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Bridging the green talent gap: a case study of product design education

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Abstract

This research examines how sustainable product design education can address the deficit in green talent. It presents a framework for a structured curriculum in product design, with hands-on activities, industry-specific case studies, and best practices in alternative design development. The impact of technologies like additive manufacturing on design is considered. Findings demonstrate that knowledge of technological capabilities, industry specific understanding, and proficiency in analytical tools such as Life Cycle Assessments contribute to sustainable designs mitigating a green talent gap.

Keywords: *sustainability education, sustainable design, life cycle assessment (LCA), green talent gap, product development*

1. Introduction

The UN's Sustainable Development Goals (SDGs) and the increasing Environmental, Social, and Governance (ESG) regulations are growing the demand for green talent. According to the OECD and the World Economic Forum report, a gap in green talent exists (OECD, 2023). This gap opens an opportunity to invest in sustainable product design education (Strietska-Ilina et al., 2012). Design education must prepare students for diverse roles beyond traditional product design. These may include product management, cost estimation, regulatory work, and requirement engineering in production or logistics - all of which play a crucial role in shaping the sustainability impact of a company and their products. In its role, design education prepares students for a variety of design related roles and empowers students to thoughtfully evaluate the entire product life cycle (Thorpe, 2010; Walker, 2011). The LinkedIn Green Jobs report highlights that between 2015 and 2021, green jobs grew by 8% annually, while the talent pool only expanded by 6% (LinkedIn, 2022). Specialized knowledge in applying, adapting, and maintaining clean technologies is not only a moral obligation but a strategic business necessity (Boone et al., 2023). Moreover, global production and consumption patterns are causing irreversible environmental harm and exacerbating social inequalities. It is important to note that around 80% of a product's environmental impact is determined during its design stage (MacArthur, 2022). A paradigm shift in product design and development that prioritizes sustainability is essential (Watkins et al., 2021). Higher education plays a significant role in advancing this transformative agenda. Educational institutions are a driver of innovation and a hub for professional development at the forefront of sustainability education and the evaluation of pathways to enhance the teaching of sustainable design principles in education. This paradigm shift involves a critical review of both the content and the pedagogical approach to teaching (Gallindo et al., 2023; Watkins et al., 2021). This research promotes a transformative educational approach in higher education. It presents an interdisciplinary course that integrates sustainability in every stage of product design and development. Rather than touching on sustainability topics within an educational program, the course integrates sustainability principles at the heart of education for designers, engineers, and other relevant disciplines. The objective of the presented course curriculum is to empower students to conceptualize, design, and develop new products or optimize existing products, aiming to create economic value without neglecting the environmental and social implications before the design process has been started. This objective aligns with McLennan's (2004) works, emphasizing creating designs that eliminate harmful environmental impacts. Integrating the social aspect of sustainability in product design education is critical in promoting sustainability. Margolin and Hernández-Leo et al. (2018) argued that a deep understanding of the social context should be integrated into design education, and Fry (2010) highlights the importance of design in supporting sustainability and social well-being. Furthermore, Tjahja & Yee (2022) emphasize the role of design in fostering innovation to tackle societal challenges. This research presents a high-level framework that integrates teaching of emerging technology in eco-design to enhance the sustainability of products. The framework draws from a higher-education course on sustainable product design and development. The course teaches the underlying principles of sustainable design and how they are applied across different industries, from the beginning and designing new products to integrating full circularity in material flows. The aim of this paper is to contribute to the academic discourse on sustainable product design education by offering insights from a sustainability perspective on the current practice of teaching product design. Educators can use the findings to strengthen the sustainability aspects of their curricula.

2. Theoretical framework

2.1. Sustainable product design

It's essential to prioritize sustainable product development in the early stages of a product's lifecycle to ensure that sustainable production processes and usage are established from the outset. Sustainable product design (SPD) considers environmental impact, social responsibility, and economic viability throughout the product's lifecycle, from sourcing materials to manufacturing, distribution, use, and disposal (Ahmad et al., 2018). To achieve this, performing a Life Cycle Assessment (LCA) is critical, as it can guide designers and manufacturers towards more sustainable practices. In addition, incorporating circular economy principles into product design can increase sustainability. Circular economy involves designing for repurposing, remanufacturing, disassembly, and reuse, allowing for an extended product lifecycle, reduced waste, and efficient resource utilization (Faludi et al., 2023; Leonardi et al., 2022). An essential framework in SPD is "The Hannover Principles: Design for Sustainability," which was created by William McDonough. These principles highlight the use of low-impact materials, energy efficiency, and emotionally durable design (McDonough et al., 2003). They underscore the significance of selecting non-toxic, sustainably produced, or recycled materials and reducing energy consumption in manufacturing processes. Emotionally durable design, a concept pioneered by Jonathan Chapman, focuses on creating products that foster long-lasting emotional connections with users. This approach promotes sustainability by increasing the durability of relationships between people and products, reducing resource consumption and waste (Chapman, 2008). SPD represents a critical approach in today's design landscape, aiming to balance aesthetic appeal with environmental responsibility, product functionality, price competitiveness, and social value (Walker, 2011). By incorporating sustainable aesthetics such as natural materials and durability, products can maintain their appeal and functionality over time, aligning with sustainability goals (Zafarmand et al., 2003). However, effective SPD requires navigating the challenge of integrating sustainability concepts early in the design process while balancing functionality and aesthetics. Additionally, it is essential to communicate the value of sustainability throughout the product's value chain and implement sustainable practices across industries (Watkins et al., 2021). Design education must prepare students for diverse roles beyond traditional product design. These may include product management, cost estimation, regulatory work, and requirement setting in production or logistics - all of which play a crucial role in shaping a product's sustainability and societal impact. According to Thorpe (2010), design education must not only prepare students for various roles but also equip them with the necessary skills to navigate

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policy-making and regulatory processes. Walker (2011) further supports this notion, asserting that design education must empower students to thoughtfully evaluate the complete life cycle of products and consider their lasting effects on both society and the environment. To address these challenges, SPD emphasizes life cycle thinking, circular economy principles, and collaborative efforts among stakeholders. Innovative and adaptive design solutions are continuously sought to meet environmental objectives and consumer needs. Studies highlight the importance of integrating a sustainability perspective from the early SPD stages, ensuring that products balance immediate use and a sustainable future (Saidani et al., 2023; Zafarmand et al., 2003).

2.2. Additive Manufacturing in eco-design

A transformative technology in the realm of sustainable product design, Additive Manufacturing (AM) or 3D printing, has revolutionized traditional manufacturing methods. AM possesses the distinct capability to create complex, customized, and lightweight designs, positioning it as a pivotal technology for the principles of sustainable design, ushering in a new era of creativity and efficiency in product development (Diegel et al., 2010). Topology optimization facilitated by AM is a significant advantage that allows the creation of functionally superior parts while being materially efficient (Tüzün et al., 2023). This approach emphasizes the reduction of material waste, a crucial aspect of sustainable design. It is in stark contrast to traditional subtractive manufacturing methods that are known for their significant material wastage. AM can enhance material efficiency and reduce environmental impact through its precise and optimized material addition. In contrast, its contribution to energy efficiency and optimized resource utilization in manufacturing plays a critical role in long term sustainability. Its inherent efficiency in material usage results in lower resource consumption, aligning with the global drive towards more sustainable manufacturing practices (Ford & Despeisse, 2016). Additionally, AM's flexibility in utilizing eco-friendly materials further contributes to sustainable practices by supporting the redesign of products for improved sustainability (Priyadarshini et al., 2022). Integrating AM with circular economy concepts, particularly the "reduce, reuse, recycle" framework, highlights its significance in sustainable design. AM minimizes environmental footprints through efficient production and enhances product lifecycle management. Its potential in distributed manufacturing models also supports local production, reducing transportation emissions and fostering local economies, which is integral to the circular economy (Chen, 2022). The development of simulation technologies has significantly complemented AM in sustainable product design. These technologies enable the prediction of potential printing issues, reducing waste and inefficiency in the production process. This predictive approach is essential for enhancing the overall sustainability of the product development process (Ford & Despeisse, 2016). AM processes can be made even more sustainable by incorporating LCA and circular economy indicators, as suggested by Saidani et al. (2023). AM is not only capable of achieving the aesthetic aspects of sustainable product design by integrating natural forms and simplicity, but it is also essential for creating sustainable, functional, and visually appealing products, as emphasized by Zafarmand et al. (2003). Research has shown that AM contributes to sustainable product design in various ways, such as creating lightweight and structurally efficient designs. Furthermore, AM supports the use of eco-friendly materials and the redesign of products for improved sustainability. The relationship between sustainable product design and AM is characterized by AM's potential to enable more sustainable and environmentally friendly product development processes (Priyadarshini et al., 2022).

2.3. Product design education

The field of sustainable product design education is constantly evolving, focusing on key areas such as energy efficiency, circularity, product service systems, and materials. The aim of this evolution is to equip future generations of product designers with the knowledge, skills, and responsibility required to become both effective designers and sustainability innovators. To achieve this, transformative learning and interdisciplinary dialogue are crucial elements that must be fostered in product and business development. Thus, eco-design doctoral education emphasises these elements (Bergeå et al., 2006; Watkins et al., 2021). Undergraduate education is also experiencing a transformation, with a growing focus on integrating sustainability into regular courses to help students better understand the complexity of sustainability. In most manufacturing industries, AM is emerging as a key technology and driver of

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sustainable product design. According to Joshi & Sheikh (2015), it can potentially reduce manufacturing time, cost, and material wastage in aerospace product design, but challenges in material quality and structural performance must still be addressed. The utilization of LCA is increasingly gaining recognition in sustainable design education. LCA offer a promising potential to enhance eco-efficiency and stimulate sustainable innovation, as emphasized by Suppipat et al. (2021). LCA enable the evaluation and comparison of the overall environmental impact of products. Integrating LCA in higher education can be seen as a shift towards practical and functional applications in sustainability education. However, adding a sustainability perspective in design education presents its own set of challenges. Hallstedt et al. (2015) and Morris et al. (2007) address the complexities of this process and emphasize the importance of credible business cases, as well as a broad, integrative, reflective, and cross-disciplinary approach. Current best practices in sustainable product design education call for more comprehensive integration of technical concepts, social justice considerations, and a focus on project-based learning and transdisciplinary approaches. These practices strive to enhance sustainability literacy and apply sustainability knowledge in design practice while cultivating a mindset of sustainability innovation in students (Bergeå et al., 2006; Watkins et al., 2021). Moving forward, sustainability education within the design industry will adopt a holistic approach that encompasses both teaching and critical analysis alongside aesthetic considerations throughout the design process. To ensure sustainability is effectively integrated into design education, it is advisable to amalgamate postgraduate research with undergraduate learning. This integration can be accomplished by outlining explicit sustainability objectives in course tasks and matching these with commercial aims. (Doğan et al., 2016). The redefinition of creativity in engineering education is currently underway, with a renewed emphasis on incorporating diverse pedagogical practices from design courses to enhance sustainability teaching. This redefinition involves adopting a holistic approach to integrate sustainability principles into design education. Additionally, capacity building and related competencies are considered vital for the successful integration of Eco-design and sustainability (Hallstedt et al., 2015). Finally, sustainable product design education is a crucial area that covers a range of essential topics, including consumer behaviour and demand. It brings with it a host of benefits, such as cost savings, improved health and well-being, social responsibility, and emotional connection. Moreover, considering aspects like repair and maintenance can be a valuable pedagogical tool that not only enhances the value, character, and aesthetics of products but also encourages circular design thinking (Terzioğlu & Wever, 2021). This approach reflects a growing recognition of the need to integrate technical education with wider ecological and social considerations, equipping future designers with the skills and knowledge they need to play a pivotal role in building a sustainable future. These benefits and innovative approaches demonstrate the confidence and conviction of sustainable product design education in driving positive change towards a brighter and more sustainable future (Faludi et al., 2023; Suppipat et al., 2021).

3. Product Design and Development course

3.1. Course structure: supporting reflection

The course is structured around the book Product Design and Development by Eppinger & Ulrich (2016). Following the initial lecture introducing the purpose and goal of the course, students were divided into reading groups based on the chapters. In these groups, they presented each chapter along with their practical experience understanding and engaged students with questions to make the environment collaborative. After the introduction and establishing a foundational understanding, students selected a real-life product for the core assignment (assignments 1-4). In addition to the assignments, industrial case studies were incorporated to increase the understanding of industry-specific product design and development processes.

3.2. Sustainability in focus: intended learnings

The objective of the course is the continuous and critical reflection on the entire product design and development process. It follows the outline of the book (Ulrich & Eppinger 2016), and each stage is examined for its significance and interconnected value, with a heightened focus on sustainability and

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environmental responsibility. The course underscores continuous, critical reflection on the entire product design and development process. Students are encouraged to adopt a sustainability perspective and to contemplate the ecological impact of products they use daily. Starting with the foundational activity of product teardown in Core Assignment 1 and successively leading to an eco-friendly redesign in Core Assignment 4, the emphasis is always on thoughtful and sustainable design practices. The seven quiz assignments serve as milestones, ensuring students not only grasp the technical concept of product design and development but also internalize their significant responsibility in shaping a sustainable future. The assignments are designed to connect with the design process, reinforcing its relevance to sustainability in all stages of design.

3.3. Learning milestones: assignments and reflection

Table 1. Assignments overview

Assignment 1: Product Teardown (core)		
Aim	Learning Tools	Learning outcome
Understand product parts, components, structures, and functions.	Hierarchical disassembly, photo documentation, and a functional structure.	Comprehensive documentation and understanding of how parts and components in a product function.
Assignment 2: Needs and Requirements (core)		
Aim	Learning Tools	Learning outcome
Analyse existing solutions, understand user needs and prioritizing requirements.	Interviews, competitor analysis integration, QFD matrix completion.	QFD matrix with prioritized requirements, understanding of identifying user needs and requirements.
Assignment 3: Sustainability Assessment (core)		
Aim	Learning Tools	Learning outcome
Assess products sustainability aspects to develop alternatives.	QFD integration, LCA, and following Design for Environment (DFE) guidelines.	LCA Report, result presentation, reflections on three new product concepts with LCA.
Assignment 4: Redesign (core)		
Aim	Learning Tools	Learning outcome
Performing a systematic redesign considering DFE principles.	Steps 4-7 in Ch.12 of the course book, three new concepts analysis, LCA, and redesign.	Understanding and the ability to communicate the redesign process, a presentation on three new product concepts.
Assignment 5: Group Reading and Summary Lecture		
Aim	Learning Tools	Learning outcome
Comprehend and communicate key points of the book, fostering a deeper understanding of design process.	Structured lecture preparation and teacher-led discussion.	A lecture that is prepared by the students, understanding how to relate the course materials to sustainability effectively.
Assignment 6: Personal Reflection Video		
Aim	Learning Tools	Learning outcome
Encourage personal insights and reflection on the overall course comprehension.	Video recording	Submitted video file with reflections on product development, and course concepts about sustainability and SPD.
Assignment 7: Short Quizzes		
Aim	Learning Tools	Learning outcome
Continuous engagement and reflection on teaching materials.	1-4 questions per quiz, 7 quizzes total during the course.	(Self-)Assessment of the understanding and the application of key concepts from the course.

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4. Promoting sustainability across industries through product design education

Promoting sustainability across industries through product design education can play a pivotal role in addressing unsustainable production and consumption patterns. By equipping designers, engineers, and business professionals with the necessary knowledge and skills, it is possible to foster a culture of sustainable innovation and responsible decision-making. This approach ensures that future products meet societal needs while minimizing environmental impact (Skerlos, 2015). The sectors, including energy, agriculture, transportation, manufacturing, etc., are among the sectors that require special attention for sustainability efforts (Hu et al., 2021). Studies highlighted the importance of tailored sector-specific strategies for these sectors to encourage integrated decision-making for effective sustainability initiatives. The product design education course formed a solid foundational understanding for attendees to understand the importance of various sustainability factors across different sectors. By integrating multiple concepts like life cycle assessment, circular economy principles, and interdisciplinary collaboration, attendees learned how to analyze and address sustainability challenges specific to each industry.

4.1. Applying sustainable: space industry case study

The purpose of this case study is to showcase how AM can be used in the space industry for sustainable product development. The term "space industry" is used to describe all the different businesses and originations that are part of what we can call the space economy. These are all the goods and services that are related to space travel, such as getting humans into space (rockets), space exploration (rovers), space technology (satellites), and associated services (Revfine, 2020). Products in the space industry, like rockets, satellites, and space stations, can be defined by their high performance and reliability requirements and their costly product development spanning several years. Consequently, one of the significant drivers for product development for space industry competition is cost. Space industry competition has increased in recent decades due to new private actors emerging, reducing the cost of access to space, some achieving this through leveraging the capabilities of AM. The term "New Space" has been coined to describe these companies that are achieving these reduced costs by creating more robustly designed products, using efficient manufacturing processes, and designing products with a focus on ease of assembly and lighter weights. These new players have drastically changed the existing market through new organization methods permitting faster development of their products compared to established players, helping the New Space actors be competitive from a cost perspective. For both New Space and established space companies, literature has shown opportunities for cost reduction benefits through the levering of AM in space product development (ISSRDC, 2015; Jones, 2018; Tyrell, 2019). Additional benefits for space products have been found through utilizing AM to produce a more sustainability-focused product (Orbex, 2022; Rocket Lab, 2020; Vialva, 2018). To stand out and provide added social value to their products, some of these new space actors are challenging the established space companies by emphasizing an overall more sustainable space product. Scottish commercial rocket manufacturer (Orbex) claims to have manufactured "the world's largest 3D printed rocket", which will be the main engine of their Prime launch vehicle. Their advertised reasoning for using AM is to develop one of the most environmentally friendly space launch vehicles (Orbex, 2022). The engine has been designed to use Bio-propane Fuel and is designed for reusability, a design that they advertise would not be possible without the use of AM. Emphasizing to customers that their more sustainable product development activities can additionally achieve competitive cost reductions. The benefits of AM for a focus on sustainability in product development include the ability to manufacture parts locally and the elimination of the need for inventory (Schwaar, 2021). Reducing the environmental impacts associated with logistics and transport whilst reducing the need to produce stock that may not get used. When stock refers to space rocket parts, it can be incredibly costly or just not feasible. AM can also enable the manufacturing of near-net-shape weight-saving part designs, impacting both cost reduction and environmental sustainability of products in two ways. Firstly, theoretically reducing material usage to only exactly what is needed and secondly, reducing mission fuel requirements due to the creation of a low-weight functionally optimized part, improving the part's environmental impact over its life cycle.

Yusuf et al. (2019) comment on how the sustainability aspects of using metal AM in the aerospace industry are scarcely discussed. Läkka et al. (2018) researched the use of AM to develop and produce habitats on the Moon and Mars, choosing AM from a sustainability view for its possibility to use local resources rather than transporting from Earth, a tenuous link to sustainable product development for space products. Similarly, Sgambati et al. (2018) also researched the use of AM for the development of Lunar base structures. Likening the on-Earth benefits of using AM, they discussed that using AM to manufacture these Lunar structures would increase the product's sustainability due to the ability to recycle unused material and waste material, break down and recycle parts and additionally enable long-term upcycling on the Moon. Mejias-Morillo et al. (2021) present the use of AM for long-term mission sustainability, highlighting how the use of AM provides easier material reusability during long-duration missions. Emphasizing the advantages of on-demand manufacturing of products when needed, reducing the need for carrying spare parts and hence using more fuel due to the excess weight to bring the parts on missions.

4.2. Sustainable product design and development in the space industry

The use of topology optimization (TO) for Design for AM enables the creation of an aerospace component that has greater sustainability but does not compromise on the mechanical properties and performance of a part (Min et al., 2019). A TO part could be, for example, designed to be self-supporting to reduce the support requirements and reduce material waste and incurred costs. The design for AM understanding is of use when devising efficient heat transfer pathways that reduce the build-up of residual stresses in the part. From a Sustainability viewpoint, an interesting note discussed by Yusuf et al. (2019) is that although AM can theoretically provide a higher material utilization and low material wastage, the energy consumption during an AM printing process is currently higher per unit component produced when compared to traditional manufacturing methods. However, AM has the advantage of developing products that can be designed to focus on lightweight parts to reduce fuel consumption, additionally enabling components to be redesigned and consolidated to improve the performance efficiency of aerospace products. Yusuf et al. (2019) state that limited literature is available regarding the long-term economic sustainability of AM aerospace products however through utilizing life cycle cost assessments to study the complete life cycle of AM products with regards to its energy and material consumption, AM processes have been shown to present significant cost savings. From an energy consumption viewpoint, literature suggests that most energy savings with regards to AM use for aerospace components are in the application of the product through the light weighting translating to less fuel consumption. For both aircraft and space craft, this can be a considerable saving in costs and CO2 emissions. Further discussion on social sustainability aspects of AM space product development is needed to consider the health safety and environmental aspects of incorporating AM into a product development process. Issues around procurement of materials and their impact on the local community should be considered (Villamil et al., 2018) Additionally, the inhalation of fine metal nanoparticles by those operating AM machinery could lead to serious health complications, while the high energy input requirement per metal AM part could mean that using AM is not necessarily the more environmentally friendly choice compared to other traditional manufacturing methods, although should be compensated for through its in-use energy reductions (Yusuf et al., 2019).

5. Concluding discussion

5.1. A course framework for sustainable product design and development

The enhancement of sustainable practices in product design and development are crucial endeavours, urging educators to shape courses that foster environmental consciousness and sustainable innovation. The course presented in this paper has been designed for final-year master's students, offering a structured approach based on Eppinger and Ulrich's foundational work in Product Design and Development. The course structure follows the logical progression used in the book, starting with an introductory part, followed by students' application of sustainability analysis on real-life products and developing redesign concepts and alternatives. The idea of the course lies in its practicality, with students engaging in the disassembly, analysis, and enhancement suggestions for products they are familiar with. The selection of commonplace products such as irons, TV remotes, or TVs grounds the learning experience in the tangible, ensuring a connection between theoretical concepts and real-world applications can be made. The hands-on approach is instrumental to developing a comprehensive understanding of the product lifecycle, its potential environmental impact, and how to optimize for sustainability. In addition, LCA was included as the fundamental tool for evaluating a product's sustainability. By integrating LCA into the curriculum, students have been equipped with a quantitative methodology to identify optimization opportunities and minimize environmental footprint. The used approach can provide the foundation to engage a broader discussion on the potential transformation of the course into a model for a sustainability-centred education across disciplines. The envisioned course would aim to offer a panoramic view of sustainable practices, incorporating additional learning topics such as design artefacts, material and supplier selection, and a comprehensive assessment of a product's environmental footprint (Faludi et al., 2023; Flud et al., 2023). The presented case study on sustainable design for AM in the space industry highlights the critical interplay between education, technology, and sustainability. The study emphasizes the implication of an educational approach that not only explores the capabilities of AM but also recognizes its limitations from a sustainability perspective. The findings underscore the importance of understanding the entire lifecycle of AM products, from design to production, and how sustainability is impacted by the design. The interdisciplinary nature of sustainable education has been revealed. The study indicates that the shorter distance between product design and development and production in AM, often the same person, can make it easier to include sustainability considerations in the process. The case study also prompted questions on general sustainability aspects, including recycling and reuse of materials in AM. Incorporating case studies from various industries into our curriculum highlights the necessity for sustainability solutions that are specifically tailored. This research presented a case study on the space industry, acknowledging the unique and significant differences regarding sustainability and the implications for sustainable product design. Cost considerations are a critical factor in product development within the space industry, where understanding the design possibilities offered by AM can be crucial for new and more sustainable practices. We utilized the space industry and additive manufacturing to illustrate that different applications and manufacturing processes demand designers to adopt a life cycle perspective to ensure sustainability is implemented systematically. The short distance between production and design with AM implies a close collaboration among actors related to sustainability, and with this, educational curricula should be more flexible to address production technology and industry-specific sustainability challenges. Underscoring the importance of cultivating an overall understanding of sustainability so that professionals have the knowledge, tools, and methods to navigate the complexities of sustainable product design and development.

5.2. Conclusion and future research

In conclusion, the presented framework of a product design course with a sustainability perspective integrated in all stages can support a transition towards sustainability. It can be used to develop the needed skills and to mitigate the effects of a growing demand for sustainability expertise. The course presented in this paper has an emphasis on sustainable design education that can serve as a robust framework for further investigation. The presented case study pointed out the need to address and include future applications of sustainability in the curricula of design education. Fast-evolving and technology intensive industries like the space industry face individual challenges, and how the presented framework can address these challenges should be investigated further. Future studies can build upon the findings, expanding and refining the presented framework to meet the evolving industrial and societal needs related to product design education. Which can include adjustments of curricula, development of learning outcomes, and examination methods. Furthermore, it should be explored how the presented educational approach can be used to counter the dynamic nature of sustainability, visible in the growing demand for Green Talent. With this, we underscore the importance of ongoing research to ensure educational programs remain effective and are in line with environmental challenges.

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