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25 May 2026

Teaching systemic design to foster sustainability learning in non-design curricula

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Abstract

Purpose – Circular economy and sustainable development in rural areas are phenomena that call for new skills and knowledge encompassing methods and tools to foster systemic thinking. Over the past twenty years, the design discipline has significantly turned towards complexity, advocating a 'designerly' approach to systems thinking that brings the focus closer to humanity. This paper aims to present a successful teaching module on systemic design as a case research study for designers and non-designers in a cross-disciplinary educational context.

Design/methodology/approach – The authors detail a European case study where four universities conducted a cross-disciplinary online training programme on sustainability and circular economy in rural areas for higher education students. The paper discusses a teaching module in systemic design that integrated theoretical learning with practical teamwork within a short timeframe. The programme involved collaboration with industrial partners and promoted varied interaction patterns in an intercultural teamwork activity.

Findings – Educational outcomes were assessed by examining students' projects and conducting a survey to gauge learners' perspectives. The paper showcases the potential of teaching systemic design outside traditional design arenas and the personal and professional benefits accessible to non-designers. Additionally, it discusses the challenges of learning in an interdisciplinary, intercultural environment, as well as the limitations and potentials of digital learning tools.

Originality/value – This knowledge is valuable for educators in higher education and professionals seeking to establish sustainability initiatives and teaching strategies that address emerging skills related to systems and design thinking. The educational experience described here underscores the significance and effectiveness of cross-disciplinary online training through digital platforms to facilitate international collaboration in sustainability education.

Keywords Design education, systemic design, circular economy, online learning, interdisciplinarity, intercultural learning

Paper type Research paper

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1. Introduction

As the principles of sustainable development become increasingly embedded in contemporary societies, attention to the Circular Economy (CE) is growing in public policy, academia, industry, and society. The CE moves away from the current linear economy towards a new economic model that is:

> *Constructed from societal production-consumption systems that maximise the service produced from the linear nature-society-nature material and energy throughput flow. This is done by using cyclical materials flows, renewable energy sources, and cascading type energy flows"* (Korhonen, *et al.*, 2018, p.39).

Studies that discussed the CE model argue that the transition to the CE will produce key environmental benefits: more sustainable use of resources, a greater focus on well-being and quality of life, and job growth resulting from new business models (Ghisellini, *et al.*, 2016; Webster, 2017; IISD, 2020). The transition to the CE opens up peculiar opportunities for rural areas from an economic and a socio-cultural point of view since it can increase the attractiveness of areas currently being abandoned and depopulated (Salvia, *et al.*, 2018). Prime case studies are emerging, such as the MonViso Institute, a real-world laboratory based in the Italian Alps. The institute was established within an abandoned compound to explore the potential of circular innovations in fostering the rejuvenation of rural areas by providing support for new businesses and future-looking lifestyles (Blanco et al., 2023). In general, Europe is progressing toward the adoption of the CE. However, the journey is fraught with challenges and disparities: the southern and eastern regions of Europe encompass considerable rural areas, yet they frequently exhibit shortcomings in sustainable practices and the adoption of CE (Crescenzi and Giua, 2020).

Moreover, circular job opportunities are not just related to production growth but rather to a vast number of activities generated by sustainable loops of products and sub-products. Relevant studies distinguish between three types of circular jobs (Circle Economy, 2020): *core circular jobs*, which close cycles of raw materials through repair, reuse, and waste management; *enabling circular jobs*, which enable the acceleration and upscaling of core circular activities (for example digital technologies); *indirect circular jobs*, that provide services to circular activities (such as education, logistics and public sector). Therefore, education plays a crucial role in the transition to a CE since teachers at all grade levels are ‘indirect circular’ workers that transfer knowledge and skills to future ‘core’ and ‘enabling’ circular professionals to meet the needs of new sustainable business models. Notwithstanding the increasing dedication of Higher Education Institutions (HEIs) to sustainable development, current curricula are insufficiently equipped to impart the new skills required for a CE. Instead, students are frequently being trained to perpetuate models based on a linear economy (Sipos, *et al.*, 2008; Ceulemans and Severijns, 2019). HEIs are tasked with addressing this gap by training upcoming leaders and professionals to develop innovative solutions and sustainable strategies through the implementation of new circular models for sustainable development.

This is the premise behind the Erasmus+ project MULTITRACES (Multidisciplinary training in circular economy and smart valorisation of the rural area for new business models), which aimed to build new circular educational pathways for higher education students from different disciplines and countries. The project involved four European universities – University of Bacau, Politecnico di Torino, University of Alicante, International Hellenic University – and focused on the sustainability transition of rural areas, which have suffered negative trends due to the phenomena of globalisation and urbanisation. This project started with the analysis of the main economic sectors of four different European regions to identify the needs of local industries, especially Small and Medium Enterprises (SMEs). Based on this analysis, a multidisciplinary training programme was built, involving 56 students from the universities involved. The training programme lasted five months, during which the students virtually took part in four thematic modules. In each module, the theoretical contents were complemented by practical experiences based on multidisciplinary and international teams. The first module was dedicated to systemic design, which Jones and Kijima (2018) define as a co-evolving field of ‘design-led systemics’, grouping a range of design approaches that clearly distinguish from Systems Design disciplines related to engineering and hard sciences. Here, the systemic design module focuses on learning how and which design skills can support innovative circular business models. The second module focused on Industrial Engineering for by-product valorisation and waste reduction; the third one focused on the smart valorisation of natural resources from an Agri-forestry lens; and the fourth one was on circular Business Management.

The paper introduces the systemic design approach and its teaching methods applied within Design schools. Then, it presents the case of the module “Systemic design for circular economy in rural areas” and the methodological and practical challenges of teaching systemic design in an interdisciplinary and cross-cultural classroom. Lastly, key results are discussed to identify the limitations and benefits of teaching systems- and design-thinking to non-designers, and how these can foster sustainability learning.

2. Context

2.1 Systems thinking in Design Education

Since the end of the 20th century, design has had a significant turn towards complexity, pursuing its aptitude for tackling ‘wicked problems’ (Rittel and Webber, 1973). Buchanan’s (2001) theory of the ‘four orders of design’ witnesses the shift from creating symbols and artefacts towards designing interactions and systems. The opening of the design scope has led to a greater interest in systems thinking. Contemporary design has drawn heavily on most widespread systems theories but, at the same time, has claimed a ‘designerly’ approach to systems thinking, where design thinking brings the focus closer to humanity (Jones and Kijima, 2018). The designers’ ability to facilitate and frame knowledge has proved to be relevant within interdisciplinary teams addressing complex technical and organisational challenges, such as sustainability transitions. This shift towards complexity also involved design education, which in recent years has faced significant changes by addressing systemic transformation and observing a growing need for transdisciplinary skills and interdisciplinary teamwork. In particular, the scopes and scales of design problems have broadened, and problem-solving strategies have been moving from an artefact-driven to a systemic approach (Pontis and Van Der Waarde, 2020). Moreover, an increasing number of Design curricula have adopted project-based learning rooted in real-world problems to prepare designers for an ever more complex world (Davis, 2017).

Since the end of the last century, it has been clear that systems thinking and interdisciplinary approaches were essential for sustainable development and sustainability education (Warburton, 2003). As Sandri (2013) states, “sustainability theory cannot be appreciated or put into practice without an awareness of the ‘bigger picture’– the complex, systemic interconnections and cause and effect relationships that surround any issue” (p. 811). From this perspective, it is evident that design education, in its systemic evolution, holds particular relevance in addressing sustainability issues, as it can merge a systemic approach with project-based learning for sustainability, thereby fostering the development of skills necessary for critical inquiry and systematic problem-solving (Holdsworth *et al.*, 2008).

Meyer and Norman (2020) stress the distinction between *training*, i.e. the focus on craft skills that characterises traditional design instruction, and design *education*, that is “gaining a deep understanding of the underlying principles and historical underpinnings of what we learn” (Frascara, 2020, p. 108). Both are important, but it is evident, Don Norman says, that in the newer forms of design, the emphasis on craft training is reduced in favour of education because complex projects - such as the design of a sustainable health system or a transportation service for rural areas - require a broader understanding of culture, philosophy, history, politics, and ethics of design. In a word, design education must be anticipatory, not just reactive, looking at a longer timeframe. On this point, Meredith Davis argues that, in current design curricula:

> *Conditions call for studies shaped by systems-level thinking — what people want and need; what the context demands; how design is planned, produced, and delivered; the outcomes we expect of a design process (including principles or guidelines); how we evaluate outcomes; and the tools and methods for studying these things (Frascara, 2020, p. 112).*

The Systemic Design Association (2024) is one of the main arenas for discussion on systemic design issues in both research and education. To date, it recognises ten higher education programmes that include systemic design courses or design methods that round out a systemic design concentration. These courses are of different levels and are provided by six universities located in Europe (3), North America (2), and Asia (1). Six other curricula are considered relevant. Although the number of systemic design programmes is still small, the research momentum around systemic design issues demonstrates a burgeoning interest in the systemic approach, also from practitioners and industries. In terms of content, systemic design programmes and courses combine the teaching of soft skills like systems thinking theories and methods (such as rich picture and system dynamics) with traditional hard skills associated with design methods (such as sensemaking or modelling) (Jones, 2014). Facing increasing complexity, systemic design has created specific tools aimed at framing the existing system, adopting a multi-level approach to envision system innovation, and establishing co-creation processes (Pereno and Barbero, 2020). In recent years, systemic design methods and tools have been applied to specific challenges related to the CE. In some cases, they were used to develop an overview of potential strategies for enhancing circularity (Shilpi *et al.*, 2023). In others, they supported the implementation of new circular production models (Fiore *et al.*, 2020), also through educational initiatives aimed at driving local industries toward CE (Bakırlıoğlu *et al*., 2021). In all instances, systemic design proved to offer significant competencies in the management of circular products, services, and systems. If appropriately assimilated into current curricula, these competencies can effectively underpin the transition to a CE (Andrews, 2015).

2.2 Design for non-designers: A shift toward systemic complexity

The work by Pontis and Van De Waarde (2020) highlights how:

> *The increasing complexity in the scope and scale of new types of design problems, and the need for multidisciplinary responses has triggered a wave of interest in design skills acquisition. In the past, students would enroll in design school to become professional designers or work in a related industry. Now students enroll in design classes for that plus many other reasons* (p. 233).

Figure 1 shows this ongoing shift in design education towards non-designer actors and arenas. This change is fostered by a rising complexity of the issues in which designers and design methods are involved, moving from the product to the system scale. As a result, design education has expanded its scope and methods, but it has also redefined its teaching arena beyond conventional design schools. This expansion entails educational collaboration with new disciplines and an increasing number of stakeholders. There is no longer a single external partner - traditionally a company - but a variety of stakeholders involving industry, public and private decision-makers, civil society.

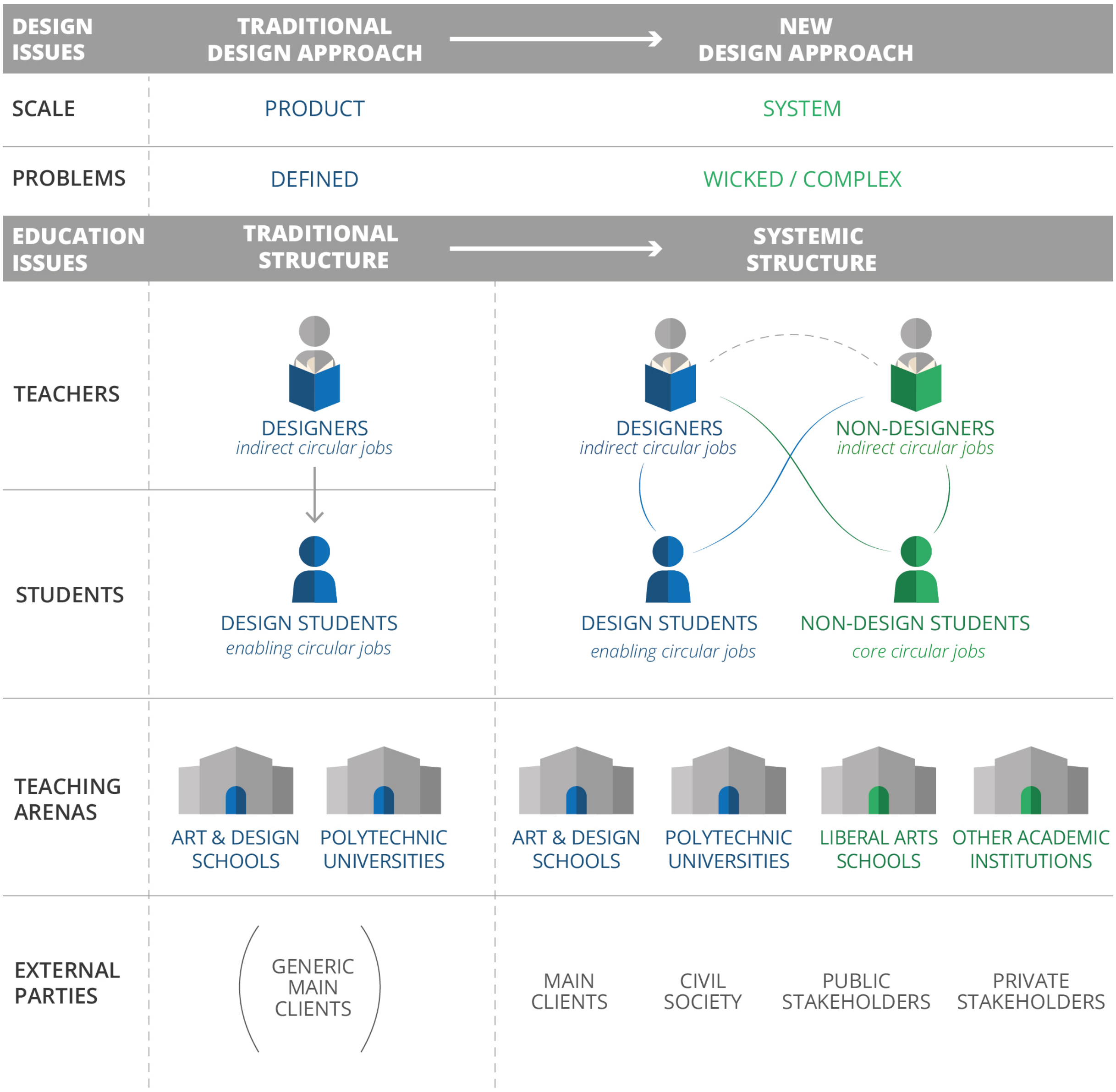

Figure 1 The ongoing evolution of design education (adapted from Pontis and Van De Waarde, 2020). Source: authors' own work.

When it comes to systemic design, the educational shift is even more radical as systemic problems call for cross-sectoral collaboration of a wide number of stakeholders. As seen above, the sustainable transition to a CE model falls within the scope of complex systemic problems, and it requires different professionals, which are categorised as *core* circular, *enabling* circular, and *indirect* circular practitioners. While the role of design educators falls under *indirect* jobs, the people they train will mainly hold *core* and *enabling* circular job positions. The comprehensive study by Burger *et al.* (2019) relates industry sectors, job types and circular strategies, categorising design as an *enabling* circular job that addresses the ‘Design for the Future’ strategy. Hence, they acknowledge that design processes require anticipation and systems skills to understand, monitor, and improve socio-technical systems through understanding the interaction of resource flows. In their study, Sumter *et al.* (2021) examine the issue of design competencies within the context of the CE. They underscore the literature’s emphasis on the necessity of systems thinking while concurrently noting the dearth of tools and methodologies available for the acquisition of this competency. In this view, the need to provide designers and non-designers with systems thinking methods and tools is as relevant as urgent. Sanna-Mari Renfors (2024) stresses that current education initiatives mainly focus on the micro level, while “all levels of implementation and circular economy objectives should be included in courses to promote systems thinking” (p.122). Brychkov *et al.* (2024) also underscore that systems thinking is an essential competency in sustainability education, as it enables students to critically analyse the key features of complex system behaviours, focusing on the interactions that occur at various levels and characterise the social, environmental and economic dynamics of sustainability challenges.

Hence, future *enabling* and *core* circular professionals need participatory, systems thinking tools to support system analysis and modelling for understanding and framing complex connections between different parts of a system (Wiek *et al.*, 2011). These tools, such as Gigamapping (Sevaldson, 2018) or Holistic Diagnosis (Battistoni *et al.*, 2019), are taught in systemic design courses. Although embedded within design curricula, the tools propose transdisciplinary approaches that make them suitable for other disciplines. In the CE framework, the capacity of design to actively engage with stakeholders through physical and visual objects is also a sought-after skill for non-designers. This includes the ability to collaborate and co-create interventions.

Among the different skills that systemic design can provide, the authors identified four macro-areas of skills that can be more relevant for non-designers working in the sustainability field: understanding complexity, visualising complexity, co-design, and envisioning sustainability transitions. In these three areas, authors have chosen the specific tools and methods that should be included in the module “Systemic design for circular economy in rural areas” based on the expected learning outcomes, as described below (see section 4).

3. Research questions

The shift to the CE necessitates a pivotal role for HEIs in the training of future professionals, calling for increased complexity and interdisciplinarity. Over recent years, design education has undergone a profound transformation, expanding its focus to address broader problem scales and involving non-designers to a greater extent. The authors posit that these shifts are interconnected and can engage in a productive dialogue to promote sustainable development. Hence, the present research is posing two main research questions:

> *RQ1*: How can design education contribute to preparing students to tackle the real-life problems of a sustainable and circular transition?
>
> *RQ2*: Which systemic design educational methods and tools can support non-design students in gaining systems- and design-thinking skills?

The experience of the international Erasmus+ MULTITRACES project and, in particular, the module “Systemic design for circular economy in rural areas” made it possible to address these questions.

4. Methods

4.1 Course background

MULTITRACES (2019-2023) is a project funded under Key Action 2 of the European Erasmus+ programme, which aims to set up interdisciplinary training activities for students from different disciplines and countries to foster CE in rural areas. This results in two main sub-goals:

1) To enable students to acquire knowledge valuable for their careers as professionals or entrepreneurs in the CE.
2) To boost the circular transition of rural areas by increasing attractiveness among young people and meeting new market needs of smart valorisation of industrial by-products and natural resources.

Building a partnership between academia and industry is at the heart of the project, so four universities and four SMEs were involved. Partners started by building common knowledge on the topic, as well as on the skills required in the CE. In the first phase of the project, partners surveyed the four regions involved, targeting companies and organisations (e.g. clusters, sectoral associations, local and national governance) from the rural sectors. The survey aimed to investigate key competencies and personal skills for future CE professionals.

During the second phase, partners concentrated on jointly developing a five-month online training programme. This programme involved 56 international students with diverse backgrounds in production engineering, design, agronomy and natural resources, business and management. The student selection process took place through a "Call for participation”, and was based on the Curriculum Vitae of each participant, combined with a motivation letter to explain the interest in participating in the course and the level of English proficiency to ensure effective communication between participants. Each university coordinated one module in collaboration with other partner universities and local companies. In each module, theoretical contents were complemented by practical projects conducted by interdisciplinary and intercultural teams, together with the local SMEs.

Table 1 outlines the four modules comprising the training programme, their learning objectives, and duration. The modalities and teaching approaches were carefully crafted and mutually agreed upon. The remote mode entailed asynchronous lectures delivering theoretical content, complemented by live sessions for team-led project development discussions.

Table 1 The module-based structure of the full training programme

Module title	Learning goals	Duration	Modalities	Teaching approach
Module 1 | Systemic design for circular economy in rural areas	1. To gain a broader, systemic perspective on the circular transition of rural areas. 2. To gain basic knowledge on the use of some systemic design tools. 3. To question the state-of-art by identifying the sustainability gaps.	5 weeks 2 sessions per week (10 hours) 1 virtual field visit 1 final presentation	Fully remote: asynchronous lectures + live discussion with teachers + autonomous teamworking sessions	learner-centred approach action-oriented learning transformative learning
Module 2 | New vision on the rural environment: by-products valorisation and waste reduction	1. To gain an overview on circular production in rural industries. 2. To gain basic knowledge on engineering methods to enhance by-product valorisation. 3. To gain basic knowledge on engineering methods to reduce waste.	5 weeks 2 sessions per week (10 hours)		
Module 3 | Sustainable development of the rural area and smart valorisation of the natural resources	1. To gain an overview on circular strategies in agrifood and agroforestry sectors. 2. To become aware of the value of natural resources and their sustainable use 3. To gain basic knowledge on methods to valorise natural resources.	5 weeks 2 sessions per week (10 hours)		
Module 4 | Business management in the framework of circular economy	1. To gain an overview of the main circular business models. 2. To identify the most suitable business models for rural areas 3. To establish qualitative and quantitative indicators to measure the impact of a circular solution.	5 weeks 2 sessions per week (10 hours)		

The third phase of the project was aimed at the interdisciplinary development of CE projects through internships in partner companies, in which teams made up of eight students (two per country/discipline) collaborated to design circular solutions and implemented them on-site.

Therefore, in the MULTITRACES project, design was embedded in an interdisciplinary context in which designers and non-designers collaborated to develop circular projects for and with local industries. The training programme was the crucial activity of the project, and it started with a systemic design-based module to build a shared approach to the CE and provide students with the skills to frame systemic problems.

4.2 Module learning objectives

The “Systemic design for circular economy in rural areas” module introduces the key issues of sustainable development and new production models based on the CE, focusing on rural areas. Then, the module delves into systemic design tools to support the circular transition of rural businesses.

The learning path has been designed to enable students to achieve three main learning outcomes:

1) Students will gain a broader, systemic perspective on the circular transition of rural areas: they will understand key principles and relevant topics of the circular economy and be able to identify the most relevant trends for rural areas in their socio-cultural context.
2) Students will gain basic knowledge on the use of some systemic design tools: they will interpret real-world situations from a systemic and circular perspective and will be able to apply the tools learned to practical cases.
3) Students will be able to question the state-of-art by identifying sustainability gaps and they will be able to find the relevant professionals and experts to address those gaps.

Thus, the module combines specific knowledge of an emerging topic with horizontal skills to underpin interdisciplinary design.

4.3 Module design: Systemic design for circular economy in rural areas

The learning path of the “Systemic design for circular economy in rural areas” module pivots around framing complex sustainability problems in rural areas and defining circular design solutions to tackle them. The design of the module considered three main constraints: the whole course had to be held online, learners had different cultural and disciplinary backgrounds, and each module had to last five weeks. Thus, the module was designed to accelerate the learning of systemic design tools through an incremental pathway to prepare students for collaborative work with rural businesses.

The programme was built on established systemic design methodologies (Jones, 2014; Bistagnino, 2018), but adopted an innovative perspective, partially relying on the Double Diamond process (Design Council, 2004; Pyykkö *et al.*, 2021). This project-based methodology is founded on an action-oriented approach that elevates task-based learning to a level where the team is fully integrated into genuine communicative practices. This places equal importance on individual knowledge and team problem-solving skills. The emphasis is on the learner as an active agent, capable of improving interdisciplinary team dynamics. Ultimately, this aligns with transformative learning, where questioning existing ideas and knowledge to build a new professional vision is a fundamental learning goal for our learners.

The proposed five-week learning path is organised in four steps (Figure 2), alternating theoretical lectures on design tools and teamwork on a practical case study provided by the partner company, Agrindustria Tecco Srl. The first two steps focus on framing problems, starting with a qualitative-quantitative analysis of the socio-technical system covered by the case study. It was crucial to address real-world situations presented by the partner company, which has shown a strong willingness to explore various systemic strategies for CE. The third step focuses on the design of the system based on the criticalities and opportunities identified in previous steps. At this stage, the project includes all possible solutions and, adopting a multi-criteria framework, it defines an ideal system in which all options are implemented. The last step concerns the study of the outcomes of the proposed solutions and their assessment through stakeholder feedback. The interventions designed by the students focused on the most feasible and effective solutions, leading to a set of systemic possibilities that stakeholders can further develop and put into practice. The collaboration with the partner company ran throughout the design process but was more intense in the first and last phases to enable students to frame the existing system and define a roadmap for implementing systemic solutions.

Five theoretical sessions, each lasting one hour, covered key aspects of systemic design, from CE principles to systemic design history, analysis methods, and data visualisation tools. The module was held online on a dedicated Moodle platform that allowed the theoretical lectures to be recorded, shared, and commented. Ten sessions on the practical case study took place synchronously on a video conferencing platform. Specific digital tools were presented and facilitated to support teamwork: the use of Miro (2024) as a collaborative tool was especially effective. A virtual two-hour field visit to the partner company and several discussion meetings with the students were also organised.

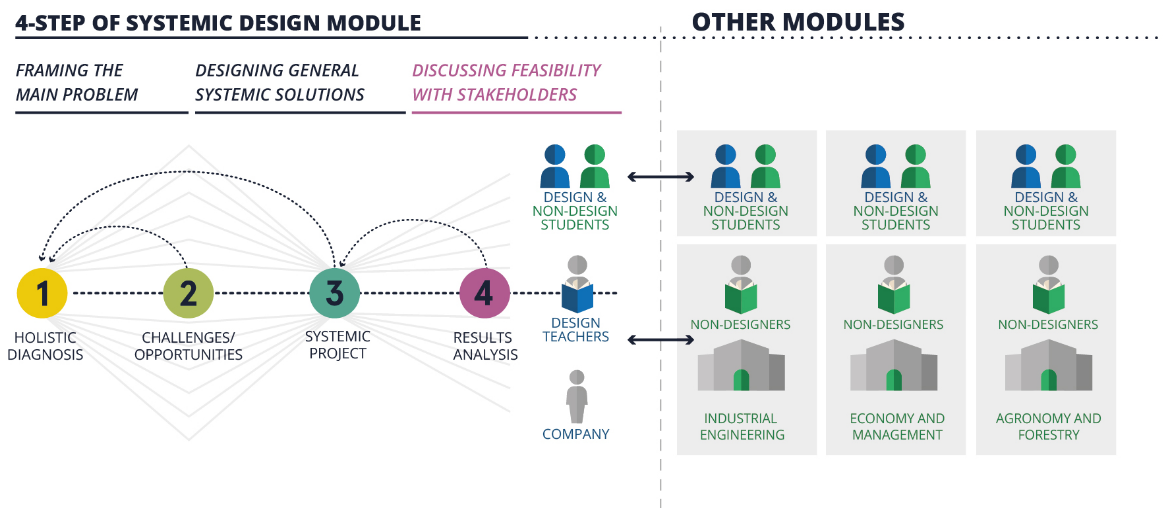

Figure 2 The MULTITRACES methodological path of the systemic design for circular economy in rural areas module. Source: authors' own work.

Overall, the teaching of theoretical knowledge and design methods was functional to the experimentation of what was learnt in the practical case study. This was called a 'mini-challenge', as it was a team-working educational activity designed in collaboration with the partner company, which proposed three main challenges related to the CE:

1) Industrial application of dyeing plants from a life-cycle perspective;
2) Valorisation of natural porous materials, especially for soundproofing; and
3) Enhancement of by-products and waste from the brewing process.

Two to three interdisciplinary and intercultural groups worked on each topic, following the 4-step methodology to better understand the context, frame the problems, and design possible systemic solutions. Each group was tutored by a systemic design expert who supported students through the mini-challenge. Also, the company CEO was involved in a weekly discussion with students, in which he provided effective and practical feedback to the groups for possible implementations of the circular solutions presented (Aulisio *et al.*, 2021). These experiences allowed students to develop what Dewey (1938) called a learning-bydoing approach, enabling both designer and non-designer students to approach the subject by putting into practice notions and theoretical insights seen through the eyes of experts (Sikandar, 2015).

4.4 Evaluation of the learning outcomes

The interdisciplinary and cross-cultural module provided a positive experience for the authors and the other teachers involved. Feedback from the teachers was obtained through both course meetings and informal interviews. Some of these interviews were also shared externally through videos posted on YouTube. In addition, the authors created project reports that included a part of individual comments on activities, stressing successful outputs but also limitations. These reports served as a monitoring tool and a means of documenting results for the European funding agency.

However, teachers’ perceptions cannot provide a comprehensive and objective evaluation of students' learning experiences and the skills and knowledge they have acquired. For this reason, two evaluation methods have been implemented to assess the attainment of learning outcomes:

1) A cross-analysis of the results of the mini-challenge to evaluate the understanding of the design tools, the ability to apply them, and the knowledge gained about sustainability.
2) A post-module questionnaire for students to assess their engagement and main competencies acquired by designers and non-designers.

The combination of the two evaluation tools made it possible to draw verified conclusions on the effectiveness of the training and its possible improvements.

4.4.1 Cross-analysis of students’ projects

The mini-challenge systemic projects were a direct reflection of the students’ understanding of the theoretical and methodological aspects of the course. Thus, the authors conducted a comprehensive analysis of their systemic projects to evaluate their understanding and mastery of the provided tools. While the analysis was collective due to the collaborative nature of the projects, it was valuable to delve deeper into the results and integrate them with individual surveys, considering the importance of teamwork within the module.

An assessment matrix has been created, based on three main criteria, which are evaluated according to specific parameters:

1) *Application areas*: systemic projects should include solutions that apply to industrial, cultural and design sectors. A correct balance of the three areas shows the proper understanding of a systemic approach.
2) *Learning areas*: systemic projects address complex problems that require contributions from different disciplines. The balance of the four disciplinary backgrounds involved in the module shows a teamwork ability to tackle the problem.
3) *Sustainability focus*: systemic projects pursue sustainable development; as such, they should consider economic as well as environmental and social dimensions. Balancing the 3Ps (People, Planet, Profit) of sustainability in the proposed solutions is a criterion for assessing that a systemic vision has been applied.

Different parameters were rated by the tutors who followed the student groups during this course. The rating scale ranges from 0 to 5, based on a generic evaluation rubric (Stevens and Levi, 2005). A rating of 0 denotes an absence or incompleteness of a parameter, while a rating of 5 signifies an excellent accomplishment of the project parameter.

4.4.3 Post-module questionnaire

The interdisciplinary approach permeates the whole learning process. To effectively assess the impact of this approach, a specific questionnaire was administered to the students who took part in the systemic design module, focusing on their individual and group experiences.

The survey has been divided into four sections: general data, prior knowledge, teamwork, benefits and challenges. Each section was assessed through a series of close-ended questions about the training and exercise carried out. Ratings were expressed in a range from 1 to 5. At least one question per section was open-ended to allow students to report qualitatively on their experience. The pool for this survey included 56 students, while the final sample comprised 33 respondents (response rate: 59%), representing a statistically relevant sample for the study. It should be noted that all designers participating in the module responded, while the sample of non-designers accounted for 45% of the pool. This is probably due to a more direct relationship with the design students, to whom the questionnaire was solicited by e-mail and verbally. To analyse the results, the authors divided the sample according to the background, as teaching a mixed group of designers and non-designers was the main novelty and challenge for the course.

5. Findings

All teachers involved in the module provided positive evaluations of the experience. Based on informal interviews and feedback gathered in meetings, it became apparent that the most beneficial aspect was the opportunity to effectively experiment with new methods for intensive teaching of systemic design to a mixed learning group. The diverse nature of the group also posed the main challenge, particularly in teaching non-designer students to use specific design tools. For instance, teachers specialised in data visualisation pointed out that the effectiveness of visualisation hinges not only on software knowledge, but also on the ability to graphically organise data – skills that cannot be mastered in such a short course.

5.1 Cross-analysis of students’ projects

As explained in the methods section, an assessment matrix has been created to evaluate the students’ projects realised within the mini-challenge. The matrix is based on three main criteria: application areas, learning areas, and sustainability focus. Each criterion is assessed through specific parameters that are rated from 1 to 5.

In Figure 3, an overview of the comprehensive analysis is presented. This includes succinct descriptions of each project, the principal elements of the proposed solution, and the illustration of the three criteria via radar charts depicting the assessment of the parameters. It is evident that the topics covered are varied, and the solutions to the same challenge differ significantly, indicating autonomous and critical group work. Additionally, all the works present a comprehensive approach to the CE, not focusing only waste but rather on new, cross-sectoral products.

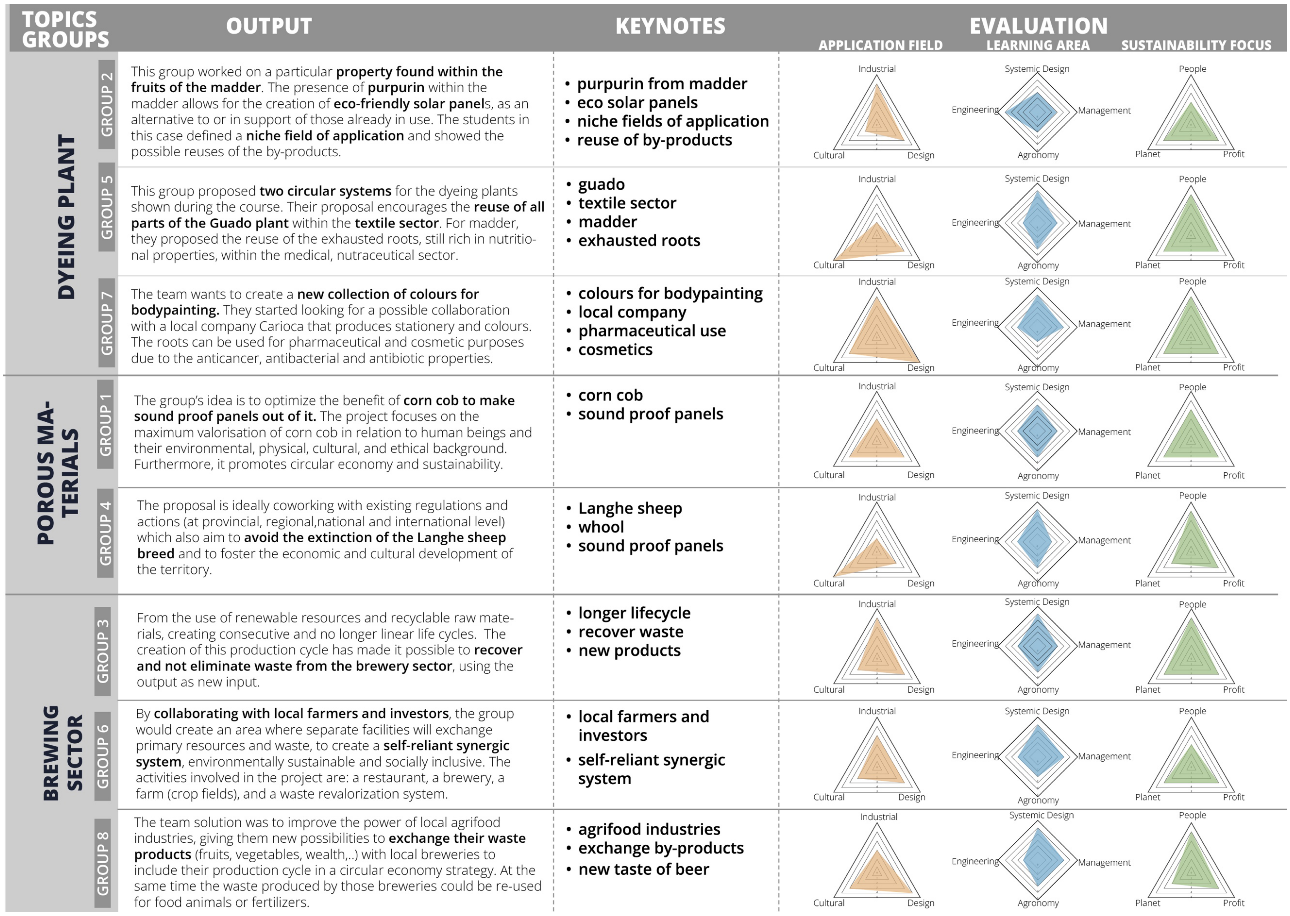

Figure 3 Cross-analysis matrix of the student groups’ projects elaborated within the mini-challenge. Source: authors' own work.

Starting from the general analysis, the graphs were combined to formulate an overall assessment of the students’ works, as illustrated in Figure 4. The systemic projects were focused on different areas of application. While some projects aimed to innovate the industrial process of the partner company, others addressed the social value of the supply chain. In most cases, the focus was on designing a multi-actor system that disrupted the existing one. This outcome aligns with the anticipatory competence of systemic design and the forward-looking vision proposed to the students. Regarding the learning areas, the projects provide insights and content across all disciplinary backgrounds, showcasing a well-rounded set of skills within the groups. Upon consideration of the focus on sustainability, most groups were able to develop solutions that carefully incorporated social, environmental, and economic factors. In isolated cases, an undue emphasis on social or economic sustainability was evident; this was attributable to specific design choices, such as solutions capitalising on the social value of a supply chain, or to the temporal constraints impeding a more profound exploration of all sustainability dimensions.

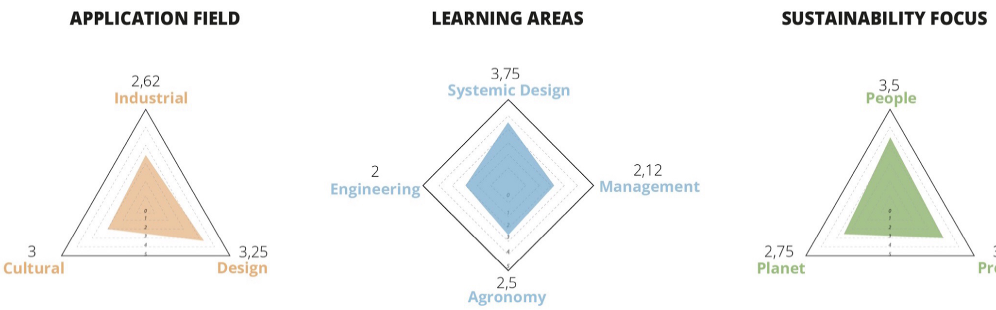

Figure 4 Overall analysis of students' systemic projects based on the three main criteria. Source: authors' own work.

5.2 Results of the questionnaires

The survey has been divided into four sections: general data, prior knowledge, teamwork, benefits and challenges. Figure 5 shows the breakdown of respondents based on their design or non-design background and the general level of satisfaction with the module structure (theory and practical activity): both groups are satisfied with the module and with what they learned on a theoretical and practical level. This is particularly relevant since most of the students had never dealt with systemic design and, in general, had limited knowledge of the CE. Therefore, the practical dimension closely linked to experiential learning has proved to be an excellent method for engaging and motivating students.

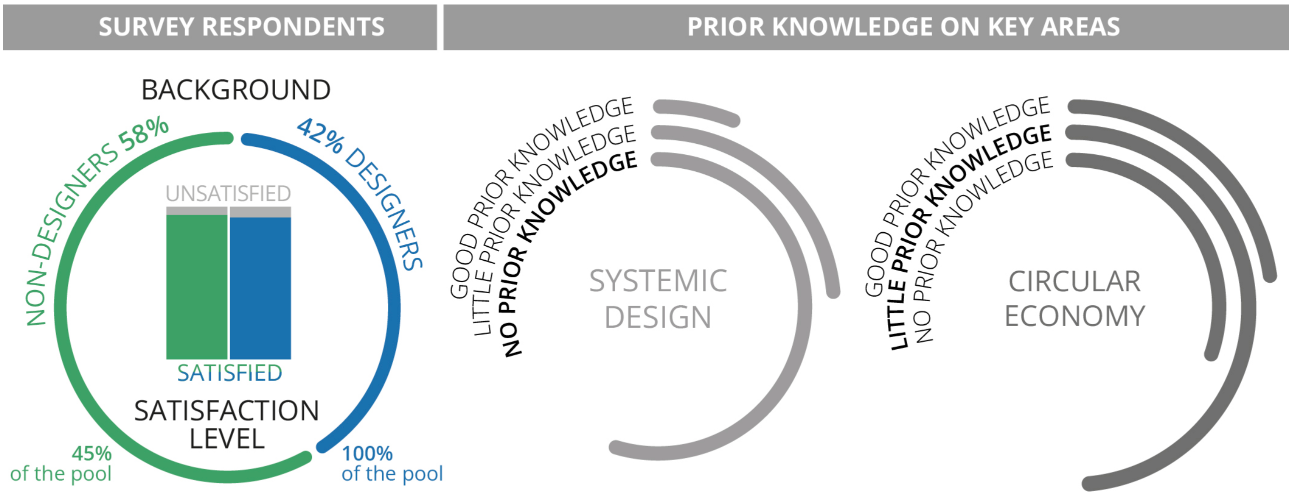

Figure 5 Classification of the sample and analysis of background knowledge and general satisfaction. Source: authors' own work.

Figure 6 reports the main benefits that students feel they received from the course as well as the main challenges they faced. To facilitate the analysis of key aspects, respondents were asked questions concerning the practical activity (mini-challenge) and teamwork, stressing the importance of their individual rather than collective perception. The distinction between designers and non-designers was maintained to compare the benefits and problems that the two categories may experience in a systemic design course.

Regarding practical activity, both designers and non-designers believe that activities involving the practical application of systemic methods enabled them to better learn tools that can be used in their university or professional future and generally provided a better understanding of the sustainability and circular economy topics addressed in the course. The interest in future applications is especially emphasised by non-designers, who point it out as the first overall benefit of the module. Regarding challenges, both groups stress problems related to the virtual environment; in particular, online tutoring is not as effective as in-class tutoring since face-to-face discussion with teachers is invaluable, especially in practical activities. Also, designers experienced difficulties in teamwork during the practical activity, probably due to being experts in the field and being forced to play a leadership role in the project; instead, non-designers experienced challenges with the complexity of the proposed challenges, which required multi-level solutions.

Regarding teamwork, for both groups, working in intercultural teams was enriching, as was the difference in disciplinary backgrounds. Designers also highlighted how working in groups improved their online experience, making them feel less lonely in the learning journey. As for the challenges faced, both groups report problems with communication with other students, mainly due to the difficulties of communicating through digital media and finding a trade-off between different education commitments and schedules. This contributes to the perception that teamwork requires more personal effort than individual learning. Certainly, the virtual environment and the interaction with different cultures and disciplines demand a greater commitment than standard curricular in-class courses.

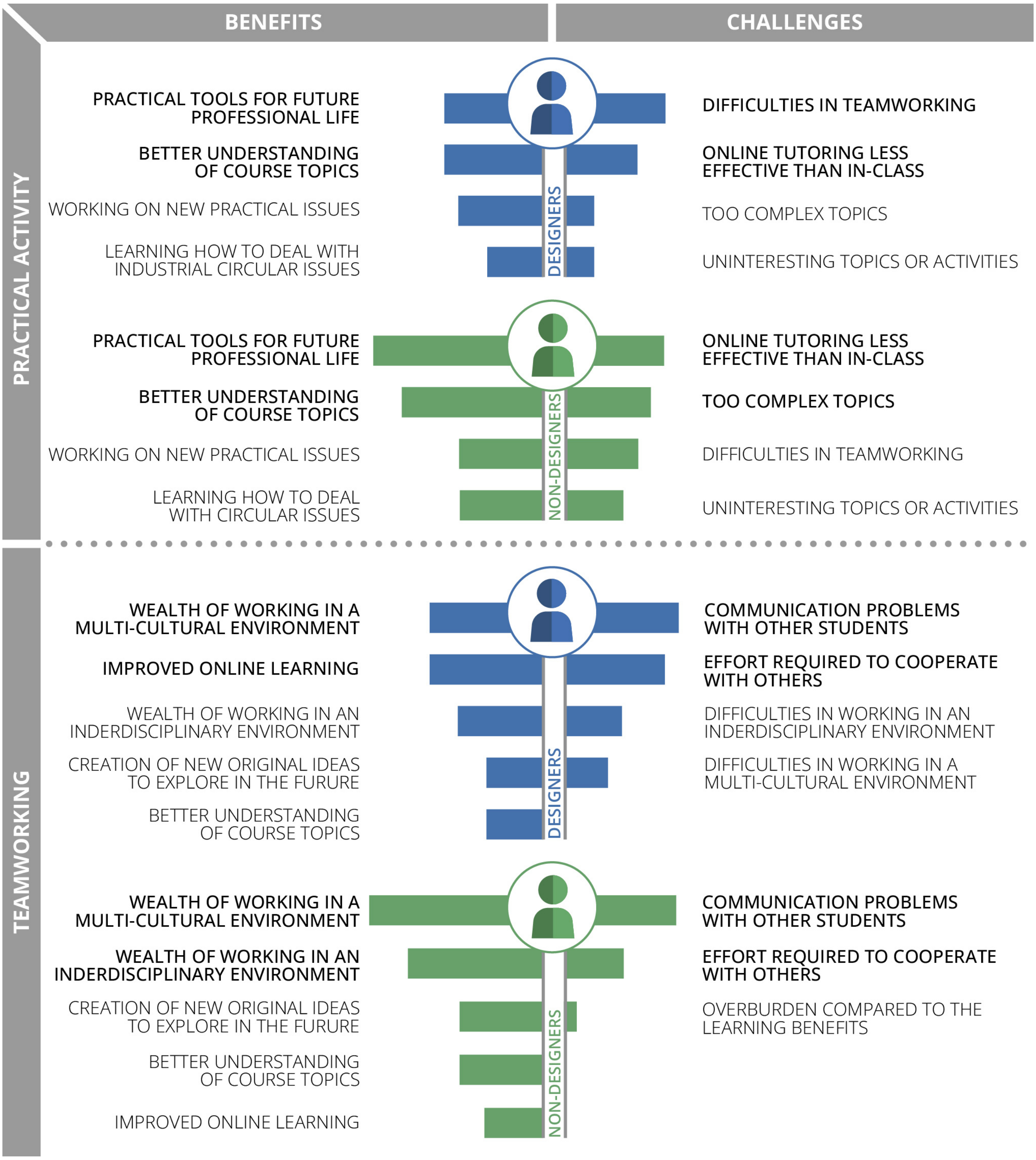

Figure 6 Benefits and challenges in terms of knowledge gained and course effectiveness. Source: authors' own work.

Overall, the survey results, combined with the cross-analysis of projects, allow us to understand the pros and cons of the educational process experimented on within the module. The experiment showed important educational benefits for both designers and non-designers in the sustainability field. Despite some difficulties related to trans-cultural and trans-disciplinary barriers, students were able to learn and apply the basic tools of systemic design. The module especially aroused the interest of non-designers, who struggled to deal with the design complexity but also gained important inspiration for their future careers in sustainability-related professions.

6. Discussion and Conclusions

Design courses typically span an entire semester and provide both designers and non-designers with the opportunity to gradually learn and develop essential design skills (Bistagnino, 2018). These skills, as defined by the Design Council (2020), include creativity, originality, initiative, critical thinking, attention to detail, and flexibility. Systemic design courses also integrate skills such as visualising complexity, co-design, and envisioning sustainability transitions (see section 2). These skills can support learners in acquiring a holistic vision and addressing complex problem-solving. In general, systemic design courses employ methods that are organised around four 'intents of systems practice', as defined by Jones (2014): understanding, prediction, design, and change.

The learning module discussed in this article introduces an innovative approach to systemic design education for two primary reasons. Firstly, in most design teaching arenas, non-designers typically serve as stakeholders or are individuals highly motivated to learn design. In our case, non-designers were prominently featured as active participants within the design team, engaging in a comprehensive, interdisciplinary training programme. Secondly, the time available was limited to only five weeks, so traditional semester-based methodologies could not be adapted *tout court* to the module. Therefore, the training methodology has been specifically tailored for this module: as illustrated in Figure 7, the aim was to prioritise research intents (understanding and prediction), while focusing on only one intervention intent (design). Following the well-known Double Diamond process (Design Council, 2004), this approach proposes a learning path that leaves the second diamond open, as depicted in Figure 2. This decision was made to address time constraints and enable all learners to acquire fundamental skills in design research and, to a minor extent, in design intervention.

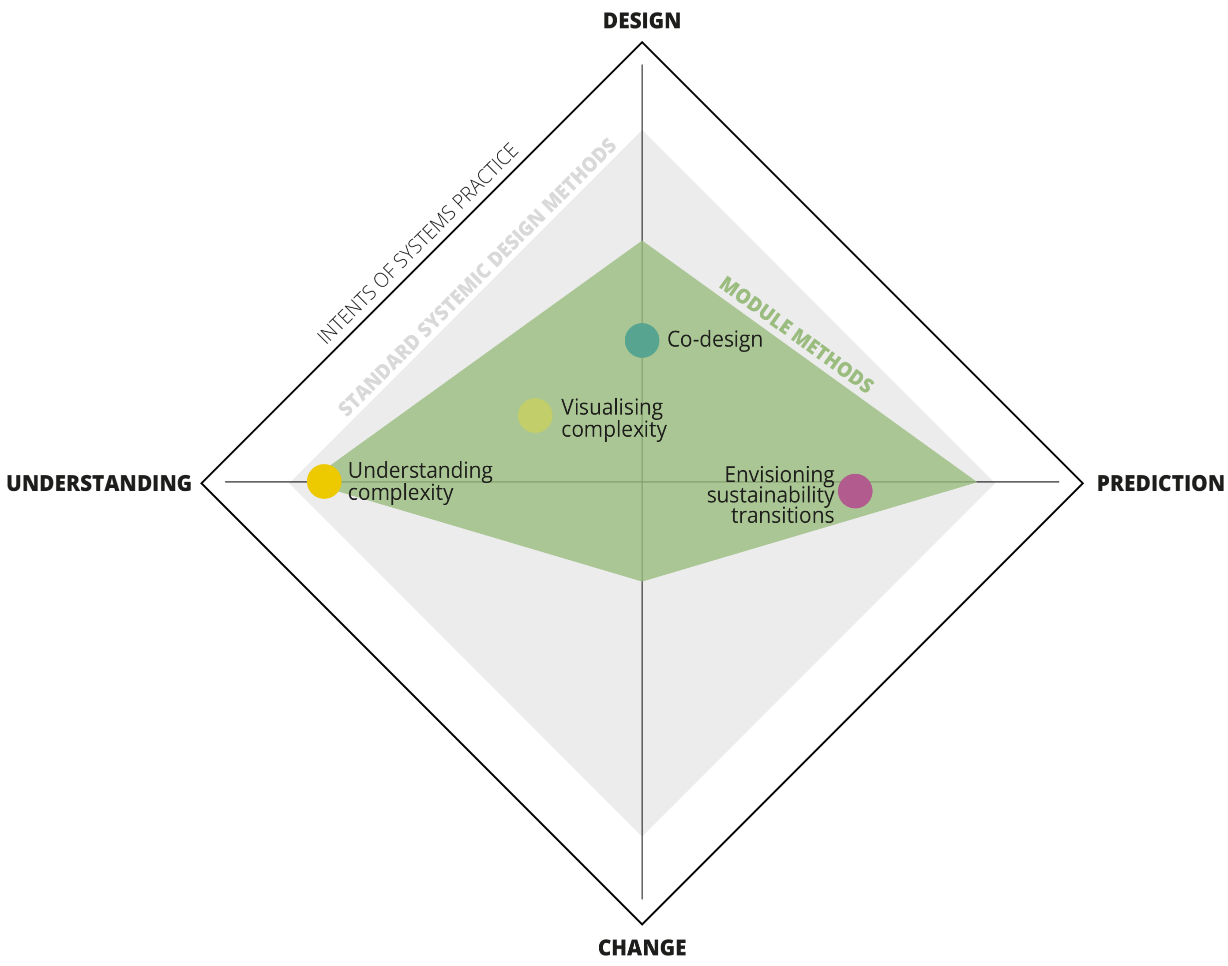

Figure 7 Graphical contextualisation of the module's four areas of systemic design skills within the four ‘intents of systems practice’ (Jones, 2014). Source: authors' own work.

Upon reviewing the students’ projects, it is evident that this was a winning choice. The projects exhibit a strong design component, along with a holistic vision proposing systemic solutions to complex problems. Despite the time constraints, the circular proposals demonstrate a commendable attention to detail and a certain level of originality, particularly in some projects. The absence of the implementation and validation phase, which is crucial for effecting change in the existing system, has not hindered the development of a long-term vision that considers the characteristics of the current system. In relation to RQ2, the methodological approach (refer to section 4.5) and the proposed tools (holistic analysis, complexity visualisation tools, collaborative platforms) have proven effective in assisting designers and especially non-designers in acquiring design- and systems-thinking skills, as confirmed by the questionnaires. The authors acknowledge that administering a pre-course questionnaire would have provided us with a more comprehensive understanding of students' prior knowledge and expectations, as well as facilitated the verification of competencies acquired. This limitation was a result of project constraints; however, this shortcoming has been partially mitigated by incorporating inquiries regarding prior knowledge into the post-course questionnaire. Moreover, synchronous online classes facilitated the collection of informal feedback, allowing us to assess the overall level of knowledge among participants.

In relation to RQ1, the outcomes of the mini-challenges exhibit a well-rounded approach to sustainability. On average, all three crucial aspects - environmental, social, and economic - are conscientiously addressed. Furthermore, systemic projects do not solely focus on end-of-life considerations, but instead advocate for a comprehensive perspective that encompasses the entire life cycle of processes and products. This is critical in the context of new CE models, which aim not merely to enhance existing practices, but to propose alternative approaches to production, consumption, and economic development (Korhonen *et al.*, 2018). From an educational perspective, practical group work, through mini-challenges, has proven to be essential in cultivating team communication, promoting interdisciplinary cooperation, and discouraging individualistic approaches. An action-oriented approach, based on the strong link between individual learning and team collaboration, is especially crucial when the learning group comprises diverse disciplines. Project-based teamwork helps to bridge knowledge gaps among the learners, preventing disengagement from experienced learners and ensuring effective knowledge acquisition for newcomers. For most students, teamwork proved to be a rewarding experience, even in an online format. Nonetheless, the authors believe an initial face-to-face meeting could enhance team building and foster better intercultural communication.

In conclusion, it can be affirmed that action-oriented interdisciplinary learning environments play a pivotal role in the acquisition of essential skills necessary for the sustainable development of local systems. The collaboration in education between HEIs and industries holds the potential to facilitate the transition of rural areas toward a CE. International teamwork facilitated by local team members allows learners to achieve a more comprehensive vision while honouring territorial identity. Recent studies (Baumber, 2022; Brychkov *et al., 2024*; Renfors, *2024*) emphasise the significance of a holistic and interdisciplinary approach to sustainability education in order to support learners in developing systems thinking competencies. In our instance, this was evidenced not only in the pedagogical strategies employed but also in the module’s content, which centred on systemic design methods applied to CE. In the cross-analysis of students’ projects (see section 5.1), systems thinking was an implicit cross-cutting competence that emerged from the team’s ability to balance different application and learning areas while considering all levels of sustainability. For future research directions, specific criteria to assess systems thinking should be defined, as this type of evaluation could provide valuable insights on how to integrate and assess systemic competencies in education for the CE.

Finally, the online mode confirmed some important pedagogical advantages and disadvantages highlighted in the literature (Hakkarainen *et al*., 2024). Our training effectively reduced financial and time investments associated with student mobility; this enabled interactions among diverse disciplines that might not usually engage in the same course and promoted new possibilities for collaboration with local industries. At the same time, our experience confirmed limitations in fostering learner engagement, cultivating a sense of community, and promoting interpersonal communication, particularly within intercultural contexts. This confirms the need for improving tools and methods for online co-design processes, to promote engagement and facilitate interaction among participants.

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