Co-funded by the European Union

3D STEAM

Final result to WP/ Activity:

2.3 Development of the Didactical Concept

Leading organization: Johannes Kepler University Linz

Participating organization:

University of Ostrava

University of Jyväskylä

University of Luxembourg

Comenius University Bratislava

OSTRAVSKÁ UNIVERZITA

JOHANNES KEPLER UNIVERSITÄT LINZ

UNIVERSITY OF JYVÄSKYLÄ
FINNISH INSTITUTE FOR EDUCATIONAL RESEARCH

UNIVERSITÉ DU LUXEMBOURG

COMENIUS UNIVERSITY BRATISLAVA

Co-funded by the European Union

3D STEAM

Project title:

Accelerating STEAM-related Knowledge and Skills via 3D Modelling and 3D Printing

Reg. number:

2023-1-CZ01-KA220-HED-000160664

Didactical Concept for 3DMP Teacher Training

This document is a partial result of the project *Accelerating STEAM-related Knowledge and Skills via 3D Modelling and 3D Printing (acronym: 3D STEAM)*

The project has been co-founded by the European Union within its program *ERASMUS+ KA220-HED - Cooperation partnerships in higher education*

This particular work package was led by Johannes Kepler University, Linz, Austria

Last revision: May 2025

OSTRAVSKÁ UNIVERZITA

JKU JOHANNES KEPLER UNIVERSITÄT LINZ

UNIVERSITY OF JYVÄSKYLÄ
FINNISH INSTITUTE FOR EDUCATIONAL RESEARCH

uni.lu UNIVERSITÉ DU LUXEMBOURG

COMENIUS UNIVERSITY BRATISLAVA

such data. The data controller and the processors listed in this privacy statement follow the rules of the Regulation.

Abstract

Integrating 3D modelling and printing (3DMP) into educational curricula offers a significant opportunity to enrich STEAM education by making abstract concepts tangible and fostering hands-on, experiential learning. However, despite the growing enthusiasm for using 3DMP in classrooms, evident challenges hinder its practical adoption. Research underscores the necessity for comprehensive teacher training programs, as many educators encounter obstacles related to technical proficiency, resource availability, and alignment with curriculum standards (Pearson & Dubé, 2022). To address these challenges and support teachers in navigating the complexities of 3DMP, this program provides a structured, challenge-based training framework specifically for in-service mathematics teachers. This framework aims to bridge technological, pedagogical, and content knowledge gaps by incorporating elements from the TPACK (Technological, Pedagogical, and Content Knowledge) model to guide teachers in effectively using 3DMP as a pedagogical tool (Graham et al., 2021).

1. Current Challenges in 3DMP Teacher Training

The use of 3DMP in education has been explored primarily through qualitative studies that often adopt an exploratory approach, highlighting an early stage of research in this field. As such, many existing programs need more theoretical and practical depth to empower teachers with sustainable 3DMP skills (Novak et al., 2021). The geographic concentration of 3DMP research in countries with established technological infrastructures, such as Austria, Luxembourg and Finland, limits the global relevance of current findings, as these studies may not reflect the challenges faced in less technologically advanced regions. Pearson & Dubé (2022) emphasise the importance of considering cultural and regional contexts when developing 3DMP training programs, as such considerations are crucial for ensuring that teachers worldwide can apply these skills within their unique educational settings.

Moreover, the literature identifies specific barriers teachers face when implementing 3DMP, such as limited access to resources, insufficient technical knowledge, and challenges in aligning 3DMP activities with curriculum standards. These obstacles underscore the need for training programs beyond basic technical instruction, offering teachers a comprehensive foundation that includes pedagogical strategies, content alignment, and practical classroom applications (Urbina & Polly, 2017). To enhance the accessibility and effectiveness of 3DMP, programs must address these areas comprehensively, enabling teachers to feel confident in their ability to integrate this technology into their instructional practices.

Benefits of 3DMP in Teacher Education

Studies have shown the benefits of integrating 3DMP into teaching practices, particularly in STEAM subjects. Teachers who successfully incorporate 3DMP can make abstract mathematical and scientific concepts more accessible to students by transforming theoretical content into manipulatable, tangible models. This hands-on approach encourages active learning and critical thinking, as students can explore complex ideas more concretely (Shelly et al., 2015). Furthermore, using 3DMP in classrooms aligns with constructivist learning theories, which emphasise the importance of experiential learning and knowledge construction through direct interaction with learning materials (Verner & Merksamer, 2015).

In mathematics education, 3DMP has shown the potential to facilitate spatial reasoning and visual literacy skills, which are crucial for understanding geometry, algebra, and other abstract topics (Graham

et al., 2021). However, for teachers to harness these benefits effectively, they must be trained in the technical aspects of 3DMP and designing and analysing tasks that are pedagogically sound and aligned with mathematical content standards (Novak & Wisdom, 2018). Task design and analysis become particularly significant in this context, as they ensure that 3DMP activities are purposeful and support the curriculum rather than serving as disconnected technological exercises.

Addressing the Gaps in Teacher Preparation

Existing research reveals a need for professional development programs that equip teachers with the skills and confidence to utilise 3DMP technology. A recurrent theme in the literature is that many educators feel underprepared to use 3DMP effectively due to their lack of technical knowledge and limited experience with 3D printing software. According to Song (2018), using 3D modelling tools presents considerable challenges for teachers, especially when dealing with advanced software. Thus, the gradual introduction of accessible, user-friendly platforms like TinkerCAD, as proposed by Karaismailoglu & Yildirim (2023) and Wan & Ivy (2021), can serve as an entry point that allows educators to develop foundational skills before progressing to more complex tools. This approach not only demystifies the technology but also helps build teachers' confidence, an essential factor in their willingness to adopt new methods in the classroom (Sun & Okojie, 2020).

In addition to technical training, teacher education programs must focus on building teachers' pedagogical knowledge to enable them to create 3DMP tasks that are relevant and effective. This includes fostering a deep understanding of task design and analysis, which allows teachers to evaluate the educational value of 3DMP activities and adapt them to meet students' learning needs. Research shows that well-designed 3DMP tasks enhance student engagement and learning outcomes, especially when aligned with curriculum goals (Sullivan & McCartney, 2017). By emphasising task design and analysis within the training framework, this program aims to equip teachers with the skills necessary to create 3DMP experiences that support curriculum objectives and foster deeper learning (Alimisi et al., 2016).

Need for a Holistic Training Approach

For 3DMP teacher training programs to be effective, they must adopt a holistic approach that combines content knowledge, pedagogical strategies, and technological proficiency. Studies suggest that effective 3DMP training programs address these three areas simultaneously, allowing teachers to understand how technological tools can convey specific subject matter and engage students effectively (Shelly et al., 2015). The TPACK framework serves as a valuable model in this context, as it provides a structured approach to integrating technological, pedagogical, and content knowledge, thus supporting teachers in their professional development journey (Graham et al., 2021).

The holistic approach also requires creating a supportive training environment that includes ongoing mentorship, resource sharing, and collaborative learning opportunities. According to Alimisi et al. (2016), establishing a community of practice among participants can foster a positive learning atmosphere where teachers feel comfortable experimenting with new tools, sharing their experiences, and seeking guidance when needed. Interactive, hands-on sessions within the training program help maintain high levels of engagement, which research has shown is critical for effective skill acquisition (Urbina & Polly, 2017). Moreover, offering an online repository with tutorials and example projects enables teachers to continue learning independently, reinforcing their skills and confidence in 3DMP.

Implications for Curriculum Alignment and Classroom Integration

One of the significant challenges identified in the literature is the alignment of 3DMP activities with curriculum objectives. Teachers often struggle to incorporate 3DMP into existing frameworks in a way that meaningfully supports student learning outcomes (Novak & Wisdom, 2018). This program addresses this issue by guiding participants through task design and analysis, ensuring that 3DMP activities are engaging and aligned with specific curriculum goals. By focusing on creating and evaluating tasks that integrate curricular concepts, the program helps teachers make informed choices about how to use 3DMP as an educational tool.

Moreover, integrating 3DMP into curricula goes beyond technical instruction; it involves strategic planning and resource alignment to support long-term success. Verner & Merksamer (2015) emphasise the need for training programs to provide educators with guidelines and practical support for integrating 3D technologies into their teaching practice. This includes establishing alignment with curriculum standards, ensuring access to necessary resources, and developing strategies for overcoming potential logistical barriers, such as limited class time and budget constraints. By addressing these aspects, the program helps teachers create a sustainable framework for 3DMP integration that can be adapted to their unique educational contexts.

Integrating 3DMP into teacher training programs represents an important step in modernising mathematics and STEAM education. This challenge-based, TPACK-guided framework is designed to support teachers in developing the skills, confidence, and pedagogical knowledge needed to incorporate 3DMP into their teaching practice. By addressing the gaps in teacher preparedness, fostering a supportive training environment, and aligning activities with curriculum objectives, this program enables educators to leverage 3DMP's full potential to enrich learning experiences. The comprehensive nature of the program ensures that teachers are well-equipped to apply 3DMP in meaningful ways, ultimately creating a more engaging and innovative classroom environment for their students.

2. General Principles

The proposed didactical concept for 3DMP teacher training is built around a series of flexible sessions; each centred on a challenge-based learning approach. This method allows teachers to engage in practical, hands-on activities that gradually increase complexity and directly apply to classroom settings.

Key elements of this concept include:

- *Challenge-Based Learning:* Each session begins with a challenge designed to engage participants in practical problem-solving using 3DMP. The challenges evolve from simple technical tasks to complex, interdisciplinary projects, providing a scaffolded learning experience.
- *TPACK Integration and Assessment:* The training incorporates the TPACK framework to help participants reflect on and develop their technological, pedagogical, and content knowledge. Self-assessments and periodic checkpoints are used to monitor progress and guide learning.
- *Reflection and Discussion:* Reflection is a crucial part of the learning process. Each session includes structured prompts and group discussions to encourage participants to think critically about their experiences and adapt challenges for classroom use.
- *Resource Support:* An online repository provides participants with technical tutorials and example projects, supporting independent learning and allowing for the sharing of ideas and adaptations.
- *Assessment and Evaluation:* The program includes self-assessment using the TPACK framework, rubrics for evaluating challenges, and peer evaluations of lesson plans to ensure a comprehensive understanding and application of 3DMP in educational contexts.

3. Didactical Concept Outline

Training Structure and Flow

Session Design: A series of 5-10 flexible sessions, each focusing on a distinct challenge.

Session Flow:

1. Challenge Introduction: The session begins with a challenge statement. The first session provides structured instructions, while subsequent sessions present more open-ended tasks.
2. Hands-On Activity: Participants engage in the challenge in small groups, allowing them to explore and apply 3DMP practically.
3. Reflection and Discussion: Guided by specific prompts, participants discuss their experiences and share insights on how the challenge could be adapted for classroom implementation.
4. Redesign and Presentation: Groups collaboratively redesign the challenge to fit their teaching contexts and present these adaptations for peer feedback.

Progression: Challenges are designed to evolve in complexity, starting with basic technical tasks and moving towards interdisciplinary and transdisciplinary projects.

TPACK Integration and Assessment

1. Initial Self-Assessment: Participants start with a TPACK self-assessment to reflect on their knowledge and skills.
2. Periodic Checkpoints: At the end of each session, participants reflect on their growth with simple prompts.
3. Final Self-Assessment: Participants complete a TPACK self-assessment to reflect on their overall development throughout the training.

Challenge Design

- *Initial Challenges:* These are structured with detailed instructions to introduce participants to the basics of 3DMP. Examples include copying simple physical objects or creating basic teaching aids.
- *Gradual Complexity:* Later challenges encourage participants to design projects integrating subject-specific content, leading to interdisciplinary and transdisciplinary tasks.
- *Collaboration:* Final challenges promote collaboration, encouraging participants to collaborate on projects that simulate real-world interdisciplinary teaching.
- *Adaptability:* Challenges are designed to be adaptable, allowing participants to modify them for various educational settings.

Reflection and Discussion

- *Prompts:* Sessions include prompts to guide reflection on technical and pedagogical aspects (e.g., "What were the main challenges you encountered?").
- *Peer Review:* Informal peer feedback is integrated into discussions, allowing participants to share their redesigns and ideas.
- *Re-Planning:* Small group work involves revising the initial challenges to better suit classroom settings. The redesigned challenges are presented to the group for feedback.

Resource Creation and Online Repository

- *Technical Tutorials:* The online repository provides tutorials on building technical skills using 3DMP tools, such as GeoGebra, Tinkercad, and Fusion360.
- *Example Projects and Challenges:* The repository also includes a range of open-ended challenges and example projects. Participants can upload their own adaptations and lesson plans for peer review.
- *Guidelines for Trainers:* A guideline document supports trainers in adapting the program to different contexts while maintaining consistency.

Assessment and Evaluation

- *TPACK Self-Assessment:* The structured self-assessment process allows participants to reflect on their growth in integrating technology, pedagogy, and content.
- *Challenge Assessment Rubric:* A rubric evaluates each challenge based on pedagogical relevance, creativity, and content integration, emphasising practical classroom applications.
- *Peer Evaluation:* For the final lesson plan, participants conduct a structured peer evaluation, focusing on clarity, feasibility, integration of 3DMP, and student engagement potential.

4. Conclusion

This didactical concept for 3DMP teacher training is designed to equip educators with the skills and knowledge necessary to integrate 3D printing into their teaching practices. By focusing on hands-on challenges, reflective practice, and the TPACK framework, the program aims to foster an understanding of how 3DMP can enhance learning. The concept's flexibility and adaptability ensure that it can be tailored to fit different educational contexts, supporting the diverse needs of teachers and learners.