Design Science

A survey to investigate approaches, methods, contents and objectives in education for sustainable design

Yuri Borgianni [1], Aurora Berni [1], Idil Gaziulusoy [2], Fabrizio Ceschin [3], Nazli Terzioglu [4], Alessio Franconi [4], Laura Ruiz-Pastor [5] and Niccoló Becattini [6]

[1]*Faculty of Engineering, Free University of Bozen-Bolzano, Bolzano, Italy*
[2]*NODUS Sustainable Design Research Group, School of Arts, Design and Architecture, Department of Design, Aalto University, Espoo, Finland*
[3]*College of Engineering, Design and Physical Sciences, Brunel Design School, Design for Sustainability Research Group, Brunel University of London, London, UK*
[4]*School of Design, Royal College of Art, London, UK*
[5]*Department of Industrial Systems Engineering and Design, Jaume I University, Castellón de la Plana, Spain*
[6]*Department of Mechanical Engineering, Politecnico di Milano, Milan, Italy*

Abstract

Limited research has explored the delivery of sustainable design in higher education globally. Therefore, the aim of this paper is to investigate educational practices on the topic. Through an online survey, we investigated numerous aspects of units of study exposing topics related to sustainable design with a focus on contents, teaching methods and educational objectives. The survey was accessed by almost 400 educators in the field of sustainable design. The data show that a variety of teaching methods are used, with a critical role played by project-based learning in addition to traditional lectures. Most respondents rated all investigated intended learning outcomes as relevant or very relevant. In terms of contents and methods treated by the respondents, product eco-design and design for X are the most frequently taught methods. Educational approaches and teaching objectives are poorly affected by the discipline of the degree in which units of study are taught. In terms of contents, design degrees include approaches to sustainable design at the spatio-social level more frequently than engineering degrees do.

Keywords: sustainable design, higher education, survey, project-based learning, intended learning outcomes

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Corresponding author
Yuri Borgianni
yuri.borgianni@unibz.it

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1. Introduction

Sustainable design education (SDE) is increasingly recognised as a critical component of higher education (HE), aligned with global efforts to address the UN Sustainable Development Goals (SDGs). These goals stress the need for transformative education that integrates environmental, social and economic dimensions of sustainability. Over the past two decades, sustainability in design and engineering education has moved from peripheral concern to a core educational objective,

particularly in Europe, where educators have shifted from fragmented add-on initiatives to more integrated and transformative approaches (Gardelle 2025).

The traditional view that design is centred on aesthetics, functionality and profitability, with sustainability being an afterthought or a peripheral consideration is changing (Davis & Dubberly 2023). Design practitioners and educators are gradually coming to realise that sustainability has shifted from being an optional feature of design to becoming a fundamental aspect of it (Humphries-Smith 2008; Deniz 2016). Design plays a critical role in addressing the pressing environmental and social challenges of our time and design educators play a pivotal role in shaping the mindset of future designers (Ramirez 2007; Watkins *et al.* 2021). They are instrumental in instilling a deep understanding of sustainability principles, practices and ethics (Findeli 2001; Vezzoli & Ceschin 2011).

Yet, while the importance of SDE is widely acknowledged, less is known about how it is currently being implemented across institutions and disciplines. This paper investigates the current state of SDE aiming to discuss and assess the extent to which educational institutions are preparing future designers to address the pressing global challenges related to sustainability. The target group of this paper is educators and academic programme designers involved in SDE at HE institutions, particularly those engaged in curriculum development, pedagogical innovation and teaching practice. This paper aims to identify current practices and existing gaps in SDE in order to offer insights to support curriculum development, enhance educational policies and strengthen the impact of SDE across diverse contexts. This enables institutions to tailor their programmes to better equip students with the knowledge and skills needed to create innovative, environmentally responsible and socially inclusive designs.

Design programmes are increasingly incorporating sustainability into their curricula and several studies exist on SDE. However, these publications usually focus on individual institutions or specific courses (e.g. Vezzoli 2003; Lilley & Lofthouse 2010; Oehlberg, Shelby & Agogino 2010; Voûte *et al.* 2020; Terzioğlu & Wever 2021). This paper adopts a broader perspective, analysing diverse methods, conceptualisations, approaches and expectations of academics on sustainable design across various institutions and countries. The remainder of this paper is structured as follows. Section 2 reviews existing literature on SDE, highlighting its diverse facets. Section 3 outlines the methodology, encompassing the specifics of data collection. Section 4 presents an overview of the findings, while Section 5 discusses their implications for SDE. The paper concludes in Section 6 with a summary of findings, limitations and suggestions for future research.

2. Background

The incorporation of sustainability into HE, particularly within design courses, is a subject that is gaining increasing attention (Kuzmina & Lofthouse 2023). This section examines the impact of teaching methods, contextual factors and core content on students' learning experiences in sustainable design.

Considering the rapid pace of global change, it is imperative for teaching methodologies to adapt and innovate to effectively address societal and environmental challenges (Wilde 2020). Wilde (2020) highlights the significance of understanding the context, selecting appropriate methods, collaborating with relevant experts and focusing on the design outcome, which she refers to as the

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"Four Pillars of Practice." This framework is consistent with the findings of Disterheft *et al.* (2015), which highlight the effectiveness of participatory approaches and stakeholder involvement in sustainability initiatives at higher education institutions. The efficiency of these initiatives is determined by both organisational variables and individual participation. This highlights the significance of adaptable teaching techniques, as proposed by Türkeli & Schophuizen (2019), who advocate for the incorporation of adjustable learning niches within larger technical and organisational frameworks. It has been argued that traditional educational methods do not adequately improve students' knowledge acquisition. Indeed, there is an increasing recognition in the field of design education, along with the broader changes in theory and pedagogy of HE Berglund 2024), that shifting from a teacher-centred to a learner-centred approach is a necessary step in effectively incorporating sustainability principles (Brosens *et al.* 2023). This shift is aligned with broader international trends that show increasing interest in sustainability-related research and curricular development in higher education institutions (Leal Filho *et al.* 2023; Berglund 2024; Bakar *et al.* 2025).

Project-based learning, as discussed by Kuzmina & Lofthouse (2023), is one effective method that not only enhances sustainability literacy but also fosters personal transformation in students. This aligns with broader institutional efforts described in recent research, which identifies stakeholder engagement, digital innovation and performance metrics as essential components of sustainable university strategies (Veres *et al.* 2025). This is particularly relevant for enhancing student involvement in addressing real-world sustainability challenges (Brundiers & Wiek 2013). Ashour (2020) further argues for the integration of inter- and multidisciplinary learning approaches, emphasising the need for responsible designers who consider the economic, social and environmental dimensions of their work.

Contextual factors also play a significant role in shaping students' learning experiences. For instance, Persson *et al.* (2023) argue that educators possess a comprehensive understanding of sustainable development; nevertheless, they lack a diverse range of educational approaches to effectively integrate this concept into their teaching practices. This limitation becomes prominent when considering that students are more inclined to engage with sustainability topics if they are introduced to them at an early stage, preferably in introductory courses (Ruff & Olson 2009). It is widely assumed that digital technologies can contribute to shaping education to broaden the range of used educational approaches. For instance, Türkeli & Schophuizen (2019) highlight how digital technologies can offer flexibility and real-time collaboration, thereby improving the quality and accessibility of SDE. Digital technology has the potential to enhance the inclusivity, interactivity, knowledge exchange, self-learning capabilities of training materials and more (Haleem *et al.* 2022).

The core content being taught is equally crucial. Humphries-Smith (2008) argues for a shift from techno-centric and eco-centric dimensions to include the socio-centric dimension in SDE. This is supported by Lozano *et al.* (2017), who propose a framework linking pedagogical approaches to sustainability competences, aiming for a more holistic and systemic sustainability education. Meyer & Norman (2020) suggest that design curricula should offer options that allow students to specialise in addressing different levels of challenges, from performance to global issues.

In the realm of sustainable development, Cottafava *et al.* (2019) and Fia *et al.* (2022) discuss the integration of SDGs into HE. While the former advocate for

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transformative learning experiences focused on SDGs, the latter note the lack of a common framework for implementing these strategies. Amorós Molina *et al.* (2023) suggest that, to advance the integration of the SDGs, lessons learned from universities worldwide should be shared broadly, equitable partnerships formed and students engaged. However, the implications and the extent of the diffusion of SDGs in education have not been studied according to our best knowledge. This gap mirrors a broader lack of empirical studies on how sustainable design methods are perceived and implemented in SDE (Faludi *et al.* 2020a; Alahira *et al.* 2024).

Contextually, much research is still needed to prioritise improving SDE to address different facets of design for sustainability (DfS), from products to systems in line with the evolution envisioned by Ceschin & Gaziulusoy (2019). Only a subset of current practices in sustainable design within HE has been thoroughly examined by researchers (Faludi *et al.* 2023). In their recent study, Watkins *et al.* (2021) offer an overview of contemporary practices in HE related to sustainable product design, drawing from the experiences of six academics across multiple countries. Their findings highlight the importance of integrating sustainability-related knowledge and skills into the core curriculum of product design programmes and the need for institutional support to enhance the quality of sustainable product design education. Similarly, Faludi & Gilbert (2019) conducted a study to explore effective approaches for teaching environmental responsibility with the aim to enhance environmental responsibility in design, engineering and business education. Although the study included interviewees from various geographic locations, its scope was limited to interviews with 19 faculty members. This highlights that future research is needed that explores a wider range of HE educators worldwide to understand the current state of SDE.

The current literature offers valuable examples of teaching experiences on sustainable design in HE, but there is a lack of understanding regarding the global scope of these educational initiatives. Studies are often limited to specific geographical areas or concentrate on particular pedagogical approaches, teaching methods, or curricular content. The diversity of disciplines of HE courses possibly affecting the delivery of SDE are generally overlooked. These shortcomings emerging from the literature, along with the need to better investigate teaching methods, taught contents (notions, approaches, methods and tools) and teaching objectives in SDE, led us to tackle the following research questions (RQs).

- RQ1 – What are the methods/pedagogical approaches used to teach sustainable design?
  - RQ1a: Are teaching methods affected by discipline?
- RQ2 – What are the fundamental notions (sustainability-related concepts, impacts, assessment techniques) illustrated to teach sustainable design?
  - RQ2a: Are these notions affected by discipline?
- RQ3 – What are the fundamental sustainable design approaches (including complementary approaches) illustrated to teach sustainable design?
  - RQ3a: Are these approaches affected by discipline?
- RQ4 – What are the expectations in terms of skills and Intended Learning Outcomes (ILOs) associated with teaching sustainable design?
  - RQ4a: Are these expectations affected by discipline?

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Answering these RQs is instrumental in the final goal, claimed in the introduction, to support curriculum development and improve educational policies in SDE.

3. Methodology

3.1. Choice of the survey as the most suitable research method and development procedure

Given the breadth of the RQs and the need for extensive participant input, an online survey was chosen as the preferred research tool, following established methodologies in educational research (Cohen, Manion & Morrison 2013). Surveys are a benchmark for capturing educator and student perspectives (Van den Beemt *et al.* 2020; Udeozor *et al.* 2023). An overview of the pertinent literature revealed that conventional protocols and structures for surveys are not discernible. This implies that survey formats and contents should be tailored to the specific situation at hand, together with the relevant information to collect.

Hence, the distinctive emphasis of this study on the content delivered and the methods used in SDE necessitated a bespoke survey design that could accommodate a wide range of variables, as will be expounded upon below. The starting point for the development of this survey was the survey presented in (Borgianni *et al.* 2022), which was considered as having the widest scope among the ones available. More in detail, the survey used by Borgianni *et al.* (2022) included parts of the survey focused on taught contents and the extraction of insights into the characteristics of the courses, e.g., HE level and number of involved students. Conversely, most surveys aim to investigate, predominantly or solely, the experience with new trends in education, such as the impact of digital media and artificial intelligence (e.g., Sarsar *et al.* 2021; Bernard *et al.* 2022; Gonzalez *et al.* 2022).

Although we used a specific survey as a model, the survey was completely redesigned to acquire the data needed to understand the current state of SDE. It is worth noting that the sections and questions of the survey (see the next subsection) were designed not only to gather sufficient data to tackle the RQs but also to acquire additional, potentially relevant information to infer the main points about the current delivery of SDE.

A first draft of the survey was developed by some of the authors, who chose contents, structure and specific ways to answer questions. Hence, we carried out a first round of evaluation and refinement internally to check the overall rationale of the survey, without missing relevant information. In this phase, one of the major challenges lied in the definition of objects to be included and evaluated (e.g., learning objectives, relevant topics within sustainable design, fundamental concepts required for effective learning) in specific questions. As far as possible, we used specialised literature to identify objects to be treated (Quelhas *et al.* 2019) to infer the relevant skills to be developed within sustainable design. However, for example, we are unaware of and were unable to identify acknowledged and comprehensive collections of sub-fields of sustainable design that can be possibly taught and researched on. This takes place despite the existence of review and position papers in the field (e.g., Rossi, Germani & Zamagni 2016; Kim *et al.* 2020; Faludi *et al.* 2020b); none of these

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contributions provide clear lists of sustainable design-related topics that could be directly included in the survey.

This led to the need to conduct some pilot studies with renowned scholars and educators in sustainable design, deemed here as experts, who were asked to test an initially developed survey and provide us with expert feedback. The conduction of pilot tests is considered as a best practice in the development of bespoke surveys and questionnaires (Jain, Dubey & Jain 2016). The involved pilot testers were made aware of the aims of the survey. They were asked to validate the survey and its contents and check the lists of objects used. In the text of the invitation email they received, they were specifically invited to give their opinion on the clarity of questions, the logic of the survey, the commitment needed to complete the survey, the alignment of the questions with the declared objectives of the research study. Fifteen pilot testers, among the invited experts, accessed this first release of the survey in Spring 2023. The feedback led us to fix some bugs, eliminate some questions that were deemed poorly relevant, add some clarifications about some used terms, among others. This allowed us to make sure that, after changes made based on the received feedback, the questions could be considered clear, relevant and understandable unambiguously by participants, in line with the requirements established in (Jain *et al.* 2016). As a result of the pilot testing, we were confident that used lists of objects were suitable and sufficiently broad for the scopes of the survey.

3.2. Target and relevant aspects of the survey

The survey targeted HE staff (e.g., professors, lecturers, teaching assistants) involved in SDE, whether as an independent subject or part of a broader programme.

The landing page of the survey clarifies that sustainable design can be broadly understood as:

- DfS, eco-design, design for the environment;
- Design for repair, recyclability, re-use, remanufacturing, circularity;
- Sustainability- and circular economy-related aspects in product and product-service system design;
- Design for sustainable behaviour and design for social innovation for sustainability;
- Transition design, DfS transitions/transformations;
- Consideration of sustainability-related, environmental and social issues in the conceptualisation and definition of systems.

This list of domains, though possibly overlapping and not comprehensive, was used to allow respondents to determine their actual suitability for participation in the survey.

To address teaching and learning activities in HE programmes and to assure the validity of the survey in a variety of different contexts, it is required to harmonise understanding among participants and avoid language/cultural biases. The term "unit of study," used in the remainder, covers any independent course or module offered to HE students, whatever its denomination is, e.g., course, module, class. Formally, the unit of study is defined as a self-contained "smallest stand-alone component of a student's award course that is recordable on a student's transcript."

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Similarly, the term (academic) degree identifies the course of studies the reference unit of study is taught in. Contextually, the degree is the programme allowing students to achieve "an award conferred (…) signifying that the recipient has satisfactorily completed a course of study."

3.3. Structure of the survey

The final version of the survey is presented below. The following list reports the sections of the survey together with their contents and label, where appropriate.

3.3.1. Scope of the survey and data privacy policy

This is to present the survey with the data policy and to check if the participant fits the expected profile of the respondent, as well as for confirming their participation [1 Yes/No question (Q1)].

3.3.2. Definitions, familiarity and experience

This section requires the participant to define sustainable design and to profile themselves as an HE educator in general and in the field specifically (in terms of years of teaching experience) [1 Multiple choice question (Q3) and 3 open-ended questions (Q2, Q4–5)].

3.3.3. Characteristics of the unit of study

The section gathers the basic information about the most relevant unit of study the participant teaches and that includes sustainable design topics. This description includes

- Country of the HE institution [1 open question (Q6)],
- Educational level [1 multiple choice question (Q7)],
- Discipline of the programme [1 multiple choice question (Q8)],
- Sustainability/sustainable design topics integration in curricula/institution [4 Likert- scale questions (Q9a-d)],
- Mandatory/elective [1 multiple choice question (Q10)],
- Teaching team composition [1 multiple choice question (Q11)],
- Cohort [1 open question (Q12) and 1 multiple choice question (Q13)],
- Additional classes [1 Yes/No question (Q14) and one open question (Q15)].

3.3.4. Contents and focus

This section includes questions on the specific aspects of the unit of study concerning the topics as well as the teaching mechanisms put in place in the unit of the study to foster learning, such as:

- Weight of sustainable design topics [1 multiple choice question (Q16)],
- Teaching methods and pedagogical approaches [4 Multiple choice questions (Q17-Q20)],
- Current and future weight of concepts related to
  - sustainability [4 Multiple choice questions (Q21a-d)],
  - sustainability-related impacts [5 Multiple choice questions (Q22a-e)],
  - sustainability assessment methods [7 Multiple choice questions (Q23a-g)],

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- sustainable design approaches [15 Multiple choice questions (Q24a-o) and 1 optional open question (Q25)],
- complementary approaches [8 Multiple choice questions (Q26a-h) and 1 optional open question (Q27)],

- Assessment method(s) [1 Multiple choice question (Q28)],
- Relevance of skills and competences to acquire [5 Likert-scale questions (Q29)]; the skills and competences chosen for the survey have been adapted from the findings reported by Quelhas *et al.* (2019) in relation to the introduction of sustainability in technical disciplines;
- Relevance of ILOs [5 Likert-scale questions (Q30)]

3.3.5. Trends and perspectives

This section is meant to gather the participant's future-oriented visions on teaching sustainability and sustainable design [10 Likert-scale questions (Q31–32) and 2 multiple choice questions (Q33–34)].

3.3.6. Academic research

This section is meant to check if the participant is also doing research in general and in the field of sustainable design specifically, together with the extent the latter has on the former [2 Yes/No (Q35; Q37), 2 Multiple choice (Q36; Q38) and 3 Likert-scale questions (Q39a-c)]. A comprehensive list of topics relevant to sustainable design is also presented to enable the participant to define through Likert-scales their relevance in their research (Q40).

The complete information about these sections as well as the formulation of questions can be accessed through the copy of the survey linked https://eu.surveymonkey.com/r/Y86RS8Y. Data will not be added to those obtained and analysed by using this link, which is intended for reviewing the survey and providing details to readers.

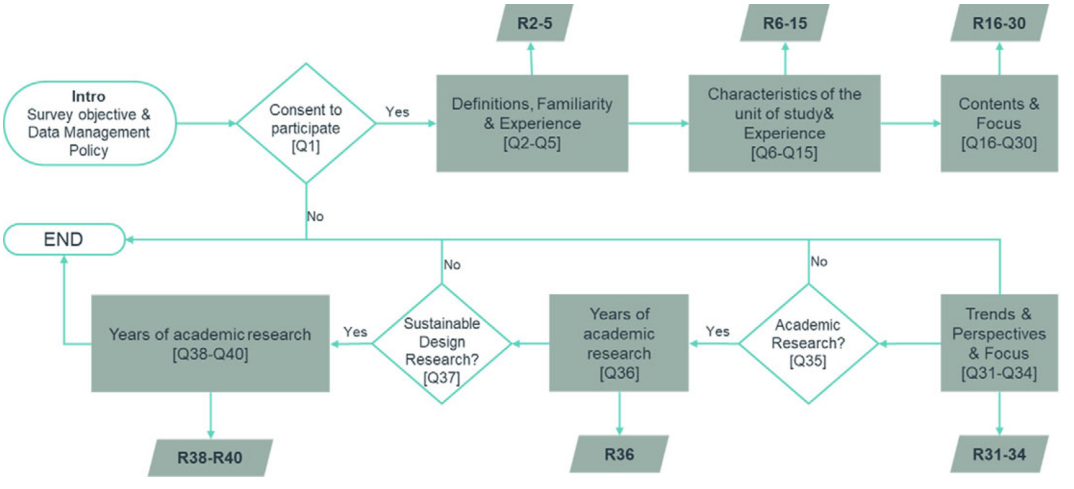

Figure 1. Overall structure of the survey: sections and branching mechanisms.

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Each question is associated with a specific code, with these codes being linked to the respective section they belong to, as per the text in brackets above. Throughout the remainder of the paper, these codes are employed to identify the answers used as sources of information to support each statement. To accommodate various respondent situations and categories, the survey employs a branching mechanism and any questions designed to redirect respondents are represented as diamond-shaped symbols in the diagram included in Figure 1.

3.4. Administration of the survey

We faced the challenge of identifying relevant respondents, consistently with the target identified in Section 3.2, and determining their numbers because an established population of sustainable design educators does not exist. To clarify, "sustainable design educators" refer to instructors and course leaders responsible for relevant courses or incorporating sustainable design elements into their classes. The population encompasses all instructors covering sustainable design in HE courses.

Since targeting this comprehensive population using existing listings or databases was unfeasible, we employed a broad distribution strategy within the academic community. This strategy included distributing the survey through personal contacts, utilising word-of-mouth mechanisms, making it available on association websites and social networks and advertising it at workshops and conferences. Consequently, a sample of convenience was formed, including potential participants who had available email addresses and met one or more of the criteria specified below.

- Appearing as lecturer or responsible within courses addressing the intersection of sustainability and design, specifically in areas involving DfS and related subjects.
- Having authored recent Scopus-indexed publications related to sustainability and design, including topics within the realm of sustainable design, and concurrently holding affiliations with HE institutions.

No geographic restriction was put in place. Potential participants who received the invitation via email were also encouraged to forward the survey to colleagues similarly involved in SDE. Both social media posts and emails contained basic highlights about the survey to trigger interest and foster access to the initial section of the survey. This includes the essential information required for obtaining informed consent, such as the study's objectives, the estimated survey completion time and the purely academic research nature of the survey with no anticipated benefits or compensation for participants. The process of obtaining informed consent was integrated into the survey's landing page. Additionally, the survey, although anonymous, underwent scrutiny for data protection and was authorised by the institution the corresponding author is affiliated with. As this institution is in the European Union and was established as responsible for data handling, the General Data Protection Regulation was closely complied with.

People asked to answer the survey received an email invitation twice in Summer 2023.

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4. Results

4.1. Description of the sample

A total of 396 participants accessed the online system to fill in the survey. Among them, just a few decided to drop as they did not give the consent to participate, reducing the respondents to 386 subjects. A first screening of the collected records made it possible to avoid the exclusion of surveys with clear out-of-scope and/or inconsistent answers as all the respondents provided relevant answers. Particular attention has been given to potential sources of biases (e.g., answers repeated mechanically or unnaturally dispersed answers in Likert-scale questions), which did not appear nevertheless in the collected answers.

Figure 2 reports the overall number of respondents completing the different sections of the survey. It is evident that not all the participants managed to complete the survey. This happened partially due to incomplete responses and partly because some questions were not presented to some respondents due to the branching mechanism.

Table 1 presents the results of the question regarding respondents' familiarity with the field of sustainable design (Q3). A total of 246 responses were collected. The respondents were asked to indicate their level of familiarity, ranging from "Not familiar at all" to "Very familiar." Most respondents (57.83%) reported being "Very familiar" with sustainable design, indicating a high level of knowledge or experience in this area. Following this, 25.70% of respondents stated they were "Somewhat familiar," suggesting a moderate level of understanding. Overall, the results indicate an overall (perceived) considerable level of familiarity with sustainable design among the respondents. In any case, those respondents answering "Not familiar at all" and "Poorly familiar" have not been considered further (most of them did not keep answering, by the way).

Questions 4 and 5 received 246 responses to compare the years of overall teaching experience (Q4) and specific experience in teaching sustainable design

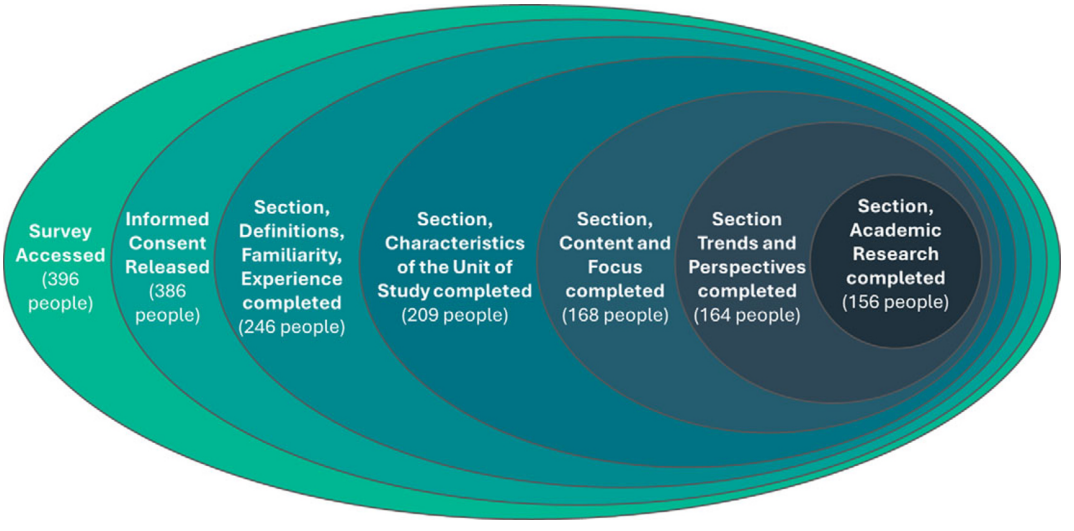

Figure 2. Number and distribution of participants that concluded the different sections of the survey.

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Table 1. Respondents' familiarity with sustainable design

Answers	Number of respondents	%
Not familiar at all	7	2.81
Poorly familiar	7	2.81
Average	26	10.44
Somewhat familiar	64	25.70
Very familiar	142	57.83

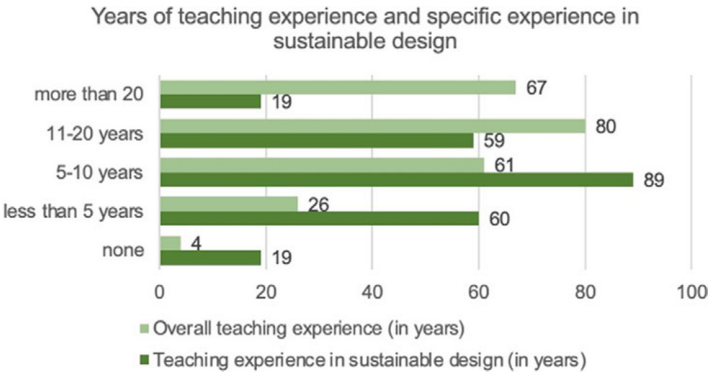

Figure 3. Teaching experience.

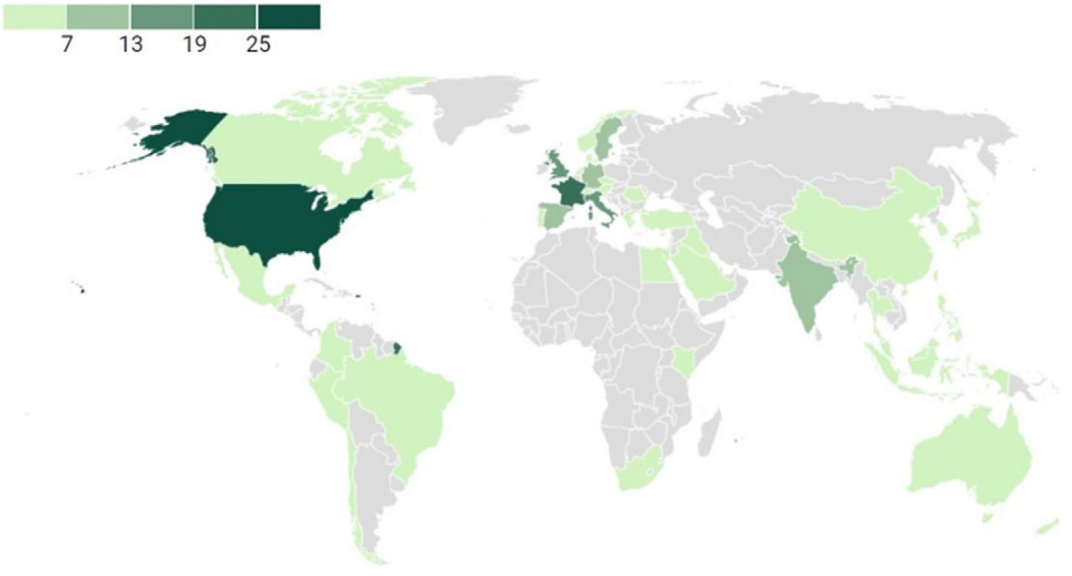

Figure 4. Number of responses per country.

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(Q5). The results (Figure 3) reveal a significant overlap between overall teaching experience and experience in sustainable design teaching. This figure might indicate that, in education, sustainable design has become a relevant discipline in only the last 20 years.

The 201 responses obtained in Q6 show the countries where the unit of study in sustainable design is taught (Figure 4). The US has the highest number of responses (31), followed by France (19), UK (17) and Italy (16). Other countries from which a considerable number of answers came include Sweden (11), Spain (9), Germany (9) and India (8). Based on the subdivision between Global North and South used by UN Trade and Development, 48 out of 201 answers come from the latter. The distribution of responses by country and geographic area highlights the global reach of the survey. The concentration of responses in certain countries may reflect factors such as the prevalence of SDE programmes, the size of academic communities, the familiarity with English among educators and the difficulty in reaching out people from specific geographic areas.

The results (Q7) reveal that most respondents teach sustainable design in a bachelor's degree. Postgraduate levels, such as taught master's and research master's, also show substantial representation. A smaller number of respondents teach in higher degrees, such as PhDs, which may partly be attributed to the lack of taught courses at the PhD level in many countries.

Based on answers to Q8, most units of study are held in degrees in Design or Engineering. Due to the data obtained regarding the disciplines, only engineering and design fields have been considered to answer the RQs involving disciplines. To address all the RQs investigating the effect of the discipline on various phenomena, the variable Engineering was created. The values assigned to this dichotomous variable were 1 if the answer to Q8 was Engineering, 0 if it was Design. This allowed us to compare teaching aspects between courses offered in engineering and design domain. For the scope of the same RQs involving disciplines, data with different answers to Q8 were removed from the analysis. Despite the prevalence of engineering and design, other disciplines like architecture and business, management and economics also show notable representation.

The leadership of the unit of study is evenly distributed among respondents, with approximately equal numbers indicating sole, collaborative or no leadership role (Q11). According to Q12, cohort sizes vary widely, with the most common range being 11–30 students, followed by 31–50 students. Smaller cohorts (1–10 students) are also present, though less frequently. Many respondents reported that the cohort size remained stable (Q13). Some respondents indicated a lack of information or recent activation of the unit of study, preventing them from answering. The answers obtained are detailed in Table 2.

4.2. Methods and pedagogical approaches used to teach sustainable design (RQ1 and RQ1a)

To answer RQ1, the data obtained from Q17 and Q18, which could be answered by ticking multiple options, were analysed (Figure 5). The following information about teaching methods and pedagogical approaches has been obtained:

- Teaching methods: Lectures are the most adopted method, with 137 respondents using it. Practical hands-on learning is popular, with 109 employing it,

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Table 2. Educational level, discipline and number of students

Education level	Otder (from tde options below)	17
	Honours programme	2
	Vocational course	1
	Apprenticeships	0
	Summer school	2
	Life-long learning programmes or continuous professional development	4
	PhD	7
	Research master or postgraduate	31
	Taught master	37
	Bachelor or undergraduate	106
Reference discipline of the programme	Computer Science	1
	Physics, Mathematics, Chemistry, Earth Sciences	2
	Art	3
	Environmental Sciences, Biology, Agriculture	6
	Business, Management, Economics	10
	Other or inter−/multi-disciplinary programme	17
	Architecture	23
	Engineering	67
	Design	78
Mandatory/elective	Mandatory/core for some of the attending students	25
	Mandatory/core for all the attending students	103
	Optional/free choice for all the attending students	79
Teaching team composition	The respondent leads the unit of study and delivers it alone	66
	The respondent leads the unit of study and delivers it with other teaching contributors	66
	The respondent shares the leading of the unit of study with other colleagues	40
	The respondent does not lead the unit of study	35
Cohort size	More than 100 students	32
	71–100 students	15
	51–70 students	23
	31–50 students	43
	11–30 students	75
	1–10 students	19
Cohort size change	Information unavailable to the respondent	28
	The unit of study has been activated recently and consequently the respondent cannot answer	8
	Substantially increased	40
	Remained stable	120
	Substantially decreased	11

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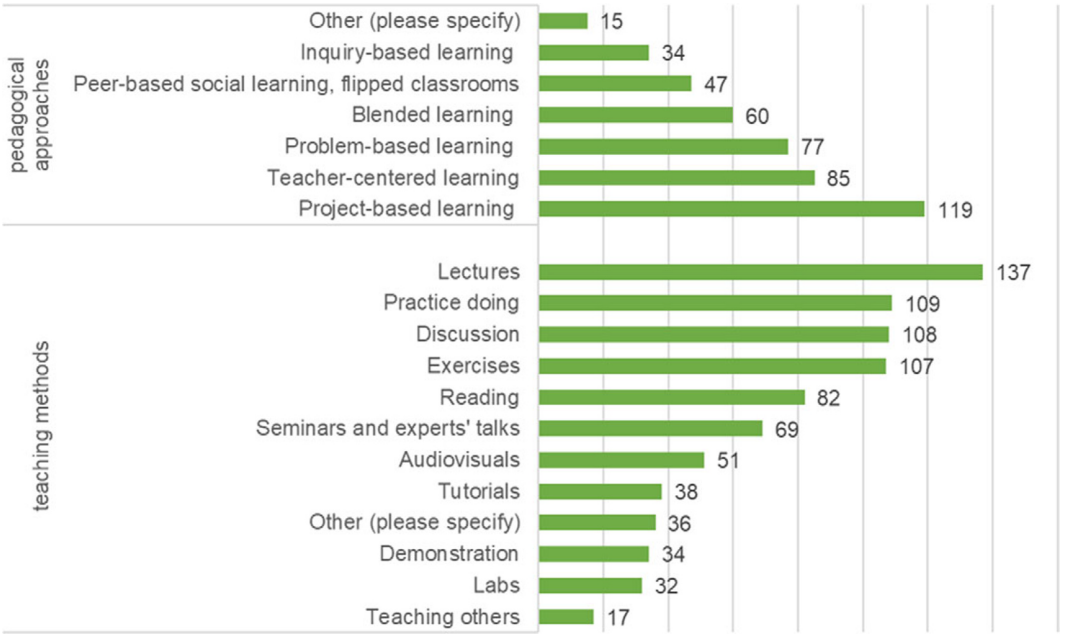

Figure 5. Methods and pedagogical approaches.

immediately followed by discussions (108) and exercises (107). Self-directed learning through reading materials is also common (82). Seminars and expert talks are popular (69) as well as the use of audiovisuals (51) and tutorials (38).

- Pedagogical approaches: among the pedagogical approaches indicated in the survey, the most employed one is project-based learning with 119 responses. This approach is followed by teacher-centred learning (85), problem-based learning (77) and blended learning (60), while peer-based approaches (47) and inquiry-based learning (34) are the least common.

To study the relationship between the categorical variables (discipline: design or engineering) and teaching methods (RQ1a), a chi square test was performed by using the variable Engineering, as well as data from Q17 (teaching methods used) and Q18 (pedagogical approaches used). The statistical test, as well as all the statistical analyses reported onwards, was performed with the software IBM SPSS Statistics (Version 29.0.1.0). Here and in the following, significance in statistical tests is intended as achieving a p-value lower than 0.05, as a rule of thumb.

Based on the outcomes of the test, none of the teaching methods showed any significant relationship with the discipline. Conversely, two of the pedagogical approaches resulted significantly affected by the discipline: problem- ($p = 0.035$) and inquiry-based learning ($p < 0.001$), which are significantly more used in design courses.

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Table 3. Inclusion, relevance and expected growth of the fundamental concepts, sustainability-related impacts and sustainability assessment methods in courses including sustainable design

		It is not included despite being relevant; it will not be introduced anyway	It is not included despite being relevant; it will be offered in the future	It is not included and it is not considered relevant	It is included but not considered relevant; its delivery will decrease or be stopped	It is included and considered relevant; its delivery will not change	It is included and considered relevant; its delivery will increase	I am not knowledgeable here and I cannot assess their relevance	TOT.
Sustainable concepts	Sustainability (in general)	5	6	0	6	69	78	2	166
	Sustainable development	8	10	5	13	54	72	2	164
	Circular economy	7	19	4	12	42	78	4	166
	UN sustainable development goals	8	14	14	17	58	50	5	166
Sustainability-related impacts	Environmental impacts	3	8	0	2	79	73	0	165
	Social impacts	6	24	2	10	42	79	3	166
	Economic impacts	9	16	1	18	56	64	2	166
	Cultural impacts	11	29	5	8	35	69	9	166
	Policy impacts	14	33	3	14	30	60	11	165
Sustainability assessment methods	Streamlined life cycle assessment	18	19	4	13	55	47	8	164
	Full life cycle assessment	22	20	6	9	51	50	6	164
	Life cycle cost analysis	30	27	13	15	32	35	12	164

Continued

Table 3. Continued

	It is not included despite being relevant; it will not be introduced anyway	It is not included despite being relevant; it will be offered in the future	It is not included and it is not considered relevant	It is included but not considered relevant; its delivery will decrease or be stopped	It is included and considered relevant; its delivery will not change	It is included and considered relevant; its delivery will increase	I am not knowledgeable here and I cannot assess their relevance	TOT.
Social life cycle assessment	27	43	8	10	19	39	16	162
Material flow analysis	27	24	7	9	36	52	10	165
Circularity assessment	18	36	9	6	22	59	16	166
System dynamics	30	24	11	4	31	48	17	165

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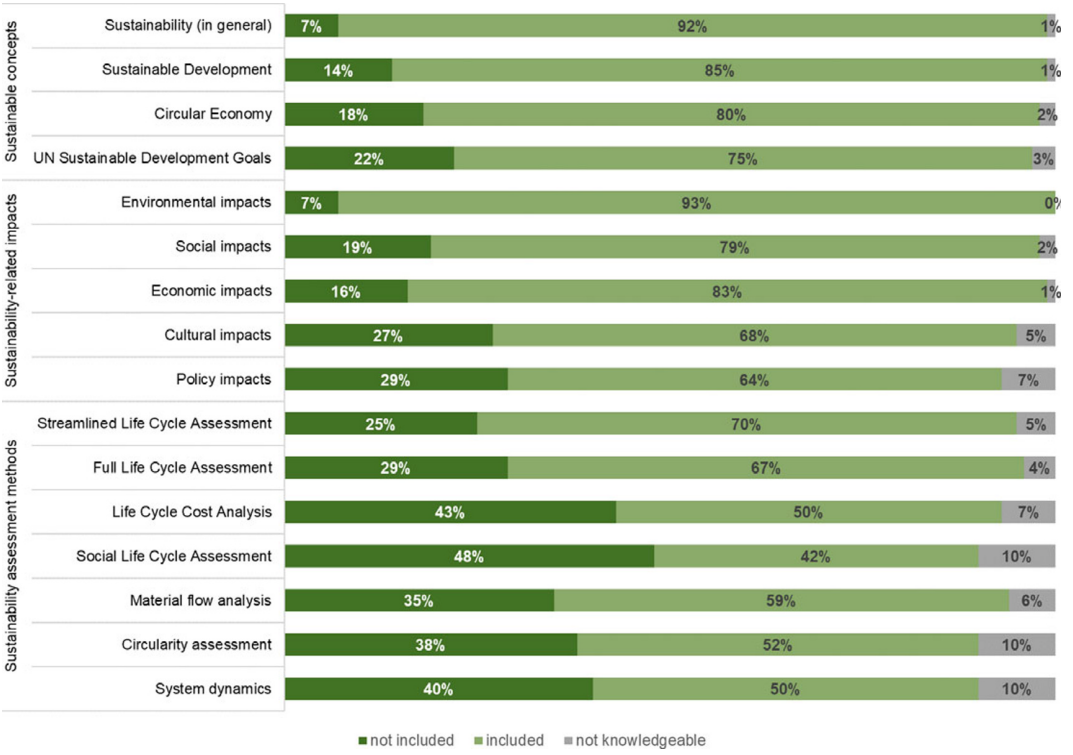

Figure 6. Inclusion of sustainability concepts, impacts and assessment methods in curriculum or research programmes. The percentages of "not included," "included" and "not knowledgeable" are shown.

4.3. Fundamental notions (concepts, impacts and assessment techniques) illustrated to teach sustainable design (RQ2, RQ2a)

The results concerning the inclusion of fundamental concepts (Q21), sustainability-related impacts (Q22) and sustainability assessment methods (Q23) in the surveyed units of study are summarised in Table 3. In Table 3, rows correspond to a specific concept or impact, while each column represents a different answer to express the delivery, relevance and possible growth of the delivery of the investigated notions. In Figure 6, we summarise these results by distinguishing the percentage of answers about the delivery of the same aspects; specifically, not included is the sum of the first to third data columns, while included is sum of the fourth to sixth data columns of Table 3.

- Sustainable concepts (Q21): Most respondents consider sustainability (in general), sustainable development and circular economy as relevant concepts. UN Sustainable Development Goals also receive considerable recognition. Overall, these concepts are considered relevant by most respondents, with minimal disagreement.
- Sustainability-related impacts (Q22): Environmental impacts and social impacts are widely recognised as relevant. Economic impacts also receive acknowledgment, albeit to a slightly lesser extent. Cultural and policy impacts are considered relevant by most respondents as well.

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- Sustainability assessment methods (Q23): Streamlined life cycle assessment, full life cycle assessment and life cycle cost analysis are widely perceived as relevant sustainability assessment methods. Social life cycle assessment and circularity assessment also receive significant recognition. Similarly, material flow analysis and system dynamics are recognised as relevant by most respondents.

Overall, there is a consensus among respondents regarding the relevance of including sustainable concepts, sustainability-related impacts and assessment methods in SDE. While there might be slight variations in the responses, most respondents view these concepts and methods as relevant to SDE.

To answer RQ2a, we extrapolated three dichotomic variables for each notion investigated through Q21, Q22 and Q23, omitting answers in which the respondent was not knowledgeable of the topic (last answer in Table 3).

- Inclusion (0 if the one of the first three answers in Table 3 was given, 1 otherwise, in line with Figure 6) to denote if a given notion is included in the unit of study;
- Relevance (0 if the third or fourth answer in Table 3 was given, 1 otherwise) to denote respondents who considered the notion important for their unit of study;
- Increase (1 if the second or sixth answer in Table 3 was given, 0 otherwise) to indicate units of study in which the delivery of the content is expected to grow.

The variables were then correlated to the engineering variable through the point biserial correlation coefficient, which was chosen because of the presence of dichotomous variables.

Below the significant correlations ($p < 0.05$) are reported.

- The inclusion of UN sustainable development goals, cultural impacts and system dynamics is significantly more frequent in design courses.
- The relevance of life cycle cost analysis is significantly more perceived in engineering courses; accordingly, the chances of observing the Increase of its delivery are significantly higher than in design courses.

All the other correlations across variables were not statistically significant.

4.4. Fundamental sustainable design approaches (including complementary approaches) illustrated to teach sustainable design (RQ3, RQ3a)

Table 4 summarises the results regarding the relevance of sustainable approaches (Q24) and complementary approaches (Q26). Many sustainable and complementary approaches are considered relevant and included in education, with expectations of increased delivery, indicating a growing recognition of their importance. However, there are mixed responses for some approaches, suggesting varying levels of understanding and emphasis within educational contexts. In Figure 7, we summarise the results illustrated in Table 4 by distinguishing the percentage of answers about the inclusion of approaches in courses held by the respondents. Similarly to above, not included is the sum of the first to third data columns, while included is sum of the fourth to sixth data columns of Table 4.

For each approach reported in Table 4, three variables were created in line with Section 4.3.1, namely inclusion, relevance and increase, to address RQ3a. By

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Table 4. Relevance of sustainable approaches to teach sustainable design

		It is not included despite being relevant; it will not be introduced anyway	It is not included despite being relevant; it will be offered in the future	It is not included, and it is not considered relevant	It is included but not considered relevant; its delivery will decrease or be stopped	It is included and considered relevant; its delivery will not change	It is included and considered relevant; its delivery will increase	I am not knowledgeable here and I cannot assess their relevance	TOT.
Sustainable approaches	Material design for sustainability	14	16	2	9	67	50	4	162
	Product eco-design, circular product design	7	13	3	9	65	67	2	166
	Cradle to cradle design	15	16	5	10	63	47	6	162
	Biomimetics, biomimicry	30	22	12	12	39	38	9	162
	Emotionally durable design, design for emotional attachment	24	18	12	6	43	46	16	165
	Design for sustainable behaviour	20	21	2	5	43	64	9	164
	Product-service system design for sustainability, circular business model design	15	19	5	6	46	60	13	164
	Design for social innovation for sustainability	22	25	5	8	30	60	15	165
	Design for the base of the pyramid	33	16	13	14	18	29	35	158
	Systemic design	19	16	6	10	40	52	20	163
	Transition design, Design for Sustainability Transitions/ Transformations	33	22	6	6	27	52	18	164
	Design futures	28	17	10	9	27	45	30	166
	Design activism	32	18	20	8	22	29	32	161

Continued

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Table 4. Continued

		It is not included despite being relevant; it will not be introduced anyway	It is not included despite being relevant; it will be offered in the future	It is not included, and it is not considered relevant	It is included but not considered relevant; its delivery will decrease or be stopped	It is included and considered relevant; its delivery will not change	It is included and considered relevant; its delivery will increase	I am not knowledgeable here and I cannot assess their relevance	TOT.
Complementary approaches	Policy design	35	21	19	12	17	32	27	163
	Design for X, e.g. reuse, remanufacturing, repair, upgradeability	11	11	2	9	63	65	4	165
	Co-design and collaborative/ participatory design	23	16	6	5	50	62	3	165
	System thinking	12	12	4	8	59	61	9	165
	Design thinking	15	12	10	4	72	51	2	166
	Futures thinking	27	24	10	6	31	52	14	164
	Social innovation	29	29	7	6	25	56	12	164
	Design creativity	26	13	8	3	53	53	8	164
	Data management	42	20	17	4	30	36	13	162
	Industrial management	37	13	24	10	28	31	20	163

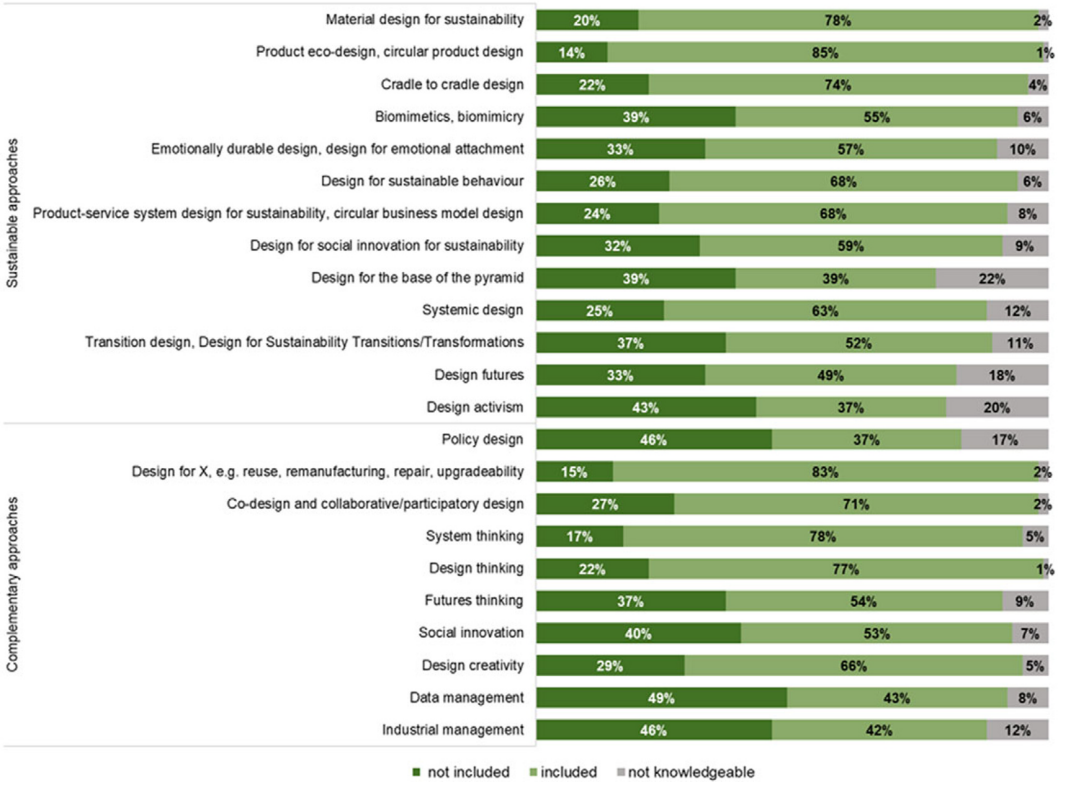

Figure 7. Integration of sustainable and complementary design approaches in educational or research programmes. The percentage of "not included," "Included" and "Not knowledgeable" are shown.

benefitting from the variable denoting the discipline (Engineering), a point-biserial correlation analysis was made. As above, the significant correlations are reported.

Many approaches are included in courses significantly more frequently in design-related degrees, namely:

- Cradle to cradle design,
- Biomimetics, biomimicry,
- Emotionally durable design, design for emotional attachment
- Design for social innovation for sustainability
- Systemic design
- Design futures
- Design activism.

Material design for sustainability is observed as significantly more relevant in courses taught in engineering degrees. The Increase of delivery of emotionally durable design, design for emotional attachment is significantly higher in courses taught in design degrees.

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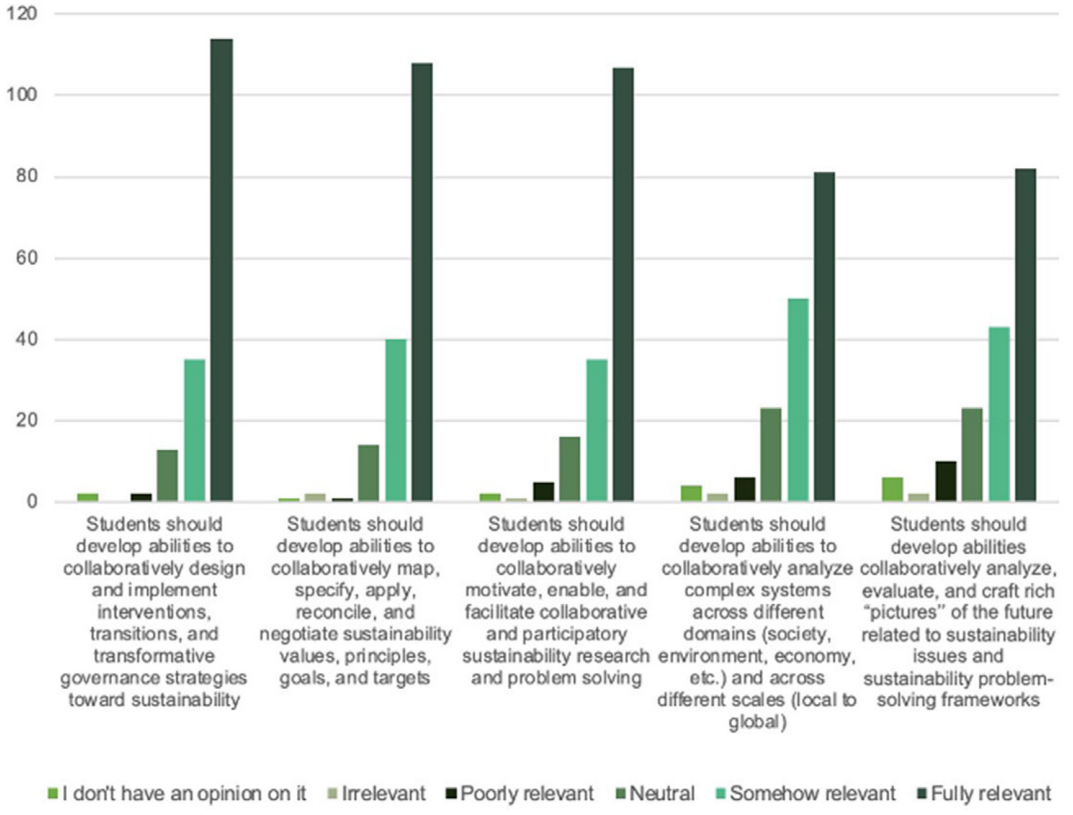

Figure 8. Relevance of skills and competences.

4.5. Expectations in terms of skills and ILOs associated with teaching sustainable design (RQ4, RQ4a)

The relevance of skills and competencies in sustainable design was addressed in Q29. Overall, there is a consensus among respondents regarding the relevance of these skills and competencies for students learning sustainable design. Most respondents perceive these competencies as fully relevant or somehow relevant, indicating their importance in preparing students to address sustainability challenges effectively, especially from a collaboration point of view (Figure 8).

The relevance of the ILOs in sustainable design was addressed in Q30, which revealed an overall consensus among respondents (Figure 9). Most respondents perceive these ILOs as fully relevant or somehow relevant, indicating their importance in assessing student learning outcomes in SDE. The data suggest that these ILOs are seen as crucial for assessing students' acquisition and application of knowledge, comprehension, analytical skills and synthesis abilities in the context of sustainability education.

To study whether the expectations in terms of ILOs (Q30) are affected by the discipline (Q8) in line with RQ4a, an ordinal regression was performed. The results indicate that no relation with the discipline is significant. Only evaluation has a

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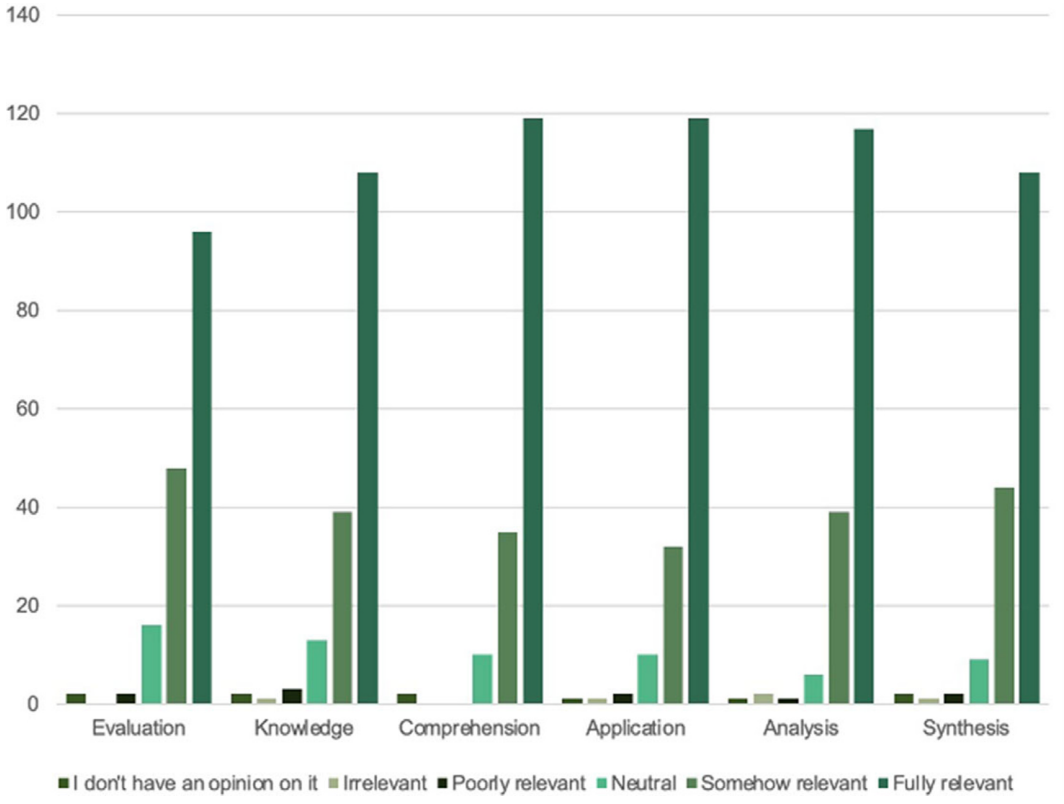

Figure 9. Relevance of the intended learning outcomes.

p-value close to the significant level, being more relevant in the design discipline ($p = 0.068$).

5. Discussion

5.1. Brief summary of the results

In Table 5, we present an overview of the main outcomes of the survey, together with their interpretation and the identification of possible implications for SDE (in terms of both the practice and research aspects of teaching). Section 5.2 provides additional analysis and discussion with a focus on the most insightful aspects emerged from the survey. Further comments are present in Section 5.3, which benefits from some additional insights into the collected data. The main open issues to pursue the goal of supporting curriculum development in SDE are reported in Section 5.4.

5.2. Education and the evolution of design for sustainability

According to Ceschin & Gaziulusoy (2016, 2019), DfS has evolved over the past decades by gradually widening the design scope, from a focus on the individual elements of a product, to product life cycles, product-service systems, social innovations and socio-technical systems. In the past few years, the focus has also

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Table 5. Summary of the most meaningful outcomes for each research question and related interpretations and implications

RQ	Outcomes	Interpretation	Possible implications
RQ1 – What are the methods/pedagogical approaches used to teach sustainable design?	A wide range of methods and pedagogical approaches relevant for SDE is used. Among the methods, lectures are most frequently used; and among the pedagogical approaches, project-based learning is the most frequently used.	The high relevance of traditional lectures is not surprising given it is a fundamental method for content delivery. The dominance of lectures however might mean, in some contexts it is the only method used. The prevalence and dominance of project-based learning is also not surprising given it is currently the state-of-the-art pedagogical approach in design education.	While the dominance of lectures is not surprising, it is unclear from our data if lectures are the only pedagogical approach in some contexts. It is also unclear in which contexts which approaches are more frequently used. There is a need to gain a more granular understanding of how sustainable design is taught. Future research should explore which methods and approaches are combined in what kind of settings. Some insights are given in Section 5.3, but these are limited by the questions included in the survey.
RQ1a: Are teaching methods affected by discipline?	The relationship between the teaching methods and the discipline (that is design versus engineering) is not significant. Two of the pedagogical approaches (problem- and inquiry-based learning) however are significantly more prevalent in design courses.	The prevalence of problem- and inquiry-based learning in design courses might reflect their systems thinking approach, whose boundaries embrace also the intertwined effects of technological development with societal issues, whilst the widely diffused engineering approach of systems thinking mostly focus on the technological factors that entail the	It is important to establish suitability of different teaching methods and pedagogical approaches to teach sustainable design in different disciplines. It is also important to critically reflect on the suitability of methods and approaches to equip learners with competencies that enable them to handle sustainability issues which are by nature systemic and

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Table 5. Continued

RQ	Outcomes	Interpretation	Possible implications
		design and development of a solution (e.g., from functionalities to manufacturing-related issues), despite courses laying at the intersection between these two disciplines (e.g. engineering design/ design engineering) aims at providing a comprehensive viewpoint on systems thinking.	complex upon graduation.
RQ2 - What are the fundamental notions (concepts, impacts, assessment techniques) illustrated to teach sustainable design?	With very little variation, sustainable concepts, sustainability-related impacts, and assessment methods are considered relevant by most of the respondents and currently included in teaching. While still more respondents teach specialised assessment methods than those who do not teach these methods, they seem to be less popular teaching topics.	It seems all topics currently relevant for SDE are being taught by most of the respondents.	At a general level, there does not seem to be a deficiency in coverage of fundamental notions in SDE.
RQ2a: Are these notions affected by discipline?	The relationship between the notions taught and the discipline (that is design and engineering) is not significant.	The fundamental notions relevant for SDE seem to be equally important in both design and engineering programmes.	It is important to acknowledge the wide relevance of fundamental notions regardless of the disciplines which teach them. However, future research should develop a granular understanding of how each of these notions can and should be taught in different

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Table 5. Continued

RQ	Outcomes	Interpretation	Possible implications
			disciplines so that discipline-based markers or measures of success for the required depth and breadth in teaching each notion can be developed.
RQ3 – What are the fundamental sustainable design approaches (including complementary approaches) illustrated to teach sustainable design?	A wide range of DfS approaches is taught, spanning across different innovation levels: material (e.g. material design for sustainability), product (e.g. eco-design), product-service system (e.g. circular business model design), spatio-social (e.g. design for social innovation) and socio-technical system (e.g. Design for Sustainability Transitions)	The better established a DfS approach is, the more frequently it is taught. This means that moving from material to product, product-service system, spatio-social and socio-technical system, the related DfS approaches becomes less frequently taught. Also, DfS approaches addressing social sustainability are less frequently taught compared to those addressing environmental sustainability.	Different design programmes require the provision of different combinations of DfS approaches. How to effectively teach multiple approaches (What years? What order? What teaching approaches?) is an important area to be explored.
RQ3a: Are these approaches affected by discipline?	The relationship between the approaches and the discipline (that is design and engineering) is significant for a considerable number of approaches, which are included more frequently in courses taught in the design field.	A subset of DfS approaches seem to be equally important in design and engineering programmes, others feature the teaching of sustainable design more typically in design-related degrees.	It is fundamental to understand the teaching needs and requirements associated with different disciplines and if this affects the delivery and the perceived importance of DfS approaches. This would allow us to define if, and how, the provision of the various approaches would require different teaching approaches (content, methods, assessment, etc.)

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Table 5. Continued

RQ	Outcomes	Interpretation	Possible implications
RQ4 - What are the expectations in terms of skills and Intended Learning Outcomes (ILOs) associated with teaching sustainable design?	Most respondents perceive the proposed skills, competences and ILOs as fully relevant or somehow relevant. However, a strong emphasis is given to those skills and competences that focus on: "define sustainability goals and apply sustainability strategies"; "design and implement interventions" and "enable and facilitate participatory approaches". Less emphasis is given to those skills and competences that relate to the analysis of complex systems and the application of design futures approaches	The skills and competences that are considered more relevant (i.e. "define sustainability goals and apply sustainability strategies"; "design and implement interventions") are typically associated with all DfS approaches. The skills and competences related to "enabling and facilitate participatory approaches" are also considered very relevant, which might indicate the emphasis placed by educators on addressing sustainability through collaboration, multi-disciplinarity and/or codesign. The skills and competences that are considered less relevant (that is those related to the analysis of complex systems and the application of design futures approaches) are typically associated with those DfS approaches that address the socio-technical system innovation level (see the different innovation levels in Figure 10). Since these are taught less	It is important to define the expected skills, competences and ILOs considering the needs and requirements of Undergraduate and Postgraduate students, and define which of those should be achieved in Undergraduate and Postgraduate programmes

Continued

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Table 5. Continued

RQ	Outcomes	Interpretation	Possible implications
		frequently (see RQ3), the result is that the related skills and competences are not considered as relevant as other proposed skills and competences	
RQ4a: Are these expectations affected by discipline?	The relationship between ILOs and the discipline (that is, design and engineering) is not significant	The proposed ILOs seem to be equally important in both design and engineering programmes	It is important to understand the teaching needs and requirements associated with different disciplines. This would allow us to better specify the ILOs

strongly expanded to cover socio-technical-ecological systems, possibly due to the increasing emphasis in research and public media about biodiversity crisis. This expansion was accompanied by a shift from a technocentric design approach to an approach where human-centric design has become more and more important. In the past years, there has been an increased focus on "earth-centric" or "life-centric" approaches, manifesting in publications on more-than-human and multispecies design (e.g. Fletcher *et al.* 2019; Heitlinger, Foth & Clarke 2024; Rosén *et al.* 2024). This evolution is illustrated in Figure 10, which shows five innovation levels and how the main DfS approaches are mapped against those levels.

When looking at the results of the survey in combination with the evolution of DfS, we can see that the DfS approaches taught span across all the innovation levels. More in particular, there is a positive correlation between how well-established a DfS approach is (that is the less recently developed it is), and how much commonly taught it is (Figure 11), showing a wider distribution of earlier knowledge in the field. For example, "design for sustainability transitions" and "design for social innovation," which are amongst the most recently developed approaches, show a lower inclusion in teaching programmes (52% and 59%, respectively) compared to most of the other approaches. The only exceptions are "biomimicry" and "green design," which present lower percentages of teaching inclusion compared to some more recent approaches. For the "green design" approach, the explanation might be that "ecodesign," since its initial development (second half of the 90s), has gradually integrated and included "green design" concepts, design strategies and principles, thus reducing its teaching relevance.

If we consider how the different DfS approaches are linked to the five innovation levels, we can notice (Figure 11) that the wider the design scope the less frequently taught are the related DfS approaches (gradually decreasing from 71%

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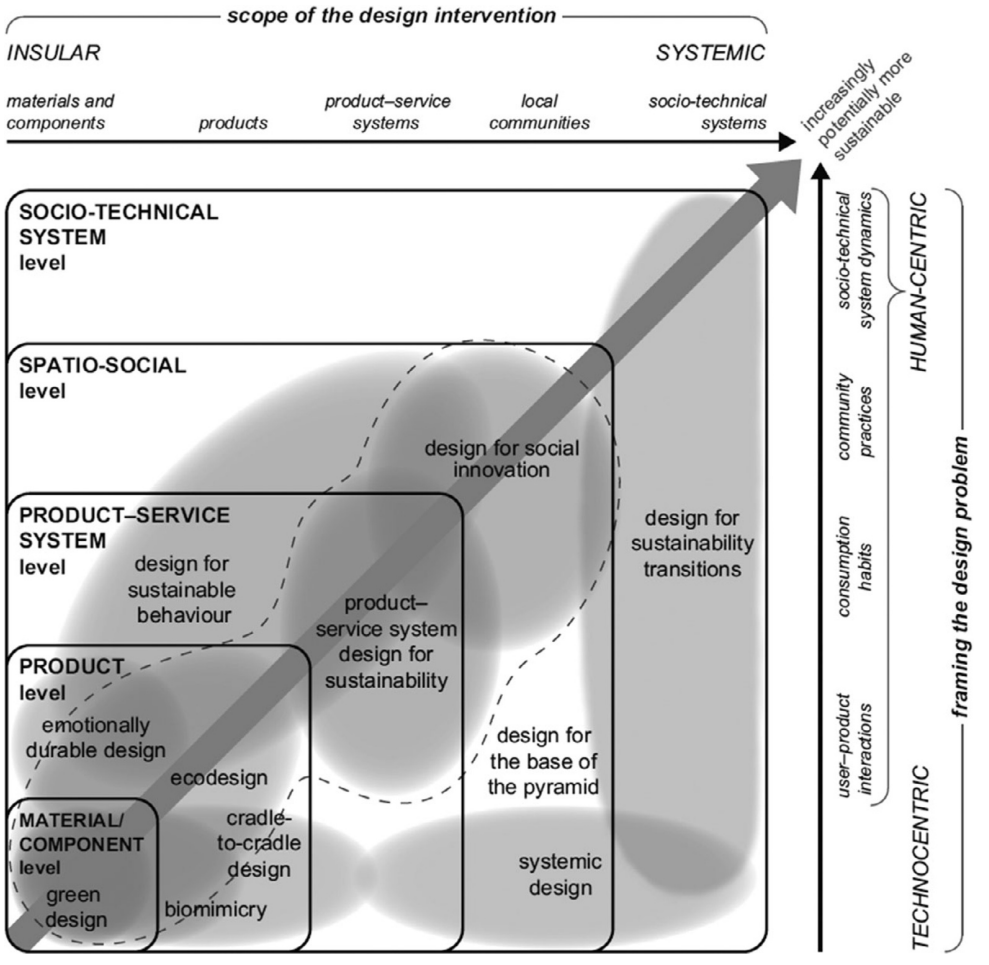

Figure 10. The DfS framework, showing how the main DfS approaches are mapped against five innovation levels (Ceschin & Gaziulusoy 2019).

for the material/component level to the 55% for the socio-technical system level). In Figure 11, percentages are taken from responses to Q24, which are summarised in Figure 7. Based on Ceschin & Gaziulusoy (2016, 2019), each DfS approach has a shade of grey which indicates when the approach was initially developed. On the left side of the framework, each of the five innovation levels is coupled with a percentage that indicates how frequent the teaching of contents related to that level is. Those percentages are calculated by averaging the frequency of the various DfS approaches associated with each individual innovation level, considering that an individual DfS approach can be relevant to multiple innovation levels; in particular:

- the material/component level considers "green design," "biomimicry," "cradle-to-cradle design" and "ecodesign";
- the product level considers "ecodesign," "emotionally durable design," "cradle-to-cradle design" and "design for sustainable behaviour";

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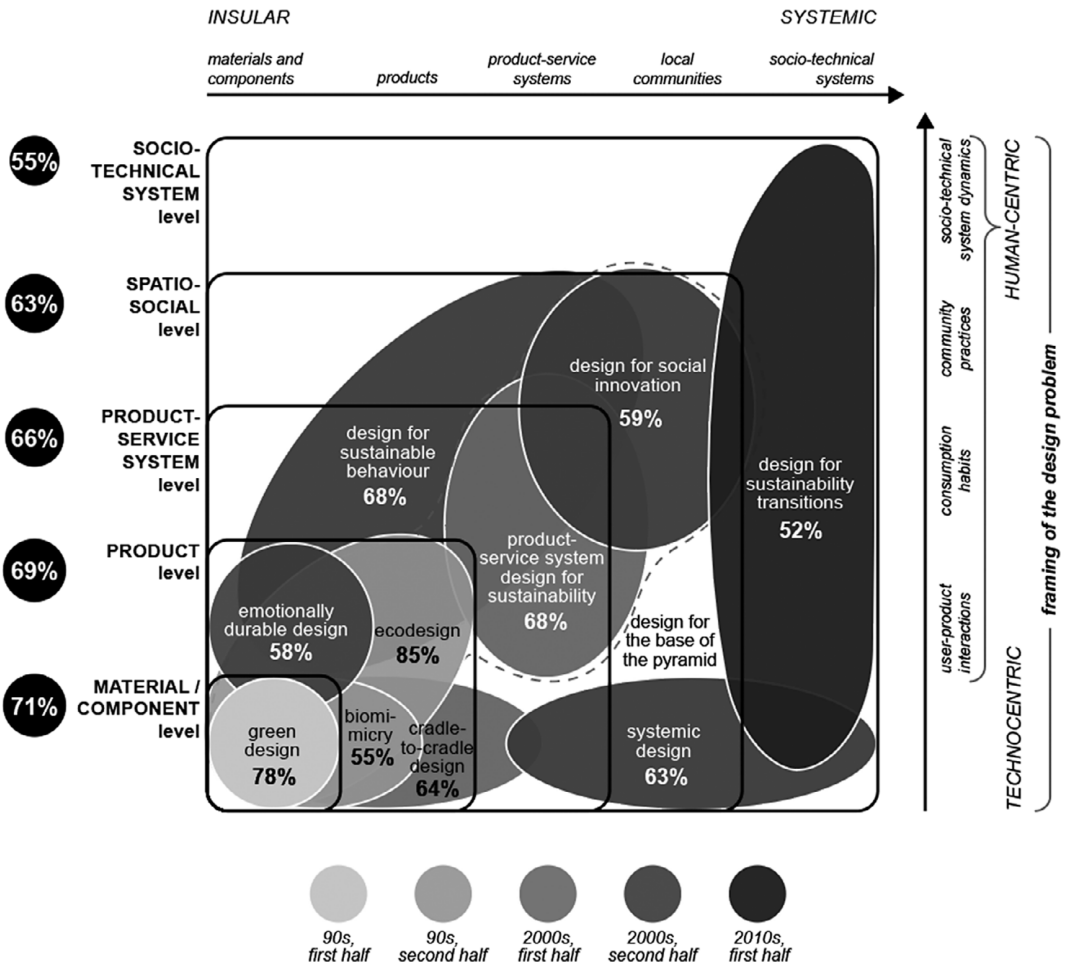

Figure 11. Comparison between the teaching relevance of different DfS approaches (percentage of inclusion in teaching courses) and how well-established they are. Each DfS approach is mapped on the framework and coupled with a percentage that indicates how frequent the teaching of a DfS approach is (Figure modified from Ceschin & Gaziulusoy 2019).

- the product-service system level considers "product-service system design for sustainability," "design for sustainable behaviour" and "systemic design";
- the spatio-social level considers "design for sustainable behaviour," "design for social innovation" and "systemic design";
- the socio-technical system level considers "design for sustainability transitions" and "systemic design."

Looking at the correlation between the topics indicated as included in teaching and those indicated as topics focused on research by the respondents, it seems that the decrease of content delivery is particularly strong for those approaches that have been most recently developed (i.e., those related to the spatio-social and socio-technical system innovation levels). This could be due to the availability of teaching materials and effective teaching methods for the more established approaches. On

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the other hand, the teaching of the most recently developed approaches, being not so established, requires the development of new contents/material and experimentation in terms of teaching methods.

5.3. Further topic-related correlations

The survey could not highlight the existence of dependencies among topics and best practices that might support educators in defining the most appropriate sequence of topics to include in a newly developed unit of study.

However, the crossed analysis of answers related to sustainability-related topics and pedagogical approaches and teaching methods highlighted some key points which might require the attention of educators. In Figure 5, we have shown that lectures are still among the most diffused teaching methods. However, these are rarely used alone as an approach to acquaint students with sustainability-related topics. Lectures are frequently coupled with one or more teaching approaches as at least two thirds of the considered units of study combined lectures with the one or more of the other most diffused active learning methods. Markedly, 67% of respondents combine lectures with practice doing. One seventh of units of studies lecture-based also include discussions. The topics that educators cover within these courses do not differ much depending on the teaching methods these adopt. However, it is worth noting that topics are not uniformly diffused, as already emerged in Table 4 and Figure 7. Product eco-design and circular product design, as well as Design for X, are the most diffused ones and our data shows that educators favour active learning approaches to teach these topics. Practice by doing and discussions are common to more than 80% of the investigated units of study. It can be inferred that there is a tendency to include both elements of active experimentation/concrete experience (typical of practice by doing) with reflective observation and abstract conceptualisation (typical of discussion), which are essential, for instance, in the Kolb's Learning cycle (Kolb 1984).

Among topics that are less diffused, a particular point of attention needs to be given to systemic design, as the collected answers highlighted a stronger prevalence of lectures and discussion compared to practice by doing. Both are mostly considered student-centred approaches, but it appears that systemic design faces some additional barriers when it needs to be implemented via active experimentation in the units of study. This might be because systemic design deals with complex systems: the design of systemic solutions within a unit of study might easily cover the generation of ideas as well as their conceptualisation, as envisaged in (Bacciotti et al., 2016). However, their effectiveness at the systemic level can be hardly estimated in practice, allowing just for mental simulations of their expected impact, which is easier to consider in shared discussions with students.

5.4. Open issues, future work and additional remarks

The analysis of the survey results has allowed us to identify a set of open issues which require further exploration and research:

- Design programmes are organised according to different combinations of DfS approaches (see Figure 7). It would be important to better understand how to teach multiple DfS approaches, considering their sequence, the year in which different approaches are taught, the teaching strategies and methods to maximise

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students' capability of harnessing sustainable design knowledge in their future work. Some universities are opting for spreading the teaching of DfS approaches over multiple years, starting with the more insular design approaches and gradually moving to the more systemic ones (e.g., Ceschin 2024), but it would be beneficial to build a more comprehensive picture of how universities are addressing this issue.

- Linked to the previous point, there is the need to better define how the teaching of different DfS approaches (in terms of amount and depth of content, teaching strategies, assessment modalities, ILOs and the expected skills and competences) has to be tailored in relation to different educational levels (e.g. undergraduate versus postgraduate) and different subject areas (design versus engineering programmes).
- In relation to the teaching of the most recent DfS approaches (that is, those related to the spatio-social and socio-technical system innovation levels) there is the need to share teaching practices, resources and content to accelerate their diffusion. It would be important to better understand how diverse the teaching of these approaches is (e.g., by considering the contexts and the countries where they are taught). This would enable teachers around the world to learn and be inspired from different teaching practices.
- Teaching of sustainable design topics is most significantly prevalent at the bachelor level. The reasons for the low prevalence of SDE in master's and doctoral levels needs to be understood as this may be related to the structure of degree programmes (e.g., no courses in some doctoral programmes) or may reflect a shortage of courses offered. This understanding would enable development of strategies to include SDE in post-graduate programmes, which is important for inspiring young researchers to take up sustainable design-related research projects and assist in continuation of scientific development of the field.
- Related to the point above, the relationship between what is researched and what is taught needs to be studied, possibly through the participation of additional educators, to understand the circumstances in which there is strong or weak relationship between research and teaching. This would enable developing strategies to create opportunities for linking research to teaching more directly and strongly, thereby increasing the quality of sustainable design teaching.

The survey included a number of questions that have been deliberately included despite they did not serve the scope of answering the RQs. We expect to use this gathered information to obtain additional insights into SDE in future papers. In addition, the gathered data lends itself to investigate the role of educators' experience, degree level, cohort size, country or geographical area on shaping SDE. For example, it would be interesting to investigate whether teaching in the Global South tends to prioritise specific methods in SDE given the different economic and social context; nevertheless, this could be better investigated by extending the coverage of the survey, as aforementioned. A dedicated study will examine the definitions of "sustainable design," which were given by almost 250 respondents through an open-ended question; this should reveal the width and variety of understandings of the concept.

Interested scholars can contact the corresponding author should they wish to use the complete data for research purposes.

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6. Conclusions

The paper investigates the status of SDE with the aim to identify current practices and possible gaps. The global perspective of the study and the large gathered dataset overcome the limitations of previous research contributions, which were aimed at studying few units of study in depth.

We selected the online survey as a methodological approach to answer the RQs reported in Section 1. The survey was accessed by 386 respondents qualifying as educators in the field of sustainable design, with a marked variety of countries in which units of study are held. Despite the large number of respondents, we cannot assess the representativeness of the sample, as the quantity of lecturers possibly taking part in SDE is unknown. This represents the main limitation of this work, along with a geographic unbalance that allowed us to get answers to the survey mainly from the Global North. Likely, other languages should be used in a follow-up survey to increase the coverage of the sample.

Based on the findings, the relevance of notions supporting the delivery of sustainable design-related contents emerged; here sustainability, sustainable development, UN SDGs, circular economy and life cycle assessment turned out to be prevalent. our respondents use a variety of teaching methods and approaches, where project-based learning integrates lectures in a relevant portion of the investigated units of study (approximately one third based on our data). All ILOs were considered relevant to very relevant by the majority of respondents. Product eco-design and Design for X resulted as the most popular contents, as they are taught in more than 80% of the investigated units of study. The discipline (design versus engineering) affected few investigated aspects, and, notably, the inclusion of a number of contents in units of study. SDE held in design degrees is more likely to include approaches to sustainable design at the spatio-social level; hence, they may provide a larger view on the context where design interventions can occur.

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