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Additive Manufacturing for Sustainability

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1 Framework

The Constructive Alignment (CA) builds upon the constructivist understanding of the learning process and it is based on the principle of an aligned and outcome-based curricula design [1]. Implementing CA means devising Intended Learning Outcomes (ILO) that are based on an Educational Goal Verb (EGV), derived from the Bloom taxonomy, which refers to the action the students are expected to learn after completion of the educational unit. The ILO, and related EGV, are then enacted through Teaching and Learning Activities (TLA) and verified through Assessment Tasks (AT) [2]. The alignment between ILO, TLA and AT is achieved by using the same EGV [3].

Sustainable development (SD) and Industry 4.0 (I4.0) are considered two of the major trends in current production systems and their combination opens up promising scenarios in the manufacturing and beyond [4]. The shift toward SD in the engineering disciplines has never been so urgent and the upcoming smart manufacturing scenario triggered by I4.0 enablers (i.e., IoT, big data and analytics, additive manufacturing, simulation, etc.) call for intensive commitment in the engineering course rethinking [5].

This works stimulates on the need to include sustainability topics in the existing I4.0. related curricula via dedicated educational units and evaluate the impact of such thematic from the students and educators perspective.

2 Methodology

The selected course for pilot study is the biomedical technologies course at the University of Pisa. It focuses on conventional and unconventional manufacturing processes with particular attention to Additive Manufacturing (AM) technologies (i.e., fusion, binding, or solidifying liquid resin and powders) in the module of manufacturing technology laboratory. Following the framework of the Erasmus+ MAESTRO project [6], a new educational unit on sustainability has been included in order to meet the Sustainable Development Goals (SDGs) according to the selected I4.0 technology enabler (i.e., AM). This new perspective has been developed by following the CA framework for the definition of TLA and AT (Table 1) starting from the defined ILO: *The student should be able to design and*

optimize the environmental impact of AM processes for single medical devices production.

Table 1. Constructively aligned Teaching Activities (TA) and Learning Activities (LA) (i.e., TLA) for the SD educational unit included in the AM course.

	Description
TA	TA 1.1: Present and explain energy analysis for rapid prototyping approaches, design methodology, pros/cons, environmental impact frameworks and standards. TA 1.2: Provide updated case studies through seminars on medicine and AM prosthesis by a sustainable perspective. TA 1.3: Set brief and provide ongoing feedback on project work. Organise students into groups of three or four and provided with a real case study project. TA 1.4: Provide prompt feedback to each group during the project development.
LA	LA 2.1: Listen, query, discuss with peers and produce an infographic to explain, describe, and visualise the information at the end of each lecture. LA 2.2: Listen, query, discuss with peers and seminar guests experts as well. LA 1.3: Discuss within the group members and provide/share ideas by a 30 minute final presentation. Check understandings with one another. Take back to the group and improve the project in a second round based on peers and teacher review. LA 1.4: Provide 1 hour final presentation to the whole class.
AT	Each project group present a final written report of the project to the professor. The group is assessed on the main standard attributes of the project: Problem presentation, CAD design, AM software and implemented solution, practical prototype realization and sustainability assessment.

3 Results

A survey after delivering the course in 2022 to 20 students and 4 educators has clearly shown that AM does not only affects sustainability in manufacturing (9), but also health (3), because it allows the mass customization of human parts. The experts have identified a focused impact on a subset of SDGs (9 and 3) vs a broader sustainability potential according to the students.

4 Conclusion

This work aims to stimulate the integration of SD dedicated modules into engineering courses. A specific focus on the process followed to add a new educational unit on sustainability for the AM course at the University of Pisa is offered. The adopted methodology in accordance to CA theory is detailed. A final survey was submitted to 20 students and 4 educators to validate the implemented topics and the perceived integration between sustainability topics and I4.0.

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