Chapter # 23

ECODESIGN AS AN INNOVATIVE APPROACH TO TEACHING IN SECONDARY SCHOOLS

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ABSTRACT
The main objective of this chapter is to provide a new tool for teaching technical subjects in secondary schools. Specifically, it is ecodesign as a systematic process of designing and developing a product, which, in addition to features such as functionality, safety, technical feasibility, etc., places great emphasis on achieving a minimal negative impact of the product on the environment, mainly from the point of view of the life cycle. The introduction to the chapter describes the product manufacturing process as a system that is managed with respect to the environment. The next part of the chapter summarises the theory on the integration of environmental aspects into the product design process using the ecodesign methodology. In conclusion, the chapter compares metal and plastic 3D printed products and considers the usual requirements for product properties such as functionality, quality, safety, price and appearance. The connection of ecodesign and environmental management systems is an effective implementation of a preventive approach to the identification of risks of products, activities and services and the subsequent setting of preventive measures, which will clearly show the students the importance of Ecodesign as a tool.

Keywords: ecodesign, sustainable development, life cycle assessment, recycling, 3D print.

1. INTRODUCTION

Text Environmental education aims to lead to responsible behaviour towards the environment, living organisms, other people, and oneself. The key question is how to approach the teaching of sustainable development in schools and how to familiarise pupils with the topic. Here, we can encounter several problematic points. The first problem point may be the student's initial knowledge. It can be assumed that students have already heard about the theory of sustainable development and environmental management, but the constant question remains how extensive and deep the knowledge is. Another problem is the implementation of the theory of sustainable development and environmental management into study programs because sustainable development has an interdisciplinary character, and therefore, we must work simultaneously in areas such as economic, environmental, social, and cultural. Therefore, the main goal of the article is to provide a new way of teaching technical subjects in secondary schools. Specifically, ecodesign as a process of designing, optimizing, or developing products is being addressed, for example, by the Mexican Ministry of Education by introducing a new educational model/programme focused on developing students' competencies in this area. This led to the need to analyze and reevaluate the current content of teaching on environmental issues, and as a result, it turned out that ecodesign is a suitable method for developing the educational process in engineering and other technical fields, because it allows students to connect knowledge with the areas of ecology and technology (Bravo-Díaz & Gutiérrez-Yurrita, 2015).

Furthermore, in France, since 2011, they have focused on integrating ecodesign into technological education in secondary schools, which includes managing technological projects with a view to sustainable development, but although students acquire technical knowledge about ecodesign, they often lack a broader understanding of economic, social and ethical aspects, which leads to a superficial approach to sustainable development (Perpignan, Robin & Girard, 2017). The research (Perpignan, Robin, Baouch & Eynard, 2020) described by the authors focused on the French education system from secondary school to university to examine the integration of sustainability and ecodesign in different technological curricula and practices. The aim was to estimate the actual place of sustainable development and ecodesign in technological education courses. Although concepts, knowledge and skills related to ecodesign appeared in many different programs, the study highlighted that there was no continuity between primary school, secondary school and university. As a result, teachers had difficulty understanding the objectives and coherence of the program and students were not very comfortable with the issues of sustainability and ecodesign. The authors (Perpignan et al., 2020) suggested improving programs and practices by developing multidisciplinary curricula that cover most sustainable topics and integrate best practices from international universities.

In Ireland, the research team (McGarr & Lynch, 2021) set out to analyse the technology education curricula for lower secondary education to examine how they responded to sustainability issues. Sustainability and the environment were mentioned across the subjects examined, but they appeared to be very narrowly focused, focusing on material choice and energy consumption in the design process. A one-way relationship between technology and society was presented, which failed to recognise the societal influence on the development of technology. Furthermore, sustainability was not conceptually defined in any of the syllabi. In examining possible reasons for this token recognition within the curricular response, potential reasons were explored, including resistance to curriculum change, partial denial of the scale of the challenge, ignorance of current unsustainable practices within subjects and a lack of understanding of how to respond adequately to the challenge. Perspectives from a wider range of stakeholders are needed to overcome this narrow thinking. This should particularly include the perspectives of those who will be most affected by the environmental sustainability crisis we now face, namely young people.

Ecodesign can be integrated into educational programs and used in specific examples when teaching technical subjects in secondary schools. Students can compare two products, where one product will be manufactured according to ecodesign rules and the other product will be manufactured in a conventional way and then analyze their impact on the environment, including economic analyses. Ecodesign contributes to the development of students' skills in the field of sustainability, critical thinking, and technical creativity by teaching them to minimize the negative environmental impacts of products, analyze the life cycle of products, and look for innovative solutions. Teachers can integrate ecodesign into their curricula through project-based learning, case studies, and practical exercises, which provide students with practical skills relevant to the current job market. Ecodesign can be integrated into school curricula as part of technical and science subjects, helping students develop the skills needed to solve environmental problems and supporting interdisciplinary learning. Visits to industrial production plants are an important part of teaching in secondary vocational schools with a technical focus, because students can see production processes in practice. Also, the practice of secondary vocational school students in industrial plants allows students to gain practical experience and connect theoretical knowledge acquired at school. Getting acquainted with production processes and especially meeting with experts from practice is an invaluable opportunity for students, which will allow them to better prepare for a future career in technical fields, and that is why part of this article is dedicated to industrial plants and production processes.

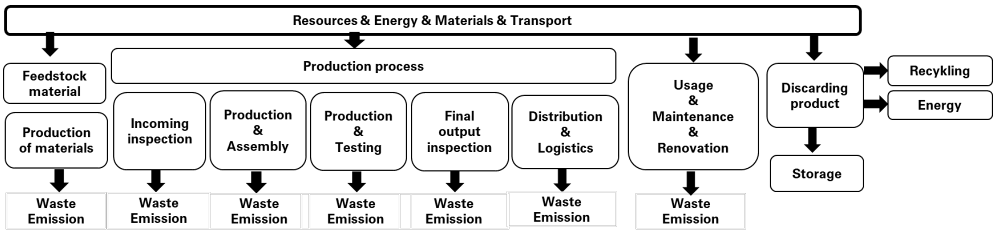
2. LIFE CYCLE ASSESSMENT OF A PRODUCT

In the following part, the teaching of the issue of sustainable development is demonstrated in the example of a comprehensive view of the general scheme of the production process, which is based on the concept of the product life cycle (Figure 1). This cycle does not start with production, but already at the stage of obtaining raw materials and materials. It continues with their transport, input control, processing in production, output control and subsequent packaging, selected transport and distribution of the final or semi-finished product. The life cycle continues with the preventive maintenance phase. In most cases, the life cycle ends with the disposal of the product at the end of its useful life.

For most products, environmental aspects and impacts occur at all life cycle stages. Inputs and outputs at each stage of the product's life cycle are key to assessing these environmental impacts (Figure 2).

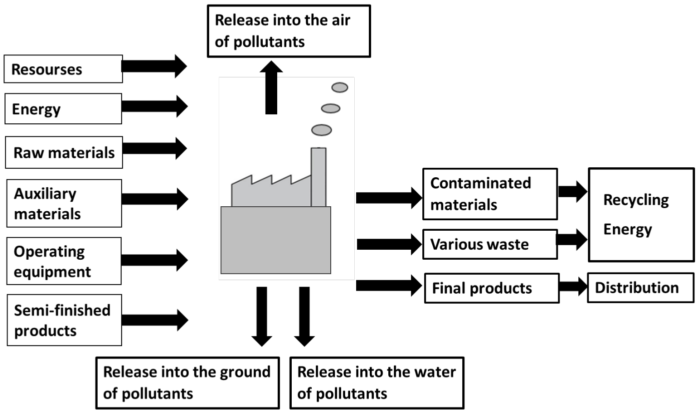
An educator who uses the goals of global education and a comprehensive view of the general scheme of the production process, based on the concept of the product life cycle (Figure 1 and Figure 2), and uses active learning methods (e.g. project and situational learning, experiential pedagogy, engaged learning), can put together a sustainable development lesson plan.

Figure 1.
General scheme of the production process, which is based on the concept of the life cycle of the product.



It is important that high school students understand the production process (Figure 1) and the general scheme of a manufacturing plant (Figure 2). It is important that the student is able to explain the production and life cycle of a product. Furthermore, he/she should be able to characterize the properties of the material suitable for production, and its subsequent disposal and the costs associated with it.

Figure 2.
General scheme of inputs and outputs of an industrial company.



Taking into account the entire life cycle of a product allows students to obtain the following interesting information: students will learn about the various raw materials and materials that are need for the production of a product, and understand their origin, availability and the environmental impact of their extraction and processing. The next part of the article focuses on the specific benefits of knowledge of the entire product life cycle for students and this knowledge will allow them to understand better the relationships between the production, use, and subsequent disposal of products, which is very important for sustainable development:

i. knowledge of all the key properties of the product, students will learn to recognize how these properties can affect its functionality, durability, and sustainability, including the composition of materials, energy consumption in production, and recycling options;
ii. knowledge of individual steps and processes of production allows students to gain a detailed overview of the separate stages of the production process, from the acquisition of raw materials to the production of the final product and its subsequent distribution, including an understanding of technological procedures, quality control rules, and logistical planning;
iii. auxiliary materials are important in achieving product quality within individual production processes and therefore it should be important for educators to convey this knowledge to students and emphasize the role they play in the entire life cycle of a product and how they can affect emissions, water consumption and/or waste production;
iv. understanding the product life cycle and its connection to the manufacturing process will help students gain knowledge about how the product is used in practice and how it interacts with other systems, and it is important to introduce students to maintenance management and the possibilities of reuse or recycling;

v. identifying possible adverse environmental impacts can teach students to evaluate the potential negative environmental impacts of a product during its life cycle, analyze the ecological footprint, and evaluate long-term environmental risks.

3. ECODESIGN – CONCEPT, GOAL, IMPLEMENTATION

Ecodesign can be defined as a comprehensive concept of designing and developing products with the aim of reducing the number of negative impacts on the environment during the entire life cycle. By considering the environmental aspects of the products in addition to their standard properties such as functionality, durability, aesthetics, quality, safety, economy and ergonomics from the initial design phase, this approach aims to minimise the negative effects of products on the environment in the future (Pigosso, Zanette, Filho, Ometto, & Rozenfeld, 2010; Bertini, Buehler, Halbheer, & Lehmann, 2022).

The goal of the ecodesign concept is to reduce the product's negative impact on the environment in terms of its entire life cycle. It is important for students to realise that the main purpose of ecodesign is to find successful innovative solutions while simultaneously reducing the negative environmental effects of products. In this context, however, it is important to draw students' attention to the fact that ecodesign is not only an approach emphasising environmental issues in product designs, but also strives to introduce a global concept of the environment, which should ensure a systematic and comprehensive assessment of environmental impacts.

Ecodesign is a concept based on the principle of prevention, as it defines, based on analysis, the possibility of reducing potential adverse effects of the product even before its production. This principle is very important in the field of environmental standards and law, as environmental damage is often irreparable (Damohorský et al., 2010; Bundgaard & Huulgaard, 2023).

The use of concrete examples by the teacher in teaching is essential to explain to students that the inclusion of hazardous and harmful substances in the production of a product can make subsequent recycling processes impossible. For example, a plastic bottle that contains toxic additives can contaminate the entire recycling process during recycling, which means that this recycled product is dangerous and unusable for the production of new products.

On the contrary, it is equally important to show students a positive example of the use of ecodesign, for example, if a product is produced without the use of hazardous and harmful substances, this can have immediate positive effects in two key stages of its life: the product can be used without posing health risks to consumers and the material can be safely recycled at the end of its life cycle, allowing it to be reused for the production of new products. An interesting and practical example is the design of electronics. Another example that will be close to students is the production of a smartphone made of high-quality and non-toxic materials, ensuring not only the safety of users during use, but also facilitating the problem-free recycling of its components (metals and plastics), which protects human health, supports sustainable development.

Critical thinking and creativity can also be influenced by the application of eco-design to educational programs at secondary technical schools, and all this can lead to a deeper understanding of the importance of environmental responsibility and sustainable development.

For a better presentation of the product life cycle to students, it is appropriate to divide the product life cycle into distinct stages (see Table 1). The first phase is the concept and requirements definition, which involves defining requirements based on market research, customer needs and regulatory standards (quality, reliability, durability, safety). The next is the design and development phase, which is the phase where the product is conceived and developed, which includes product design, selection of suitable materials, creation of initial production documentation, subsequent production of prototypes, conducting initial tests and marketing activities. The main phase of the product life cycle is production, which includes serial production according to pre-approved documentation, obtaining materials from suppliers, conducting incoming material inspections, various tests, setting rules for final output inspection, issuing certificates of conformity and delivering products to the customer. During the operation phase, which is mainly focused on maintenance and system setup activities, which ensure safe and trouble-free operation of machines and equipment. The last phase of the product life cycle is disposal, which includes sorting, disposal, disassembly, recycling of the product and possible use in new products.

The knowledge and skills of educators were defined for the individual stages of the product life cycle. For the students to be involved in the discussion, basic requirements for the student's knowledge were assigned for each stage of the product life cycle.

Table 1.
Educator's competency matrix for the presentation of the product life cycle to students.

Stage Nr.:	**Ecodesign process**	**Knowledge and skills of a teacher**	**Requirements for student knowledge**	**Newly acquired knowledge and experience**
1.	conception and determination of requirements: the definition of requirements for quality; reliability; service life; safety; price	orientation in the standards and requirements of customers from various industrial sectors; knowledge of quality management financial analysis;	knowledge of the division of industry and its history; awareness of the role of work in our lives;	connecting the necessary knowledge from the field of quality to specific industrial sectors; basic knowledge of reliability theory;
2.	design and development: product design; material selection; creation of production documentation; marketing;	knowledge of 3D modelling; knowledge of the basis of marketing and its role in product development; prototype production;	knowledge of the structure and physical properties of substances; basics of technical drawing;	connecting the knowledge of the material engineering with technical documentation; knowledge of the role of prototype production;

Stage Nr.:	Ecodesign process	Knowledge and skills of a teacher	Requirements for student knowledge	Newly acquired knowledge and experience
3	production phase: serial production; delivery of materials from suppliers; inspection and delivery of the final product to the customer;	knowledge of the importance of quality control of incoming material and final product in relation to the environment; overview of audit types;	knowledge of the classification of industries;	overview of the activities of production and non-production processes in a production company; knowledge of the setting production process;
4	operation and maintenance;	knowledge of the type of maintenance; basic maintenance rules; knowledge rationalization;	types of machines and equipment in households and industrial companies;	knowledge of role of diagnostics and preventive maintenance;
5	disposal of the products: decommissioning; disassembly; recycling;	differences in the recycling of plastics, metal and other materials; carbon footprint;	knowledge of basic waste sorting rules;	knowledge of sustainable development goals and ecodesign;

4. 3D PRINTING TECHNOLOGIES AND DEVELOPING CREATIVITY

This part of the article is devoted to the 3D printing process, which begins with the design and continues with modeling, which is the process of creating a digital version of the future print. Another important step is the control and preparation of the material (e.g. filaments, fibers, powders, liquids, composites) depending on the type of 3D printer, and then follows the gradual application of layers of material according to the previously created model, and the result is the final product. After the 3D printing itself, it is very often necessary to finish the product and the finishing operations include both the assembly of the print itself and surface treatments to improve the quality of the product, for example, removing support structures, smoothing the surface, improving aesthetic properties or other treatments, and finally, a final quality control is performed to ensure that the final product is manufactured according to the drawing documentation and model and also meets all required specifications.

Within mechanical engineering, 3D printing is widely used for the production of prototypes, which significantly increase flexibility in the testing phase of developing new designs. 3D printing can also be used for small-scale production.

Casting, forging, machining, pressing and extrusion are some of the traditional, classic manufacturing methods that also start with design and modeling, but the material is prepared in a different form of suitable semi-finished products. As for production, it is carried out using different methods: casting involves pouring molten material into a mold, forging uses compressive forces to shape the material, machining involves removing material using cutting tools, pressing shapes the material using presses and extrusion pushes the material through templates. Also, in the case of traditional production, subsequent heat treatment or surface treatment is performed and the final product is then subjected to final quality control.

If we compare these two manufacturing methods or technologies, several key differences can be revealed. Design flexibility, complex and detailed models that would be very difficult to achieve with classical methods are among the priorities of 3D printing. The advantages of traditional methods include that they can process a wider range of materials and are more proven in industrial, mass production (Krotký, Honzíková & Moc, 2016; Böhm et al., 2023). Traditional methods are also associated with various rights and obligations in relation to the environment, waste management and assessment of environmental aspects (Tomaskova & Bicova, 2021; Tomaskova & Bicova, 2022; Zhichao, Qiuhong, Zhang & Tao, 2016; Al Rashid, & Koç, 2023). Some differences in the processes of 3D printing and standard production are listed in Table 2.

Table 2.
Differences in the processes of 3D printing and standard production.

Topic	**Standard production**	**3D printing**
Production method	Subtractive; Formative;	Additive
Production process	a) Transformation; b) Control quality; c) Transport & Storage;	a) Transformation; b) Control quality;
Production cycle time	Longer	Shorter
Materials according to production technology	Metals: Plate, Block, etc.; Plastics: Granulate;	Metals: Powder; Plastics: Filament, Tapes, Liquid Photopolymer;
Efficiency	Lower	Higher
Waste	Larger	Smaller
Human Recourses	Higher the number of various specialists	Deep knowledge of specific specialists
Life cycle	Longer	Shorter
Finance & Cost	Lower	Higher

Safety is always paramount in the production of a product, whether it is traditional manufacturing or 3D printing, and this means ensuring that the materials used for production are non-toxic and suitable for a specific application. The product must always reliably and effectively fulfill its intended function, which means that it is another critical aspect and this includes careful consideration of the materials used and their properties, such as strength, flexibility and durability, etc. Setting up a quality control process for products manufactured using 3D printing is necessary to verify that the product meets the required specifications and standards.

3D printing has also found its application in education, where it serves teachers and students in various forms, for example, statements from 3D printers can be used in schools and in many cases, printing yourself is cheaper than buying products on the market. Another benefit of 3D printers is that it allows students to actively create their own models and observe the production. The use of the models themselves created during 3D printing lessons extends to almost all subjects taught in elementary school, for example, physical models, or other teaching aids and interactive educational games.

5. CONCLUSION

In environmental education, it is important to pay attention to the connection between seemingly disparate topics and to explain these connections even in distant areas. More and more secondary schools are currently following the trend of introducing 3D modeling into their teaching. This area is receiving increasing attention, partly because secondary schools are purchasing 3D printers for educational purposes. Since teaching 3D modeling and 3D printing seems to be a very current topic, this area should be given attention at the level of subject didactic theory in technical subjects. Integrating 3D modeling and 3D printing into secondary education not only improves technical skills but also provides a platform for interdisciplinary learning. Students can examine the environmental impact of their designs in terms of factors such as material selection, energy consumption and waste generation.

Implementing ecodesign into educational programs will help students better understand the importance of an ecological approach and sustainable development. In this way, students can not only gain theoretical knowledge, but also practical experience in the field of technical design and environmental responsibility.

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