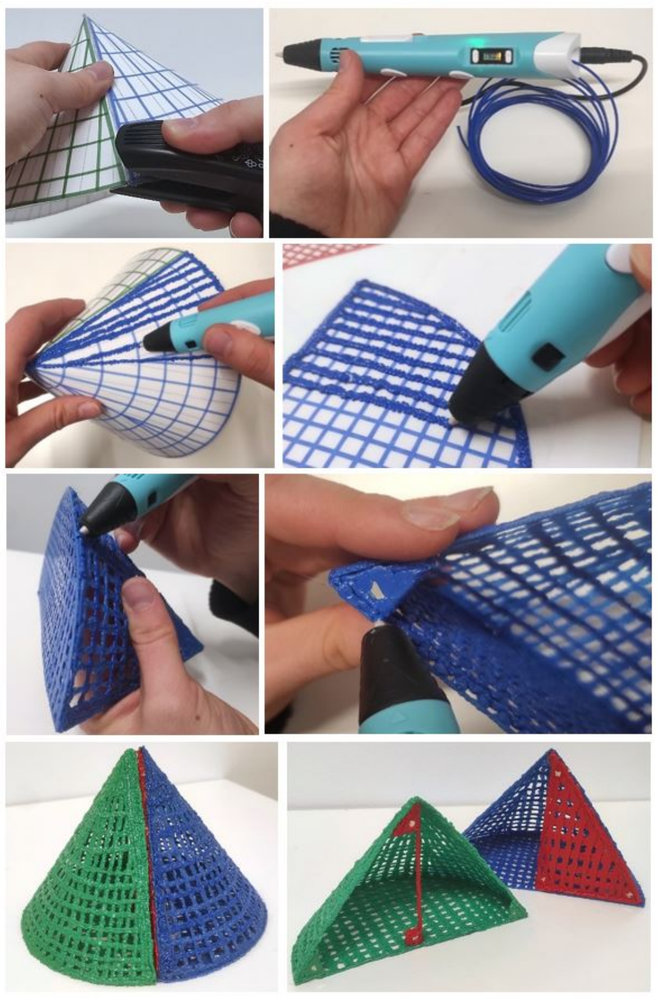


Figure 1. After preparing the supporting template and the 3D pen, the lateral surface and the base of the cone are constructed. The individual components are then assembled and fitted with embedded magnets, allowing the model to be disassembled and reassembled. The resulting model enables students to explore the external shape of the cone through touch. Once disassembled, it also provides access to the internal structure, allowing students to examine the geometric elements and relationships within the solid.

Expert Validation

Close collaboration with the *Primary boarding school for blind and visually impaired children in Bratislava* was a key aspect of the model development process. A special education teacher with over 45 years of experience working with students with visual impairments provided expert validation of the models. Additionally, two students who are blind participated in testing the prototypes. Based on their feedback, models of a cone (Figure 1), a regular hexagonal pyramid, and a regular square pyramid (Figure 2) were developed and received highly positive feedback.

Although this approach appears promising for inclusive education, certain limitations remain. Therefore, future research will focus on quantitative testing across multiple schools for students with visual impairments to evaluate the effectiveness of the developed teaching aids in educational practice.

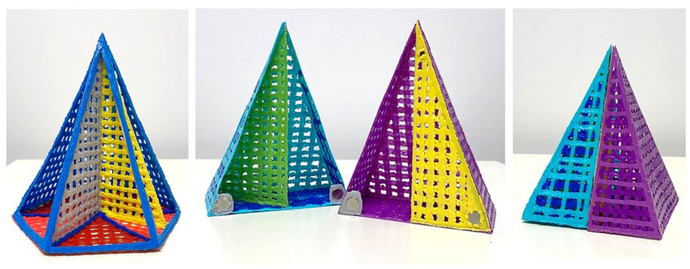


Figure 2. Additional models created using a 3D pen.

References

[1] Terezie Kochová.
Tak a tak na taktilní knížku.
Asociace rodičů a přátel dětí nevidomých a slabozrakých v ČR, Praha, 2 edition, 2012.

[2] Oi-Lam Ng and Francesca Ferrara.
Towards a materialist vision of learning as making: The case of 3D printing pens in school mathematics.
International Journal of Science and Mathematics Education, 18(5):925–944, 2020.

[3] Oi-Lam Ng and Huiyan Ye.
Doing mathematics with 3D pens: Five years of research on 3D printing integration in mathematics classrooms.
In Frederik Dilling, Felicitas Pielsticker, and Ingo Witzke, editors, *Learning Mathematics in the Context of 3D Printing: Proceedings of the International Symposium on 3D Printing in Mathematics Education*, pages 143–162. Springer Spektrum, Wiesbaden, 2023.

[4] C.-F. Wu, H.-P. Wu, Y.-H. Tu, and I.-T. Yeh.
3D pen tactile pictures generated by individuals with visual impairments.
Journal of Visual Impairment & Blindness, 114(5):382–392, 2020.

This work was supported by KEGA 070UK-4/2026 and KEGA 038UK-4/2024, carried out at Comenius University in Bratislava.

FAKULTA MATEMATIKY, FYZIKY A INFORMATIKY
Univerzita Komenského v Bratislave

MATFYZ CONNECTIONS

Zuzana Kucharová
Department of Mathematics, Physics and Informatics Education

Barbora Pokorná
Department of Algebra and Geometry

Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava