ENVIHEI

Title of the PBL challenge:
Application of 3D Printing Technologies for Sustainable Manufacturing

Name of the responsible lecturer

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University / Department / Degree program

Silesian University of Technology / Scientific and Didactic Laboratory of Nanotechnology and Material Technologies / Bachelor's Degree in Mechanical Engineering

Course / Subject in which implemented

1st and 2nd Course / Application of 3D printing technologies

Implementation period (dates)

March 2, 2026 – June 15, 2026

Total duration (weeks/hours)

15 weeks / 30 hours

Number of students involved

36 students

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1. Project Design

1.1 Brief description of the project and the challenge proposed

The project focused on the practical application of 3D printing technologies in engineering design and manufacturing. Students were challenged to develop a product or component that could be effectively manufactured using additive manufacturing technologies. The task included defining functional requirements, preparing a 3D model, selecting an appropriate material and manufacturing parameters, producing a prototype, and evaluating the final product. Particular attention was given to optimizing material use, reducing waste, and considering the environmental impact of the proposed solution.

Topics addressed by student groups/sections:

- Future of fitness, modular 3D-printed exercise systems
- Water filtration system
- Armrest
- Design and manufacturing of a functional lamp using 3D printing technology
- Wall-mounted bottle opener with cap counter
- Project of a personalized 3D-printed wrist support
- Personalized orthopaedic shoe insert
- Modular elastic mat cover

1.2 Expected learning outcomes (academic and transversal competences)

Students were expected to develop knowledge and practical skills related to additive manufacturing, including 3D modelling, material selection, preparation of models for printing, selection of process parameters, and evaluation of manufactured components. The project also aimed to develop transversal competences such as problem-solving, critical thinking, teamwork, communication, project planning, creativity, and decision-making. Students were encouraged to justify their technological and material choices based on technical, economic, and environmental criteria.

1.3 Targeted sustainability competences

The project addressed sustainability competences through systems thinking and understanding the relationship between design, materials, manufacturing, use, and end-of-life; critical assessment of material and energy consumption; sustainable design and responsible material selection; identification of opportunities for waste reduction; development of innovative solutions based on additive manufacturing; and consideration of circular economy principles and the potential for reuse or recycling of materials.

1.4 Sustainability approach and how it is integrated into the project

Sustainability was integrated throughout the project, from the initial design concept to the evaluation of the manufactured component. Students considered how design choices influence material consumption, manufacturing efficiency, product functionality, and waste generation. The use of additive manufacturing enabled students to explore material-efficient design strategies, including lightweight structures, topology modifications, and optimization of component geometry. Students were also encouraged to compare alternative materials and manufacturing solutions and to consider the environmental consequences of their decisions throughout the product life cycle.

1.5 Methodologies and tools used (PBL structure, facilitation techniques, etc.)

The project was implemented using a Project-Based Learning (PBL) approach combining theoretical knowledge with practical engineering tasks. Activities included problem definition, concept development, CAD modelling, preparation of models for additive manufacturing, material and process selection, 3D printing, evaluation of manufactured parts, and presentation of results. Digital design and slicing software, 3D printers, and basic measurement and evaluation methods were used. The lecturer supported the teams through consultations, technical guidance, discussions, and feedback at key stages of project development.

1.6 Organization of the project (group formation, timeline, milestones)

Students worked individually or in small teams, depending on the complexity of the proposed solution. The project was organized into the following stages: definition of the engineering problem and functional requirements; development of the initial concept; preparation and optimization of the 3D model; selection of material and additive manufacturing technology; preparation of the manufacturing process and selection of printing parameters; production of the prototype; evaluation and, where necessary, modification of the design; and presentation and discussion of the final results. Key milestones were concept approval, completion of the CAD model, prototype production, evaluation of the manufactured component, and final presentation.

1.7 Deliverables requested from students (type, format, deadlines)

Students were required to prepare a digital 3D model of the proposed component, files prepared for additive manufacturing, a manufactured prototype, a brief technical description covering the design concept, selected material, manufacturing technology and process parameters, an evaluation of the final solution including technical and sustainability aspects, and a final presentation summarizing the project and its results. The deliverables documented both the development process and the final engineering solution.

1.8 External collaborators involved (mentors, companies, experts…) and their role

No external collaborators were directly involved in the implementation of this PBL challenge. The activities were carried out using the expertise, laboratory infrastructure, and additive manufacturing equipment available at the university.

2. Project Evaluation

2.1 Assessment criteria and methods used

Assessment combined evaluation of the design process and the final engineering solution. Criteria included correctness and functionality of the 3D model, appropriate selection of material and additive manufacturing parameters, quality of the

manufactured prototype, ability to identify and solve manufacturing problems, consideration of material efficiency and sustainability, and clarity of technical documentation and presentation. Feedback during project development supported iterative improvement of the proposed solutions.

2.2 Evidence of student learning (examples, outputs, results)

Evidence of learning included CAD models, files prepared for additive manufacturing, manufactured prototypes, observations from the printing process, technical documentation, and final presentations. These outputs demonstrated students' ability to translate a design concept into a physical component, select suitable manufacturing parameters, assess print quality and functionality, identify limitations, and propose improvements to the design or process.

3. Reflections and Recommendations

3.1 Main achievements and strengths of the project

A key strength of the project was the direct integration of design, materials engineering, and manufacturing practice. Students gained hands-on experience with the complete additive manufacturing workflow, from concept development to prototype evaluation. The project encouraged independent decision-making, iterative problem-solving, and awareness of the relationship between component geometry, material selection, processing parameters, product quality, and material efficiency.

3.2 Challenges faced and how they were addressed

The main challenges were related to preparing geometries suitable for printing, selecting appropriate process parameters, and achieving the expected dimensional and functional quality of prototypes. These issues were addressed through design corrections, modification of model orientation and printing settings, repeated evaluation of manufactured parts, and technical consultations. The iterative approach enabled students to treat unsuccessful or imperfect prints as part of the engineering learning process.

3.3 Lessons learned for future implementations

Future implementations should maintain the strong practical component while introducing clear checkpoints for design review, print preparation, prototype assessment, and sustainability reflection. More systematic comparison of alternative design variants, materials, and printing parameters would strengthen engineering decision-making. Documenting design changes and the reasons for process modifications would also make the learning progression more explicit and improve the quality of final project conclusions.

4. Supporting Material

4.1 Lecturers' materials and project documentation

Lecturers' materials and project documentation are available in the following link:
https://drive.google.com/drive/folders/1KLm2eUpxDCSV3hoB3MDwsbYt_sOA87Nv?usp=drive_link

4.2 Deliverables produced by students, final presentations or pitch materials

An example of deliverables produced by students is available in the following link:
https://drive.google.com/drive/folders/1CaGoYOB6jAc8ZoGDXSjb0wD3y6sFZe4L?usp=drive_link

Students' final presentations are available in the following link:
https://drive.google.com/drive/folders/1-T5exfVAfpU_6yLbIzl9CMW4vU_jWXvu?usp=drive_link

4.3 Images/videos (with consent)

Photographic and video records were captured with the explicit consent of the participating students, and are available in the following link:
https://drive.google.com/drive/folders/1NohaqjKxydJhIMoy81TCclGIK3syXOX8?usp=drive_link

4.4 Any other relevant material

All the materials, including this report, are available in the following link:

https://drive.google.com/drive/folders/1bD7r6UC3KpaoxWbBCU5Kcbay9kic6y1-?usp=drive_link