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LIFE CYCLE ASSESSMENT OF A PRODUCT FROM 3D PRINTER AS A NEW TOOL FOR SCHOOL

Tetjana Tomášková[1], Daniel Duda[2], Jan Krotký[1], & Jarmila Honzíková[1]
[1]*Faculty of Education, University of West Bohemia (Czech Republic)*
[2]*Faculty of Mechanical Engineering, University of West Bohemia (Czech Republic)*

Abstract

The article is devoted to life cycle assessment, specifically determining the carbon footprint of a product produced with the help of a 3D printer. The aim of the article is to help the LCA (Life Cycle Assessment) method used not only to show students and pupils places with a negative impact on the environment but also how to identify them and possibly eliminate or limit them. At the beginning of the article, mind maps are described that relate to a specific product printed on a 3D printer, which has clearly defined goals: to describe the individual phases of the product's life cycle; orientate yourself in concepts related to product quality; define product life cycle costs; assess the impact of various factors on product quality; to evaluate the impact of production using a 3D printer on the environment. The next part of the article is devoted to the creation of a carbon footprint calculator. There are various calculators for calculating emissions, which, after filling in, will evaluate the result. However, it is often impossible to look at how the process was calculated to know how a particular value arrived at. Therefore, a simple calculator was created in Microsoft Excel, in which the method of calculation is clear, and the sources of the coefficients can be found. At the end of the article, recommendations will be made on how to apply the sustainable development of active learning methods to teaching.

Keywords: *Life Cycle Assessment, production process diagram, 3D printing, product quality, active learning methods.*

1. Introduction

Sustainable development and environmental management make it possible to satisfy the needs of the human population and, at the same time, do not threaten the standard of living of future generations while preserving the intact ecosystem of our planet. And it is here that sustainable development education and environmental education in schools play an irreplaceable role. The key question is how to approach the teaching of sustainable development in schools and how to familiarize pupils with the topic. In addition to basic information about the reasons for the emergence of the idea of sustainable development, its application in specific practical areas is also extremely important. The concept of education has a great advantage for sustainable development, namely the use of the current content of education and the connection with ordinary life. Another important condition of education for sustainable development is the maximum involvement of students. One part of the environmental management is LCA (Life Cycle Assessment). LCA is a system analysis focused on collecting and evaluating inputs, outputs, and possible impacts of a product (or service) on the environment during the entire life cycle. During the assessment, all impacts associated with the product are mapped, from the extraction of raw materials, production, and use to the end of the product's useful life and disposal.

3D printing is recognized as an efficient and sustainable technology in the field of advanced manufacturing. In the last few years, there has been considerable research, including technological innovation in industrial enterprises to support 3D printing for better manufacturing performance (Zhichao et al., 2016; Krotký et al., 2016; Böhm et al., 2023). 3D printing technology can be applied, for example, in civil construction, mechanical engineering, electrical engineering, medicine, education, art, and confectionery. This article will show the impact of 3D printing on the environment, which will allow students to understand the issues of 3D printing and, at the same time, provide researchers and educators with better guidance for future research.

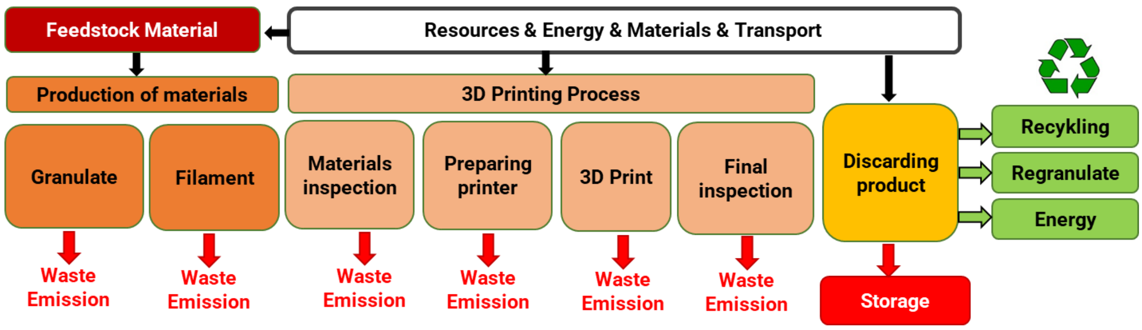
2. Education for sustainable development

Education for sustainable development must use all four perspectives on the content of education: economic, environmental, social and cultural. This concept offers methods to educate in a different way. The life cycle of a product is the time interval from the determination of the product concept to its disposal. Costs are also related to the product life cycle and sustainable development. Life cycle costs are total (cumulative) and can be divided into acquisition costs (for example, market research, project design and management, software development), ownership costs (for example, production planning, quality management, maintenance of production equipment, modernization, employee training), costs for disposal (for example collection and processing of non-functional products, legal fees (Bertini et al., 2022, Al Rashid et al., 2023).

2.1. Life cycle assessment of a product from a 3D printer

The 3D printing process begins with design and modelling, followed by material preparation, printing and quality control of the final manufactured product. Time can be saved because it is not manufactured according to standard processes, such as casting, forging, machining, pressing, extruding, etc. (Zhichao et al., 2016). But even for 3D printing, an environmental analysis is necessary. It is interesting to study that home 3D printing produces minimal waste, reducing its environmental impact. Home 3D printing reduces transportation needs, including packaging, which means less plastic (Drizo & Pegna, 2016). That's why we used a home 3D printer to calculate the Life cycle assessment of a product.

Figure 1. Scheme of the production process of 3D printing.



2.2. Creation of a carbon footprint calculator

Choosing the right emission factors is the key to correctly calculating the carbon footprint, but unfortunately, it is not always easy to calculate. Determining the boundaries of analysis is a key initial step for any carbon footprint analysis. It means determining which steps of the production process (Figure 1) are included in the calculation of greenhouse gas emissions and which are not. The following stages were chosen to determine the product's greenhouse gas emissions using 3D printing: material transportation, production of Polyethylene terephthalate (PET) material granules, energy consumed for printing, and material recycling PET.

Calculation of CO_2 emissions for 1 litre of diesel fuel: 1,92 kg of oxygen is needed to burn 1 litre of diesel fuel (0,84 kg); the resulting carbon dioxide is equal to the sum of 0,72 kg of carbon and 1,92 kg of oxygen, which is 2,64 kg of CO_2 from 1 litre of diesel fuel burned (Baťhová, 2021). The amount of carbon dioxide that a vehicle emits into the air is directly proportional to the amount of fuel it consumes and the carbon content of the given type of fuel. PET material is produced from oil and natural gas, which we import, for example, from Saudi Arabia (Hamieh et al., 2022). The road distance between the Czech Republic and Saudi Arabia was considered to be 5295 km. The total fuel consumption of diesel fuel is 371 litres.

Due to the lack of information and data on combustion, emissions from the petrochemical industry are generated from three main sources: fuel combustion, electricity consumption, and input raw materials. Consumption of basic raw materials to produce 1 kg of PET granulate: oil 0,64 kg (33,18 MJ) and natural gas 0,23 kg (12,63 MJ) and CO_2 in the production of 1 kg of PET granulate is 2,3 kg (Přibylová, 2000).

The university's laboratory carried out calculating CO2 emissions related to the printing process and energy consumption per 1 kg of product. Prusa MK2.5 3D printer was used to print the product. Consumption for preheating the pad and nozzle was 11 Wh (40 kJ). Energy 93 Wh (335 kJ) was used to print a product weighing 4,14 g. The energy to print 1 kg is 22,5 kWh (81 MJ). From the statistical data of the Ministry of Industry and Trade of the Czech Republic, the value of the CO_2 emission factor from public electricity production for the year 2022 was 0,413 t CO_2/MWh. When 1 MWh of electricity is produced in the Czech Republic, 413 kg of CO_2 is released (430 g of CO_2 is released when 1 kWh of electricity is produced).

When calculating CO_2 for PET recycling, it was assumed that the combustion would take place in a high-quality incinerator, where a highly controlled combustion process would burn PET and produce carbon dioxide and water. The amount of CO_2 is calculated from the PET chemical formula: HO- [-CH_2 -CH_2 -O-OC- C_6H_4 -CO- O-] n -OH. Burning 1 kg of PET produces 2,2 kg of CO_2. In the case of incomplete combustion, other substances can be formed, which can also cause an increase in CO_2 values.

3. Conclusion

Primary, secondary and grammar schools can use the concept of education for sustainable development. Thematically, they can stay with well-known areas, which they can supplement with economic, social, environmental, and cultural areas. Methodologically, it is important to connect school teaching with the real, practical world; for this, it is proposed to use the method of locally embedded and situational learning, which are characteristic of education for sustainable development. Education for sustainable development is often also implemented in projects where, for example, engaged learning and experiential pedagogy can be applied. Further research will focus on the comparison and repeatability of the 3D-printed product. Part of the research will focus on the design of the product and the properties of the selected materials. Analysis and evaluation of crossing, retraction, room temperature and airflow during printing will be needed. A more detailed analysis of the issue of CO_2 emissions and 3D printing and its relation to active learning methods will be carried out, including specific case studies.

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