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Full Length Article

Eco-preneurship education and its role in developing sustainability and entrepreneurship competences and eco-preneurial intentions

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ABSTRACT

This study examines how an eco-preneurship course integrated into an engineering curriculum supports the development of entrepreneurship and sustainability competences, as well as the formation of eco-preneurial intentions. Informed by the EntreComp and GreenComp frameworks and the Theory of Planned Behavior, the research investigates how students engage with sustainability challenges through experiential entrepreneurial learning. Data were collected from pitchdeck assessments and semi-structured interviews with eleven participants. Findings indicate that the course fostered the development of a wide range of competences, boosting their confidence in entrepreneurial skills and deepening their understanding of engineering's environmental impact. Although the strength of entrepreneurial intentions varied, many participants experienced a mindset shift, increasingly aligning sustainability with their personal and professional goals. Some began to see eco-preneurship as a viable path, while others emphasized the broader applicability of the competences acquired for their future professional roles in engineering and other fields shaped by technological and sustainability transformations. The study underscores the value of interdisciplinary education in building human capital and mindset transformation and offers exploratory insights on applying the Theory of Planned Behavior in an eco-preneurship context within engineering education.

Introduction

To what extent does the integration of environmental sustainability in entrepreneurship education influence the development of the next generation of eco-preneurs?

In the contemporary globalized and technologically driven economy, Higher Education Institutions (HEIs) face an inevitable challenge: preparing students to work in a dynamic, rapidly changing environment (Pinheiro & Abualrub, 2021). Entrepreneurship education is seen as a crucial vehicle for equipping individuals with the knowledge and competences needed not only to launch entrepreneurial ventures (Volkmann et al., 2010), but also to act upon ideas and transform them into societal, cultural, or financial value (EntreComp, Bacigalupo et al., 2016). As entrepreneurship is about identifying challenges and finding solutions, entrepreneurship education emerges as an enabler for competence development in driving positive change to the environment and society (Hoppe & Namdar, 2023; Rosario & Raimundo, 2024). While several initiatives and policies around the world highlight the necessity for new ventures to tackle environmental challenges, the European Commission has launched the Green Competence Framework – GreenComp (Bianchi et al., 2022), which defines a set of competences promoting more sustainable ways of thinking and acting. Developing competences through education and experience has been described in literature as 'human capital' (Goldin, 2024). Broadly, human capital encompasses the knowledge, skills, abilities, and experiences individuals acquire over time, which contribute to their capacity for productivity and innovation and eventually to economic and social advancement (Becker, 1964; Brüderl et al., 1992; Marvel et al., 2016). Understanding how human capital is developed through sustainable entrepreneurship education warrants further research.

In an era when technological innovation is central to both economic renewal and climate resilience, entrepreneurship grounded in sustainable technologies is increasingly viewed by institutions as a lever for just transitions, green industrial transformation, and future-oriented

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education systems (UNESCO, 2023; OECD, 2023; European Commission, 2022). Scholars and practitioners have also been advocating the necessity to integrate environmental sustainability into entrepreneurship education (Rosario & Raimundo, 2024; Lourenço et al., 2012 ; Lans et al., 2014). The intersection of entrepreneurship and environmental sustainability, often referred to as eco-preneurship (Schaper, 2002; Jakobsen & Storsletten, 2020), presents an exciting avenue for fostering innovative solutions to global problems. Recent studies emphasize that sustainable entrepreneurship education has expanded rapidly, yet the field remains fragmented and dominated by business and management studies (Hesselbarth & Schaltegger, 2014; Diepolder et al., 2021; Rosario & Raimundo, 2024; Makuya & Changalima, 2024). Within engineering education, published work has tended to focus on conceptual models, curriculum mapping or descriptive accounts of student satisfaction (Latham et al., 2023; Ilyas et al., 2024; Gonzalez-Dominguez et al., 2025). These contributions have been important in positioning sustainability as a curricular priority, but they rarely examine how pedagogical interventions actually shape competence development or intention formation. Even when TPB has been applied in sustainable entrepreneurship education in higher education (Tsaknis & Sahinidis, 2025) or to traditional entrepreneurship within engineering education (Souitaris et al., 2007; Valencia-Arias & Montoya Restrepo, 2020), competences and learning processes are often treated as background factors rather than operationalized systematically. This leaves a gap in understanding how engineering students acquire entrepreneurial and sustainability competences, and how these competences influence intentions.

This study addresses this research gap by examining qualitative data from participants who completed an eco-preneurship course, thereby offering insights into how education fosters individuals' capacity and intentions for initiating sustainable ventures. To frame this investigation, this study combines the EntreComp (Bacigalupo et al., 2016) and GreenComp (Bianchi et al., 2022) frameworks, which together outline the entrepreneurial and sustainability competences that can be cultivated through educational interventions. To understand how these competences translate into motivation to act, the study also employs the Theory of Planned Behavior (TPB) (Ajzen, 1991), a widely used model linking attitudes, subjective norms and perceived behavioral control to intention formation. This combined perspective provides a synthesized lens: GreenComp provides the "*why*" behind eco-preneurship, EntreComp offers the "*how*" (Planck et al., 2024) and TPB explains the "*whether*" these competences and values translate into eco-preneurial intentions.

Addressing this gap is relevant both theoretically and pedagogically. From a theoretical perspective, combining competence-based frameworks (EntreComp, GreenComp) with TPB provides a more dynamic account of how intentions are shaped through educational processes. From a pedagogical perspective, evaluating a challenge-based eco-preneurship course in engineering offers insight into how experiential formats can foster competences and intentions simultaneously. This contributes to ongoing debates on the design of sustainability-oriented curricula by moving beyond satisfaction measures to evidence of competence gains and motivational shifts, highlighting the educational impact of integrating sustainability into entrepreneurship training for future engineers.

The following research questions guided the investigation:

1. What types of skills are developed through participation in the eco-preneurship course?
2. What role does participation in eco-preneurship courses play in fostering eco-preneurial intentions?

The study was conducted during the Spring semester of 2024 (January–April) in Cyprus, a small EU member state where entrepreneurship education in engineering is still emerging. The 2022/2023 National Global Entrepreneurship (GEM) Report highlights that post-school entrepreneurial education in Cyprus ranked low among key ecosystem conditions, falling below European benchmarks (GEM Report 2022–2023, Polyviou et al., 2024). This study illustrates how EU-level frameworks are translated into national higher education practice and underscores the importance of examining how an eco-preneurship educational intervention within an engineering curriculum may help bridge the identified educational gap in the Cypriot context.

Literature Review and Theoretical Background

Human Capital in Eco-preneurship Education

Human capital is defined in the literature as the skills, knowledge, and competences individuals acquire through education, training, and experiences, which enhance their productivity and potential contributions to society (Becker, 1964; Brüderl et al., 1992; Unger et al., 2011). Eco-preneurship education represents an educational approach aimed at equipping future entrepreneurs with the skills and mindset to integrate the principles of the triple bottom line (people, planet and profit) into the development of entrepreneurial ideas (Patzelt & Shepherd, 2011). As a result, human capital in eco-preneurship education encompasses the deep understanding of sustainability challenges and innovative problem-solving abilities to achieve market success (Schaltegger, 2002), as well as an active engagement in hands-on, real-world problem-solving through experiential learning (Corbett, 2005; Motta & Galina, 2023).

Research emphasizes the significance of interdisciplinary learning, combining insights from the natural sciences, social sciences, and humanities to achieve a comprehensive understanding of complex sustainability challenges (Rosario & Raimundo, 2024; Yiatros, 2017; Barth & Michelsen, 2013)). Educating future eco-preneurs as '*change agents*' (Hesselbarth & Schaltegger, 2014), involves the development of specific competences around entrepreneurship and environmental sustainability. The development of human capital in eco-preneurship education therefore requires a deep understanding of how learners acquire, apply, and adapt their skills in eco-preneurial contexts. Numerous studies emphasize the importance of equipping future entrepreneurs with sustainability skills, climate impact understanding and innovative thinking (Shepherd & Patzelt, 2011; Cohen & Winn, 2007; Rosario & Raimundo, 2024), yet there remains limited empirical evidence on how eco-preneurship education actually cultivates these competences in practice.

Entrepreneurship and Sustainability competences: EntreComp and GreenComp

Entrepreneurship and sustainability, though traditionally viewed as distinct domains with different goals, are increasingly recognized as interdependent and complementary. At their core, both share the concept of longevity, whether through the preservation of resources for future generations (sustainability) or the creation of enduring solutions (entrepreneurship) (Greco & de Jong, 2017). Similarly, entrepreneurial and sustainability competences seem to have significant overlap (Lans et al., 2014; Ploum et al., 2018). This convergence has led scholars to explore how entrepreneurial and sustainability competences can be combined to foster eco-preneurial capacity. Frameworks such as EntreComp (Bacigalupo et al., 2016) and GreenComp (Bianchi et al., 2022) have emerged as leading models for structuring this integration.

Entrepreneurship competences have been the focus of several studies through the years with scholars identifying key competences for an entrepreneur to succeed: *opportunity recognition* (Shane & Venkatara-

man, 2000; Bird, 2019; Audretsch, 2012), *risk taking and management* (Sarasvathy, 2001), *resource mobilization* (Baum & Locke, 2004; Morris et al., 2013), *resilience and adaptability* (Shepherd, 2003; Stevenson & Jarillo, 2007) and *creativity and innovation* (Drucker, 1985). The EntreComp framework (Bacigalupo et al., 2016) adds one additional competence as a core competence for all entrepreneurs, which is not mentioned in other entrepreneurial competence frameworks (Bernadó & Bratzke, 2024): *ethical and sustainable thinking*. This addition demonstrates the significant role that entrepreneurs play into shaping not only viable economies, but also sustainable societies, highlighting the importance for entrepreneurs to consider the impact of their ideas on the planet.

Complementing EntreComp, the GreenComp framework provides a structured, cross-sectoral model for sustainability education, promoting ways to "*think, plan and act with empathy, responsibility, and care for our planet and for public health*" (Bianchi et al., 2022, p.4). It organizes sustainability learning into four interconnected dimensions: Embodying Sustainability Values**,** Embracing Complexity in Sustainability**,** Envisioning Sustainable Futures, and Acting for Sustainability. These areas collectively frame sustainability not as an isolated topic, but as an integrated, action-oriented component of learning. GreenComp builds on earlier sustainability competence literature (Wiek et al., 2011; Lans et al., 2014; Ploum et al., 2018), synthesizing key competences such as systems thinking, futures literacy, action competence, and interpersonal skills into a unified vision.

Recent research highlights the complementary roles of GreenComp and EntreComp, with GreenComp providing the *why* behind entrepreneurship and EntreComp the *how* to achieve it (Planck et al., 2024; Moon et al., 2022). Together, these frameworks offer a dual lens for understanding and designing sustainable entrepreneurship education. However, although recent evidence shows that sustainable entrepreneurship competences directly predict intentions (Joensuu-Salo et al., 2022), the specific interplay between sustainability competences and eco-preneurial intention remains under-researched. In particular, few studies have systematically applied these established frameworks to analyze how competence development unfolds in educational practice and how it connects to intention formation.

Eco-preneurial Intentions and the Theory of Planned Behavior

Within educational settings, where directly observing entrepreneurial behaviors can be challenging, examining entrepreneurial intentions and the constructs that influence them has been shown to provide valuable insights "*into new venture initiation, even without observing that initiation*" (Krueger & Carsrud, 1993, p. 315). The Theory of Planned Behavior (Ajzen, 1991) offers a robust framework for understanding entrepreneurial intentions, i.e. an individual's likelihood of engaging in entrepreneurial activities, by encompassing three core constructs: attitude, subjective norms, and perceived behavioral control (PBC). These constructs have been consistently used in entrepreneurship education research to assess learners' readiness and motivation (Miliou & Ioannou, 2024; Souitaris et al., 2007; Kautonen et al., 2015), and meta-analyses confirm that TPB explains a significant proportion of variance in entrepreneurial intentions, with PBC and attitudes often emerging as the strongest predictors (Schlaegel & Koenig, 2014). In the context of eco-preneurship, these constructs capture the extent to which individuals value sustainable business practices (attitude), perceive themselves as capable of starting and running a sustainable venture (PBC) and feel supported by their social and professional networks to do so (subjective norms).

In sustainable entrepreneurship education, TPB has been applied to examine how learning experiences shape students' intentions to create ventures that integrate economic and environmental objectives. Recent quantitative studies highlight PBC as the primary pathway through which sustainability education strengthens entrepreneurial intentions (Tsaknis & Sahinidis, 2025; Valencia-Arias et al., 2025. Another recent study emphasizes the role of solidarity values, mediated by attitudes and PBC, as additional predictors of sustainable entrepreneurial intentions (Gimenez-Jimenez & Harc, 2024). Collectively, these findings suggest that in sustainability contexts, attitudes and PBC function as critical mechanisms linking education to intention, while also raising questions about whether current pedagogical approaches sufficiently foster attitudinal and self-efficacy development.

With the growing number of Sustainable Entrepreneurship Education (SEE) programs introduced in higher education (Del Vecchio et al., 2021), several studies have examined their impact on developing eco-preneurial intentions through quantitative methods (Vuorio et al., 2018; Joensuu-Salo et al., 2022). However in eco-preneurship education or SEE, the absence of a widely accepted definition and a limited understanding of how eco-preneurs are formed, highlight the importance of closely examining and deeply understanding individuals experiences (Hill & McGowan, 1999), which may be overlooked in quantitative studies. Consistent with this, Liñan and Fayolle (2015) emphasize the importance of employing more '*comprehensive and qualitative methods'* in designing and performing entrepreneurship intention research. Sustainable entrepreneurship skills and intentions are briefly discussed in literature through qualitative analysis (Bonnet et al., 2006), without providing deep findings on the development of the participants' skills and intentions. This study extends prior work by applying TPB in an engineering classroom, exploring through qualitative data how intention formation is influenced not only by entrepreneurial reasoning but also by sustainability values.

Theoretical contribution of the study

Within the field of entrepreneurial intentions, models such as the Theory of Planned Behavior have been particularly influential, focusing on cognitive antecedents of intention (attitudes, norms and perceived control).While this approach has proven robust in predicting intentions, it has also been criticized for its static treatment of intention as a snapshot measure and for neglecting the developmental processes through which intentions evolve or are being shaped (Krueger, 2007; Nabi et al., 2017). Scholars have argued that entrepreneurial education not only changes short-term cognitions but also shapes identity, values, and competences over time, dimensions that are difficult to capture through traditional TPB constructs alone (Fayolle et al., 2014; Nabi et al., 2017; Lans et al., 2014).

This study advances the field by combining competence-based and behavioral frameworks within eco-preneurship education. While recent studies have applied TPB to sustainability-oriented entrepreneurship (Diepolder et al., 2025; Tsaknis & Sahinidis, 2025), they often treated competences as background factors. Our findings extend this work by demonstrating that EntreComp and GreenComp articulate the competences and values underpinning eco-preneurial learning, while TPB explains how these are converted into intention (Fig. 1). In doing so, the study provides initial evidence that entrepreneurial intentions are not only shaped by cognitive predictors, as assumed in traditional TPB models, but also by the competences and sustainability values which can be cultivated through educational interventions. This theoretical contribution offers preliminary support for extending entrepreneurial intention theory by linking cognitive antecedents with competence- and value-based mechanisms of intention formation in eco-preneurship education.

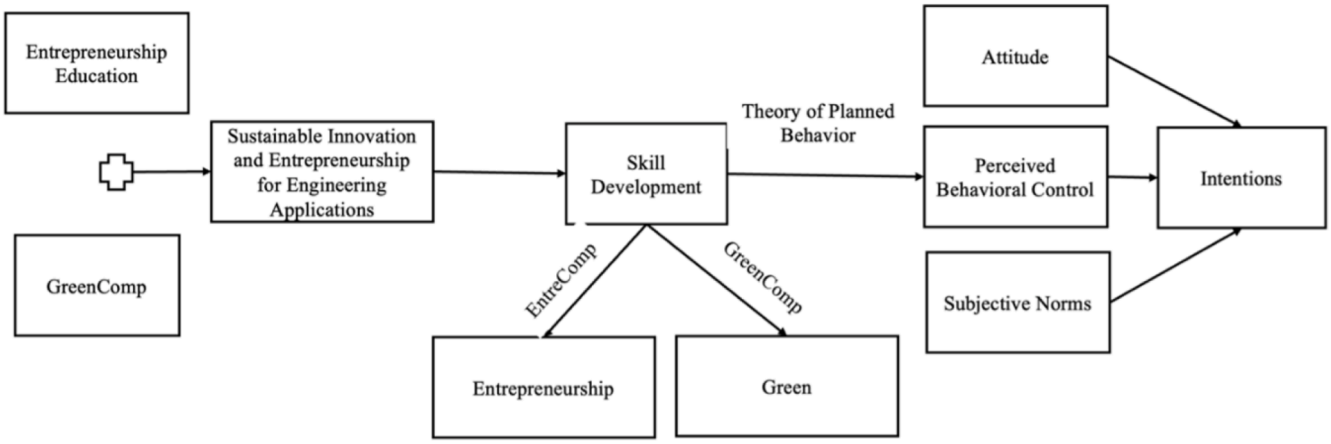

Fig. 1. Conceptual framework linking TPB, GreenComp, and EntreComp in the study design.

Material and Methods

Research Context and Course Design

The study was carried out as part of a semester-long course titled "*Sustainable Innovation and Entrepreneurship for Engineering Applications*", offered by the Civil Engineering and Geomatics Department at the Cyprus University of Technology. This elective course aimed to familiarize students with the principles of sustainable entrepreneurship. It provided training in idea development while fostering skills related to both entrepreneurship and sustainability. The course material was developed using a combination of resources, including the Climate-Launchpad Workbook (Blazer et al., 2020) and systems thinking tools (De Vicente & Matti, 2016), designed to analyze the root causes of challenges.

The course began with an introduction to three challenges the teams had to choose from: (a) Construction and Demolition Waste Management, (b) Low-emissions buildings, (c) Need of digital solutions in the construction sector, requiring participants to develop an entrepreneurial solution to address the chosen challenge. Spanning 13 weeks and conducted in person, the course was structured into four distinct phases: the Systems Thinking phase (3 weeks), the Climate Entrepreneurship Training phase (8 weeks), the Dirty Prototyping phase (1 week), and the Pitching phase (1 week).

Phase 1 - Systems Thinking (Weeks 1–3): The first phase, lasting 3 weeks, introduced participants to the "Systems Thinking" approach. This phase focused on exploring the specific challenge participants selected to address. Throughout this phase, participants conducted thorough research into the broader system underlying the challenge. This included analyzing historical data, identifying key stakeholders, reviewing relevant laws and regulations, and investigating global best practices. This research served as a basis in a brainstorming session employing a Systems Thinking canvas from the EIT Climate-KIC Visual Toolbox, specifically the "Fishing for Barriers" (De Vicente & Matti, 2016). This tool allowed participants to deconstruct the problem into its main categories and identify barriers. This activity provided participants with a comprehensive understanding of the challenge, enabling them to pinpoint the aspect they intended to address and brainstorm an entrepreneurial idea for development.

Phase 2 - Climate Entrepreneurship Training (Weeks 4–11): The second phase, titled Climate Entrepreneurship Training, spanned 8 weeks and was built around the ClimateLaunchpad competition materials (ClimateLaunchpad Workbook, Blazer et al., 2020), an initiative of the European Institute of Innovation and Technology (EIT) and Climate-KIC, aimed at promoting cleantech innovation and supporting startups in this field. This phase consisted of 8 distinct modules, including a module dedicated on Climate Impact, and guided participants through the process of refining their entrepreneurial ideas. Key elements of this program included identifying their initial target market, defining their unique selling proposition, gaining an understanding of basic financial principles and calculating the potential climate impact of their proposed solutions. By the end of this phase, participants had developed a pitchdeck of their idea.

Phase 3 - Dirty Prototyping (Week 12): The third phase consisted of a hands-on, single-session activity designed to create a "dirty prototype" of their idea. Using simple materials such as cardboard, colored paper, scissors, and glue, participants were tasked with visually representing their entrepreneurial ideas. This exercise emphasized the importance of having a tangible prototype or minimum viable product (MVP) for potential pitching scenarios. It also allowed participants to physically visualize their ideas, identify potential areas for improvement, and iterate on their designs.

Phase 4 - Pitching (Week 13): The final phase centered on a live, in-person event where participants presented their ideas to a jury consisting of key stakeholders from the local innovation ecosystem. This event gave teams the opportunity to pitch their ideas (as shown in Table 1) and receive feedback from professionals in the field, ensuring the culmination of their semester-long journey into eco-preneurship.

Table 1
Eco-preneurial projects.

Project title	Description	Challenge tackled	Participants
MagnetMorph	Utilizing magnetic simulations to create reusable 3D models to improve client understanding in construction design	Digitalization in the Construction sector	P7, P9, P10
FunginEring	Creating mushroom-based insulation panels to replace traditional rock wool insulation	Green Buildings	P3, P5, P6
AsfaMax	Creating eco-friendly asphalt with recycled asphalt and tires to reduce carbon emissions and enhance the durability of road construction materials.	Construction and Demolition Waste Management	P2, P8, P11
Honest Furniture	Repurposing construction waste into sustainable, design-led furniture	Construction and Demolition Waste Management	P1, P4

Methodology

This study employed a qualitative research design, drawing on primary data from pitchdeck evaluations and semi-structured interviews. A deductive thematic analysis was conducted using predefined categories informed by the GreenComp and EntreComp frameworks. Guided by the Theory of Planned Behavior, the research examined how students experienced and responded to a sustainability-focused entrepreneurship course, with particular attention to changes in their attitudes, skill development and short-term eco-preneurial intentions.

Participants

The course entitled *"Sustainable Entrepreneurship & Innovation for Engineering Applications"* included fourteen (14) students, primarily undergraduates and two graduate students. All participants successfully completed the program by pitching their entrepreneurial ideas, earning a passing grade.

All students enrolled in the course were invited to participate in the study. Inclusion criteria consisted of successful completion of the course and willingness to take part in the research, while no exclusion criteria were applied beyond non-consent. Recruitment was carried out through an in-class announcement followed by an email invitation distributed after course grades had been finalized, to avoid any influence on assessment. Eleven students (seven male, four female; mean age 25 years) volunteered to participate at the interviews. The Cyprus National Bioethics Committee approved our interviews (reference number 2023.01.295) on December 5th, 2023. Respondents gave written consent for review and signature before starting interviews.

Data Collection and Analysis

Pitchdeck analysis (RQ1)

The student teams followed a structured template for their presentations, based on the modules taught in the course. The baseline of the pitchdeck comprises 9 slides, including the following elements: (1) Title Slide, (2) Deal Slide, (3) Beachhead Market, (4) Customer Value Proposition, (5) Product, (6) Customer Discovery, (7) Key Financials, (8) Climate Impact and (9) Founders' Dream & Team.

The analysis of the student teams' pitchdecks was conducted to address Research Question 1, which focused on identifying the skills developed through the course, using the EntreComp (Bacigalupo et al., 2016) and GreenComp (Bianchi et al., 2022) frameworks. Each 9-slide presentation was examined through deductive thematic analysis (Braun & Clarke, 2006), guided by the evaluation rubric presented in Annex 1. For every competence in the two frameworks (total of 27 competences), a specific guiding question was formulated to support a consistent scoring process on a 1–5 Likert scale, where 1 indicates minimal evidence and 5 indicates strong demonstration of the skill. Four competences, two from EntreComp (*Motivation and Perseverance; Coping with Uncertainty, Ambiguity and Risk*) and two from GreenComp (*Adaptability; Individual Initiative*), were excluded from analysis due to the lack of observable evidence within the pitchdecks alone. The remaining 23 competences were independently assessed by two researchers using the structured rubric with indicators (Annex 1) and rating on a 5-point Likert scale. The two researchers have familiarized themselves independently with the four pitchdecks and have trained between them using a subset of the data to ensure consistency in data interpretation (Nowell et al., 2017). Annex 2 includes illustrative examples of coding decisions across different competences and teams to demonstrate how the rubric was applied in practice.

Semi-structured Interviews (RQ1 & RQ2)

The interviews, conducted in Greek - the participants' native language, ranged from 30 to 60 min in duration and were transcribed word-for-word by the researcher. Following transcription, the content was translated into English for data analysis. The qualitative data were analyzed using deductive thematic analysis aligned with the study's research questions. Specifically, the analysis focused on participants' sustainability and entrepreneurial skills development, as well as the role of the course in the development of eco-preneurial intentions (Patton, 2002). A deductive coding scheme was developed using predefined categories derived from the EntreComp and GreenComp frameworks, as well as the Theory of Planned Behavior (TPB).

Code saturation was achieved after nine interviews, when no new codes emerged. Meaning saturation, defined as the stability and nuanced elaboration of existing codes, was confirmed during the subsequent two interviews (Hennink & Kaiser, 2022). This sample size is consistent with established methodological research showing that six to twelve interviews are often sufficient to achieve thematic saturation in relatively homogenous groups (Guest et al., 2006). Data collection ceased once two consecutive interviews yielded no new insights, providing confidence that the sample was adequate for rigorous thematic interpretation.

To ensure credibility and consistency in the analysis, a systematic multi-step process was followed. Both researchers began by independently reading and re-reading all interview transcripts to develop a comprehensive understanding of participants' experiences and perspectives. Initial joint discussions were conducted to share observations and align on a coding approach informed by the study's objectives. Approximately one-third of the 11 transcripts were randomly selected and coded independently by both researchers using this shared framework. The resulting coded transcripts were compared, yielding an intercoder agreement exceeding 85 percent. Discrepancies were resolved through discussion and consensus, leading to a refined and consistently applied coding scheme. The lead researcher then coded the remaining transcripts using the agreed framework. Both researchers reconvened to review the full coded dataset and finalize the thematic analysis. Finally, methodological triangulation was applied by comparing interview findings with pitchdeck assessments, thereby enhancing the credibility and validity of the results.

Ultimately, six themes were identified, shaped by the research questions and issues highlighted in the literature. Of these, two themes (Themes 1 and 2, with 5 and 4 sub-themes respectively) addressed the first research question (RQ1), while the remaining four themes (Themes 3–6) addressed the second research question (RQ2), as outlined in the next section.

Findings

Findings from pitchdeck analysis

After independently reviewing and familiarizing themselves with each student presentation, the two researchers evaluated all 23 competences drawn from the EntreComp and GreenComp frameworks. Cohen's kappa statistic was calculated to assess interrater reliability, yielding values between 0.62 and 0.70. Both the average value ($\kappa = 0.66$) and each group of competences respectively, are considered substantial (McHugh, 2012). Any discrepancies in scoring were subsequently resolved through consensus discussions. The final scores for each team's pitchdeck are presented in Table 2. Given that 23 competences were assessed per presentation (as detailed in Annex 1), the maximum score per pitchdeck was 115 points when assessed by one

Table 2
Pitchdecks, total scores and Kappa values.

Pitchdeck title	Total score	Kappa value
AsfaMax	164	0.67
FunginEering	163	0.64
Honest Furniture	161	0.62
MagnetMorph	159	0.70

researcher and 230 points in total across both raters.

All presentations scored relatively high, which may be linked to the use of a standardized template, prepared alongside the course modules. This may suggest that integrating modules such as Climate Impact or Key Financials in the course and consequently in the pitchdeck template, incites the student teams to reflect and research on these elements, thereby supporting the development of the respective competence.

Findings from interviews

The final themes represent recurring patterns across participant narratives and are directly aligned with the study's two guiding research questions. Themes 1 and 2 address RQ1, which explores the types of skills developed through participation in the eco-preneurship course. Theme 1 captures the development of entrepreneurial skills, while Theme 2 focuses on sustainability-related competences, as they emerged from the EntreComp and GreenComp frameworks. Themes 3 through 6 correspond to RQ2, examining the role of the course in shaping eco-preneurial intentions. Specifically, Themes 3, 4 and 5 relate to constructs of the Theory of Planned Behavior (TPB): attitudes, perceived behavioral control and subjective norms, respectively. Theme 6 reflects participants' evolving eco-preneurial intentions and the extent to which sustainability was integrated into their entrepreneurial outlook. Together, these themes offer insight into how educational experiences influence both competency development and intention formation, as shown in Fig. 2.

Theme 1: Skills related to Entrepreneurship

Working with others. Participants reflected on how teamwork was essential in shaping ideas, with one explaining: "*I learned that we need to be a team to make the idea more convincing. It is better to collaborate with other people to come up with a good idea*" (P6). Beyond generating ideas, participants valued the opportunity to engage in meaningful dialogue, noting that the course helped them develop "*a better ability to dialogue and listen to fellow students*," adding, "*we could build on each other's ideas and come up with a better idea*" (P2). The importance of collaboration extended beyond idea generation to execution: "*even those little things […], if everyone did them on their own, [it] wouldn't work out. We all had to be together.*" (P1). This project demanded true teamwork, as another participant remarked, "*in all the other courses you could do it alone, [but] not in this one. If we didn't collaborate, it wouldn't have worked out.*" (P3).

Valuing Ideas. As described in the EntreComp framework this skill includes the ability to judge what value lies in an idea in social, cultural and economic terms. One participant reflected on how the process pushed them to judge their ideas from multiple perspectives: "*We developed critical thinking about entrepreneurship and the process of thinking about an innovative idea, and also looked at different factors: society, the environment, us as individuals and as a team*" (P6). Recognizing the importance of an evaluative approach, another participant shared how they began to discern the true value of their ideas and make intentional decisions: "*I also learned to reject things, not to see everything so perfectly. […] I learned both to see some opportunities and to reject some*" (P3).

Vision. Participants reflected on how pitching their ideas helped them imagine future scenarios, refine their concepts, and shape a clear vision to turn ideas into action – as presented in the EntreComp framework. For many, the course provided their first experience of articulating an idea in a way that could inspire others: "*I've never had the chance to pitch a product of my own, it was the first time, and the pitching helped. I gained skills like proper posture, how to present a product*" (P7). Others emphasized the importance of delivering their vision in a compelling and engaging way to ensure it resonated with audiences. One participant explained, "*On the pitching side, the skills I gained were the confidence to speak to an audience, the ability to present with a dynamic nature and being able to present with an open posture to your audience.*" (P2). Participants also reflected on the role of tools such as a pitchdeck in helping them craft their vision with clarity and precision. As one participant noted, "*The structure of the pitchdeck, it's nine slides, but it has a lot of things in them. You start from quantity, and then you go to quality and sum it up in a pitchdeck*" (P4), highlighting how creating a structured

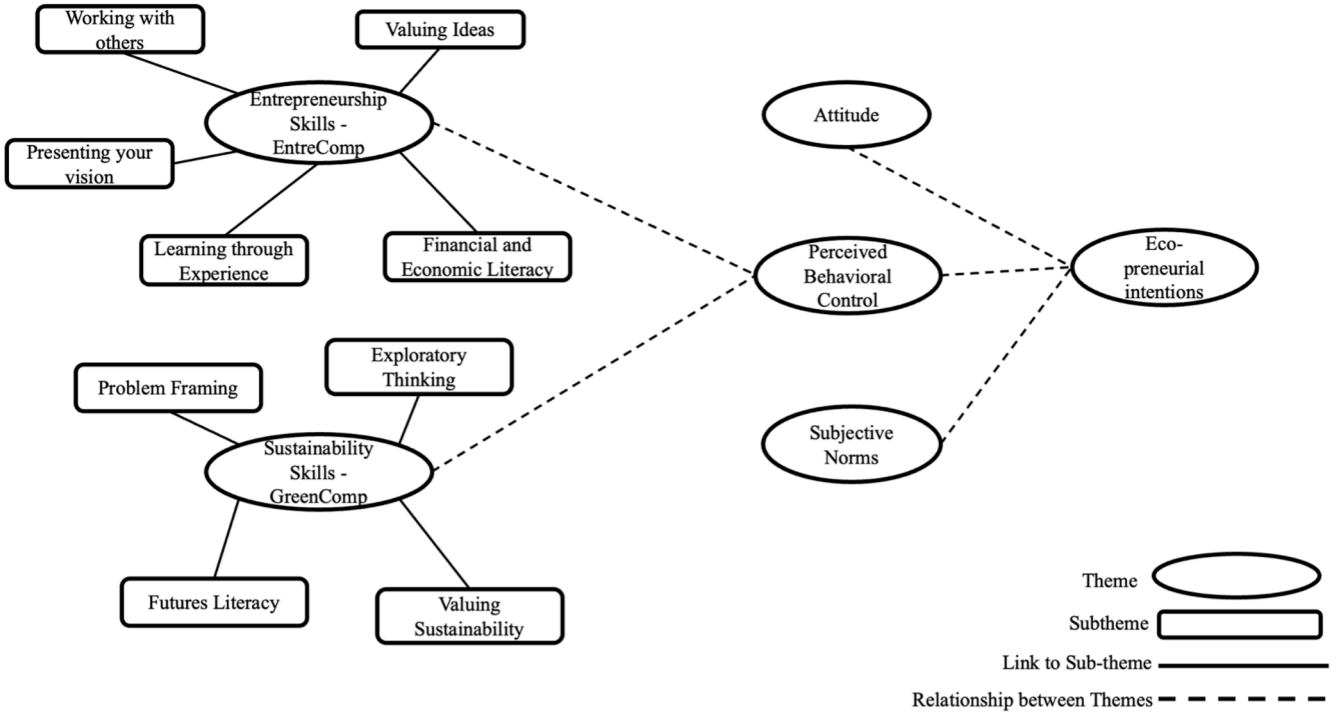

Fig. 2. Conceptual framework connected to the major themes emerged from interviews.

plan helped them visualize the steps to bring their ideas to life.

Learning Through Experience. The course helped participants develop a hands-on understanding of the entrepreneurial process. Many reflected on how experiential learning challenged them to think critically and address real-world aspects of bringing a product to life. One participant explained, *"We had found our idea, but we also had to see if it was functional, how many years our product would last, how much should it cost, how should it be manufactured, what materials, how should we assemble it? How are we going to start, where are we going to sell it?"* (P9). Another highlighted the importance of breaking down complex tasks into manageable steps, noting that, *"almost everything, as big as it seems, you can break it into smaller pieces,"* while also emphasizing that the course was about turning abstract ideas into something concrete: *"It's the translation between 'I have an idea' and 'I share my idea,' learning how to frame thoughts in business terms and use tools like a pitchdeck to communicate"* (P4). The experiential structure also revealed the value of progression, as another participant noted, *"If I had seen these things at the beginning, I wouldn't have understood anything. But by the end, working step by step, we understood what we were saying and what the others were presenting"* (P1).

Financial and economic literacy. The course enabled participants to estimate the costs of turning their ideas into value-creating activities. For many, engaging with financial concepts and tools led to transformative insights. One participant described their experience: *"It was a shock when I saw actual numbers, it's like, wow, you know… And that financial sheet, it really just shows you numbers, like, oh, maybe that's how much money this idea could make, and it has to reach that many people."* (P4). The course also expanded participants' understanding of the financial aspects of running a business, building on their existing knowledge. One participant stated, *"I gained [skills] in financials, it wasn't something we generally learn as civil engineers." (P3)*. Another participant highlighted how the course filled gaps in their understanding of moving an idea forward financially: *"Financials in particular. I had no idea how we could move forward in business in relation to money…, not how to go to the market."* (P10).

Theme 2: Skills related to Sustainability

Valuing Sustainability. Participants highlighted the importance of being environmentally conscious in their decisions and actions. One participant emphasized the need "*to have critical thinking, to be environmentally friendly, to be more aware, to fight for the environment*," and to develop ideas "*from the beginning to be right… better for the future*" (P5). Similarly, another participant reflected on how the course helped shift their mindset: *"Before the course I was indifferent, and then after we got into the process of thinking about our idea, … it helped me understand more that the environment is a factor I have to take seriously both in developing a business idea and in life"* (P6). For some, the course highlighted aspects of sustainability they had not previously considered, leading to a deeper understanding of environmental impacts. One participant noted, *"I was unconcerned, to a fairly large extent, about the environment. Until I did the course and I realized the seriousness of the situation"* (P7). Another participant shared that for the first time they calculated environmental impacts thoroughly, saying, "*it was quite important, I never calculated environmental impact before… We calculated all the possible pollutants."* (P3).

Problem Framing. This was a key skill participants developed during the course, enabling them to formulate current or potential challenges as sustainability problems. Reflecting on this skill, one participant emphasized the importance of fully understanding the problem before taking action: "*I also learned that you need to realize the problem you're trying to solve before you try to solve it*" (P4). The course encouraged participants to move beyond surface-level observations, analyzing the roots of issues to develop approaches that not only address challenges but also promote sustainable solutions. As one participant explained, "*I think that the course helped me to have more critical thinking, to be able to look deeper into the roots of the problem and not just see it superficially, which I think is an important element to have for someone who wants to be involved in entrepreneurship"* (P2). Additionally, participants gained practical tools to frame sustainability problems strategically while considering the required resources and stakeholders involved: *"we learned how to put the needs down, find the problem, understand the economics, find our persona, our beachhead market, etc."* (P1). This skill aligns strongly to the Spotting Opportunities competence of the EntreComp Framework.

Exploratory Thinking. This skill enabled participants to link disciplines, think creatively, and experiment with novel ideas or methods, as described in the GreenComp framework. Participants highlighted the challenge of balancing construction practices with environmental concerns: "*in civil engineering… we create buildings that always have an impact on the environment… we need to have an idea of how to do it without negatively affecting it"* (P10). The course emphasized the need to innovate within harmful industries like construction, where traditional practices prioritize profit over sustainability. As one participant noted, *"the construction sector is actually very harmful to the environment… Bringing this thinking to such an industry is more useful [than] to some other industry. If you did this course in business [studies], it would not have the same impact as it would have on future engineers making material decisions"* (P3). Another stressed the importance of "*choosing more environmentally friendly materials, taking the environment into consideration more than using the same things that everyone else uses"* (P7).

Futures Literacy. This was a key skill reinforced by the course, preparing participants to envision alternative sustainable futures by imagining and mapping out scenarios, as well as identifying the steps needed to realize a preferred sustainable future. As one participant explained, "*we had to look at materials that impact the environment… and come up with an alternative that enhances the environment and doesn't pollute it through processing or through mining"* (P6). Another emphasized this forward-thinking mindset, stating, *"if I'm going to do something that makes the environment worse, I personally won't do it. I'll try to find something else that's more environmentally friendly"* (P9). The course also encouraged participants to think about broader societal needs when planning for the future. One participant described their goal-setting process: "*I set what exactly I want to look for: What problems does society have? Where can I address it? … What benefits are there? Or what can society benefit from this product… and who can use it?"* (P8). Futures Literacy aligns with the Vision competence of the EntreComp framework.

In response to RQ2 evaluating the role of the sustainable entrepreneurship course in fostering eco-preneurial intentions, four themes emerged, including the TPB constructs influencing intentions (attitudes, perceived behavioral control and social norms), as well as eco-preneurial intentions directly.

Theme 3: Attitude. The course shaped participants' attitudes, both positive and negative, towards sustainability and green entrepreneurship, fostering a sense of possibility while also revealing challenges inherent in the process. On the positive side, many participants expressed enthusiasm and a newfound commitment to sustainable practices. For instance, one participant stated, "*it is a nice experience to have a green business that will help the environment… it is something that links all the areas that I think it is good for a person to think about*" (P10). Another participant expressed excitement about taking action for the environment, noting, "*at the first opportunity I will definitely get involved in green entrepreneurship… you see that it has a positive impact on our environment*" (P11). A participant even noted a shift in career preferences, such as one who said, "*I'd rather be a green entrepreneur than a civil engineer"* (P7). This sense of optimism was often tied to personal growth and readiness, with participants emphasizing their preparedness and perseverance: "*I am aware of the steps needed, I have them. I have a good*

mentality to not give up when the first problem arises" (P4). The course also broadened perspectives, as another participant reflected, *"through this course, it has given me that ability to keep sustainability and green entrepreneurship in mind. Before it could have not even crossed my mind"* (P2).

However, not all attitudes were uniformly positive. Some participants expressed concerns about the challenges and uncertainties of implementing green initiatives. "*The course showed me that it's not a simple thing; it's too hard, you need too much strength and the hours in the day are few*" remarked one participant (P1).

Theme 4: Perceived Behavioral Control. The course had a notable impact on participants' perceived behavioral control regarding sustainable entrepreneurship, enhancing their sense of readiness and capability to some extent, while also highlighting areas where further learning might be needed. On the positive side, many participants expressed increased confidence and determination to pursue sustainable business ventures. For example, one participant shared, "*it helped me to be both more ready and more determined to create a business, projecting an idea that is innovative and attractive*" (P6). Another participant noted that the skills and steps learned during the course made them feel more prepared to take actionable steps forward, stating, *"it helped a lot, because it gave me these skills, these steps, I think it made me more capable of being able to move forward in the stages of a business"* (P10). Some participants highlighted their boosted confidence, such as one who said, *"I'm more confident now to build an idea and share it"* (P4). Similarly, another remarked on how the course shifted their mindset*: "Before, I thought I couldn't… Now I realized that yes, it is possible to do it."* (P1).

However, participants also reflected on limitations in their perceived preparedness, indicating areas where further support and knowledge might be necessary. One participant admitted, *"I think there are so many things I would like to learn that I don't know"* (P7), while another noted, *"you can't just from one course, 3 months, say I know everything that is needed"* (P5). This suggests that while the course positively influenced participants' confidence and determination, continued education and experience are essential to fully equip them for the challenges of green entrepreneurship.

Theme 5: Subjective norms Subjective norms surrounding green entrepreneurship reflected the varied degrees to which others' attitudes and opinions affected their decisions. On the positive side, several participants felt encouraged and inspired by the support and interest they received from others. For instance, one participant mentioned, *"they were very positive. It affected me positively because they were interested, and they gave me the opportunity to talk and open up about it."* (P2). However, participants also expressed varying levels of independence in making their own choices, regardless of perceived support or skepticism from significant others. For some, others' opinions had little to no impact on their determination. One participant confidently stated, *"if it's something I want to do, I will do it. Whether they would support me or not is not something that concerns me."* (P9). Another echoed this sentiment, saying, *"If I consider one day that I want to open a green business, I will open it. If they have some arguments, I will think about them, but I will definitely go ahead with the idea"* (P10).

Others admitted that social feedback could influence their mindset, with positive reactions providing motivation and negative ones sparking doubts. One participant explained, "*yes definitely their attitude does affect… if they say negative things, you will think about that stuff. It might change your mood. "* (P7). However, not all participants fully trusted the authenticity of feedback, with one sharing, *"it's nice to get, , good comments, but people don't really say their honest opinions. So knowing that, it doesn't affect me. They have to say some very specific comment for me to consider"* (P4).

Theme 6: Eco-preneurial intentions The course had a significant impact on participants' eco-preneurship intentions, shaping their views on starting a sustainable venture and incorporating sustainability into their entrepreneurial goals. Many participants noted a shift in mindset, with the course acting as a catalyst for envisioning eco-preneurial possibilities. One participant shared:"*it influenced me positively because, through critical thinking, it helped me to include the environment in the decision of what product to promote, to reduce any problem that negatively affects the environment … I had no intention of creating a green business; the environment was not among the factors when creating the business. After the course, this reflection came in, that in order to develop an idea for my business, it is a serious factor that should not be neglected and taken into account"* (P6). Similarly, another participant shared"*these skills I gained will help me for a product, an idea I already have […]. It gave me a lot of ideas in the course on how to promote my own project"* (P2). Specifically around sustainability, P2 also shared:"*it wasn't something I was thinking about. After the course, it gave me this click to go through my mind how to make it greener, more eco-friendly."* Many participants expressed a strengthened intention to pursue green entrepreneurship in the future. One emphatically stated, "*actually, if I ever do something, I think it will only be a green business"* (P3). Another envisioned using the knowledge gained from the course, saying, "*after the class I noticed that it opened my eyes to the fact that I can start my own startup company to be eco-friendly with my product and not expect others to do it, to do something myself"* (P9). Some also expressed excitement about applying their learning, as one shared, "*I've already used, I've taken the pitchdeck and I've used it to assess a business idea and wrap it around sustainability"* (P4).

On the other hand, some participants voiced hesitations about the challenges of starting a green business or developing their ideas further. One noted, *"to start a green business in the future, if I have to put a percentage, it would be 15 %. Before the course, it was 0. [The course] gave me a foundation that didn't exist before. But getting it done is too hard"* (P1). Another expressed concerns around the difficulty and risk involved, reflecting, *"it takes a lot of work, passion, time… and the truth is that I would not open my own (business) because I see it as very difficult"* (P7). Another participant remarked that although the course didn't infuse entrepreneurial intentions, it helped them grow an environmental awareness: *"it certainly didn't make me develop my own company or an idea, but it taught me some things that I can use in my everyday life, in society"* (P5).

Table 3 summarizes the main themes, along with indicative quotes illustrating the participants' reflections. These themes collectively illustrate the ways in which the course fostered entrepreneurial and sustainability skills, attitudes, and intentions. They also highlight the diverse perceptions and challenges participants experienced on their journey toward eco-preneurship.

Table 3
Themes and indicative quotes from interviews.

Theme	Indicative Quotes
Skills related to Entrepreneurship	We had found our idea, but we also had to see if it was functional, how many years our product would last, how much should it cost, how should it be manufactured, what materials, how should we assemble it? How are we going to start, where are we going to sell it?" (P9)
Skills related to Sustainability	I was unconcerned, to a fairly large extent, about the environment. Until I did the course and I realized the seriousness of the situation" (P7)
Attitudes	At the first opportunity I will definitely get involved in green entrepreneurship (P11)
Perceived Behavioral Control	It helped me to be both more ready and more determined to create a business, projecting an idea that is innovative and attractive" (P6).
Subjective Norms	If I consider one day that I want to open a green business, I will open it. If they have some arguments, I will think about them, but I will definitely go ahead with the idea (P10)
Eco-preneurial Intentions	Actually, if I ever do something, I think it will only be a green business. (P3)

Discussion

The intersection of entrepreneurship and environmental sustainability continues to evolve as a significant site for theoretical exploration, particularly in how educational interventions shape the competences and intentions of future eco-preneurs. This study complements recent TPB applications in sustainable entrepreneurship contexts (Diepolder et al., 2025; Tsaknis & Sahinidis, 2025) by illustrating, in an engineering education setting, how competence-based pedagogies can influence the formation of eco-preneurial intentions. This discussion unpacks how students made meaning of their learning experiences, how theory helps interpret these experiences, and what this implies for designing sustainability-oriented entrepreneurship education. In doing so, the study also responds to Nabi et al.'s (2017) critique that research in this field often lacks detail on pedagogical methods, by illustrating how specific design features shaped competence development and intentions.

The results indicate that competence development (EntreComp/GreenComp) and intention formation (TPB) operate in tandem rather than in parallel. In particular, attitudes toward eco-preneurship were shaped by value-oriented and future-oriented competences, e.g., *Valuing Sustainability* (GreenComp) and *Valuing Ideas/Vision* (EntreComp), as participants articulated a stronger commitment to environmental aims and imagined desirable entrepreneurial futures. Perceived behavioral control was reinforced by action-oriented competences, notably *Learning through Experience* and *Financial & Economic Literacy* (EntreComp), which gave students a clearer sense of feasibility.

Competency development and framework alignment (RQ1)

With respect to RQ1, participants' reported development of entrepreneurial and sustainability competences reveals how these domains are not only interlinked in practice but also mutually reinforcing. The EntreComp and GreenComp frameworks provided a lens to interpret how students navigated ideation, teamwork, and communication in a sustainability-driven context.

High scores in EntreComp competences such as *Working with Others, Valuing Ideas, and Presenting Your Vision* from the pitchdeck assessments were reinforced by participants' reflections in interviews. Students consistently emphasized collaboration, iterative ideation, and confident communication, which are core competences within the EntreComp framework. For example, the teamwork needed to build convincing business ideas was echoed in participants' remarks about group interdependence. Likewise, the development of presentation skills highlights the role of the deck structure in clarifying and communicating ideas. The theme of *Learning Through Experience* also strongly complements the experiential nature of the pitch task. Participants spoke of translating abstract ideas into actionable plans, mirroring the structured articulation assessed in their final pitchdecks. Additionally, the inclusion of financial projections in the pitchdeck was validated through qualitative data indicating transformative learning in financial and economic literacy, students reported increased financial awareness and practical understanding of business economics. Such task-specific learning reflects earlier concerns about engineers' limited exposure to business competences (Valencia-Arias & Montoya Restrepo, 2020). Competences aligned with the GreenComp framework, such as *Valuing Sustainability, Problem Framing, and Futures Literacy*, were visibly embedded in both the assessed pitchdecks and participants' narratives. The interview data shows that students developed a deeper environmental consciousness and adopted critical thinking approaches toward sustainability, reflecting their ability to embed these values into their business models. These competences, often scored highly in the pitch assessments for content and context, were reinforced by students' quotes on shifting environmental attitudes and practices, including materials research and lifecycle considerations. Furthermore, *Exploratory Thinking* emerged in both data sources, with students experimenting with green solutions in traditionally harmful industries like construction. This experimental mindset was often scored during assessments under innovation or opportunity spotting and validated through interviews referencing sustainable material choices and forward-thinking design. Additionally, the results highlight how entrepreneurial and sustainability skills are not separate domains but rather complementary competences that reinforce each other. For instance, the entrepreneurial skill of *Valuing Ideas* directly supported the sustainability competence of *Valuing Sustainability*, as participants evaluated their concepts through multiple lenses: economic, social, and environmental. Participants demonstrated this integration when calculating environmental impacts alongside financial projections, suggesting that the course promoted the ability to combine economic viability with environmental responsibility. This aligns with the pitchdeck analysis findings, suggesting that a structured template incorporating these elements prompts students to engage in reflection and research.

A particularly significant finding is the recognition among participants that industries like the construction sector, have important environmental impacts that require innovative approaches, echoing recent studies arguing that sustainability must become a core principle in engineering education (Sabri, 2025). The integration of futures literacy with entrepreneurial vision represents an interesting combination for eco-preneurship education. Participants demonstrated the ability to envision, analyze, and evaluate possible futures through calculating environmental impacts and considering long-term implications of material choices. The progression from abstract ideas to concrete implementation plans, what one participant described as *"translation between 'I have an idea' and 'I share my idea'"*, demonstrates how experiential learning bridges theoretical knowledge and practical application. These patterns are consistent with Nabi et al.'s (2017) claim that experiential formats drive learning, providing exploratory insight into which competences may be most implicated in that process within engineering, thereby offering design-level implications rarely specified in prior work.

While these findings confirm the relevance of competence-based approaches, applying frameworks such as EntreComp and GreenComp in engineering contexts also entails distinct challenges. The structure and culture of engineering education often privilege technical accuracy and problem-solving efficiency over the exploratory and reflexive modes of learning that entrepreneurship frameworks require (Ilyas et al., 2024). As a result, competences emphasising creativity, ethical awareness, or systems thinking may receive less attention unless explicitly embedded in design tasks. Studies analysing engineering students' competence profiles show uneven development across domains, with stronger gains in analytical and teamwork skills than in opportunity recognition or civic engagement (Pasic et al., 2023; Ahmad et al., 2025). These challenges highlight the need to adapt competence models to context. They can effectively guide curriculum design when used flexibly, but their application should reflect the specific culture and practices of engineering education.

Eco-preneurial intentions and the theory of planned behavior (RQ2)

In addressing RQ2, we explored how participation in the eco-preneurship course influenced students' intention to pursue sustainability-oriented entrepreneurship. While the Theory of Planned Behavior (Ajzen, 1991) offers a structured model through its three core constructs attitude, PBC and subjective norms, our findings suggest that the formation of eco-preneurial intentions is not merely a cognitive outcome but a dynamic, situated process shaped by experiential learning, social interaction and reflective engagement. Previous applications of the TPB in engineering education have shown that while the model effectively captures changes in these constructs, it tends to overlook the disciplinary context shaping them (Valencia-Arias & Montoya Restrepo, 2020; Joensuu-Salo et al., 2022). Engineering students often approach entrepreneurship through a technical and feasibility-oriented lens (Ilyas et al., 2024), which influences how they

perceive control and opportunity within the TPB framework. By examining TPB dynamics in an eco-preneurship course for engineers, this study illustrates how contextualized experiential learning can activate the model's constructs in an enginerring educational environment.

Attitude toward sustainable entrepreneurship emerged as multifaceted, often reflecting both a growing excitement about the potential for positive impact and a realistic awareness of the challenges involved. Participants described a form of "value tension" as they tried to reconcile idealistic goals with real-world feasibility. For some, this tension led to deeper commitment, seeing sustainability as a non-negotiable design principle. For others, it created hesitation, indicating that intention strength is shaped not just by belief in outcomes, but by the learner's evolving sense of self within an entrepreneurial identity. This highlights the need to view attitudes not as static predictors but as emotionally and ethically charged positions that evolve during the learning process. This resonates with Fayolle et al.'s (2014) argument that intentions are embedded in normative and motivational systems, not just evaluative judgments, and with Wilson et al.'s (2007) view of entrepreneurial intention as part of identity development.

Perceived behavioral control was strongly influenced by the experiential design of the course. Rather than reporting a general sense of competence, participants often described specific shifts in self-efficacy tied to concrete tasks: pitching an idea, researching sustainable materials or constructing a business model. These moments of confidence-building reinforce the assumption that PBC plays a major role in the formation of intentions and eventually behaviors, as argued in the literature (Kautonen et al., 2015; Schlaegel & Koenig, 2014; Tsaknis & Sahinidis, 2025; Joensuu-Salo et al., 2022). At the same time, some participants also expressed awareness of gaps in their knowledge, revealing an important nuance: that recognizing what one cannot yet do may also strengthen intention by sparking longer-term learning motivation, resonating with Bandura's (1997) self-efficacy theory.

Subjective norms played a dual role. On one hand, participants articulated a growing sense of independence from external validation, often expressing a desire to "do something meaningful" regardless of societal expectations. On the other hand, peer recognition, instructor feedback, and imagined societal impact all contributed to shaping their self-perception as potential eco-preneurs. For many, these interactions served as a form of identity building, helping them internalize a role they had not previously considered. This points to the importance of social learning environments in intention formation, expanding TPB's treatment of norms beyond external influence toward a more participatory and relational process.

Finally, with respect to *eco-preneurial intentions* themselves, the findings support a spectrum rather than a binary outcome. Participants demonstrated varying levels of commitment, ranging from tentative exploration to clearly articulated future plans. Importantly, even the participants who initially chose topics not explicitly sustainability-oriented (e.g., digitalization in construction) reported increased environmental awareness and a reframing of their personal and professional goals (P7, P9, P10). There is a varying strength of intentions, including negative or resistant ones, which demonstrates the complex nature of entrepreneurial intentions, and even more so of eco-preneurial intentions. These intentions appear to be influenced by personal background, aspirations, prior experiences, and the presence or absence of entrepreneurial role models (Krueger, 2007). This suggests that intention may emerge indirectly, as a latent outcome of engaging in sustainability discourse, rather than only as a deliberate target of learning.

In sum, the course did more than shift isolated variables in the TPB model; it provided a structured yet open-ended environment in which learners could experiment with future selves. The interplay between theoretical constructs and experience underscores the value of challenge-based eco-preneurship education in shaping not just what students know, but who they begin to become. Our findings therefore illustrate what Lans et al. (2014) envisioned when arguing that sustainability competences must be embedded within entrepreneurial education, while also reinforcing Souitaris et al.'s (2007) insight that entrepreneurship education could influence intentions by enabling students to reflect on their identities and preferences.

Implications for research, practice and society

This study suggests several preliminary implications across academic, pedagogical, and societal domains:

For *research,* the study contributes to entrepreneurial intention theory by demonstrating how competence-based frameworks can enrich TPB in eco-preneurship contexts. This integration suggests new avenues for inquiry: examining how competences and values act as mechanisms of eco-preneurship intention formation across disciplines, testing the transferability of such findings beyond engineering education, and employing longitudinal designs to explore how competences shape intentions over time. These directions highlight the importance of moving beyond static models of intention to a more dynamic, competence-informed understanding of how sustainable entrepreneurship education achieves impact.

For *practice*, the findings provide actionable guidance for educators designing sustainability-oriented entrepreneurship curricula for engineers or other technical fields. Embedding sustainability challenges into interdisciplinary, experiential learning formats helps cultivate both entrepreneurial and sustainability competences. For example, students highlighted how teamwork and dialogue were essential for shaping and advancing their ideas, suggesting that collaborative formats should be deliberately structured into course design. They also valued tools such as pitchdecks, which helped them refine their vision and communicate it effectively, while engagement with financial literacy gave engineering students a clearer sense of feasibility and decision-making. Similarly, the development of problem framing and futures literacy indicated that situating projects in authentic sustainability challenges supports learners in linking technical problem-solving to long-term environmental and social outcomes. Educators are therefore encouraged to combine experiential learning with structured templates and reflective tools that support the translation of abstract ideas into actionable plans. More broadly, these insights underscore the need for entrepreneurship education that aligns with the twin green and digital transitions, where sustainable technological innovation becomes both a driver and a context for eco-preneurial learning (UNESCO, 2023; OECD, 2023; European Commission, 2022).

For *society*, the study shows how educational interventions can foster meaningful shifts in students' sustainability-related attitudes. Several participants described becoming more aware of environmental impacts, rethinking their professional trajectories, or expressing stronger commitment to sustainable entrepreneurship. These findings suggest that such courses can prepare engineers not only to address technical challenges, but also to act as agents of sustainable innovation. By documenting these attitudinal and intentional changes, the study provides initial evidence that sustainability-oriented entrepreneurship education can contribute to broader cultural and economic transitions toward more responsible forms of innovation.

Limitations of the study

The present study was intentionally designed to provide in-depth insight into students' experiences within a bounded educational setting. As such, its contribution lies less in broad generalizability and more in the potential for transferability to comparable contexts. The rich contextual detail included in the course description, data analysis and participant narratives is intended to support readers in assessing how the findings may apply to their own settings and the conclusions should be interpreted as exploratory rather than definitive.

The first limitation lies in the self-selection of participants, which may indicate an inherent interest or bias toward entrepreneurship or environmental sustainability. Future studies could address this by

involving participants from mandatory classes thereby capturing a more diverse and potentially less biased sample. A further limitation concerns the temporal scope of the data, as the study captured immediate post-course reflections on eco-preneurial intentions, but did not examine whether these intentions persisted or translated into entrepreneurial behaviour. While such a short-term focus is common in exploratory educational research, it constrains our ability to assess long-term impact. Longitudinal designs would therefore be valuable for tracing how competences and intentions evolve, under what conditions they persist, and when they result in entrepreneurial action. As with any qualitative research, concerns about subjectivity and consistency of findings remain. These challenges, could be mitigated by replicating the study across different contexts and disciplines to evaluate whether the results can be applied across similar situations. Additionally, future research could employ a combination of quantitative and qualitative data to provide a deeper analysis and exploration of the qualitative findings. Examining these aspects across various educational contexts, such as other engineering and business programs, would help determine the transferability of the findings and the wider applicability of this educational model.

Despite these limitations, the study benefits from its authentic educational context, which enhances its ecological validity (i.e. transferring to different setting in similar disciplines). By offering detailed descriptions of the setting and participants' experiences, the study provides valuable insights into whether the approach and outcomes could be adapted and applied in other, similar contexts or disciplines. Readers are thus enabled to determine how applicable the findings might be to parallel scenarios.

Conclusion

This study demonstrates the role of eco-preneurship education in equipping engineering students to address the dual challenges of economic viability and environmental sustainability in entrepreneurship. The findings reveal that entrepreneurial and sustainability competences are mutually reinforcing when developed through experiential learning, enhancing students' teamwork, financial literacy, and futures thinking while strengthening their awareness of sustainability's relevance to their professional identity. These results highlight the importance of embedding sustainable entrepreneurship within engineering curricula to foster both human capital development and eco-preneurial intentions.

The study advances knowledge by providing empirical evidence from a challenge-based eco-preneurship course in engineering, an underexplored educational context in literature, and by offering a theoretical lens that integrates EntreComp, GreenComp, and the Theory of Planned Behavior to explain how developed competences can translate into intentions. By situating engineering education at the intersection of entrepreneurship and sustainability, the study underscores the need for pedagogical models that prepare future engineers to use sustainable technology for positive change. Future research should extend this framework through mixed-methods and longitudinal designs, comparing diverse student groups across disciplines to assess the transferability and long-term impact of sustainability-oriented entrepreneurship education.

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Ethical considerations

The Cyprus National Bioethics Committee approved our interviews (reference number 2023.01.295) on December 5th, 2023.

Consent to participate

Respondents gave written consent for review and signature before starting interviews.

Data availability statement

Data sharing is not possible for this article. Although the study has ethical approval and the participants signed an informed consent, we did not foresee or get approval for sharing the original datasets as generated from the interviews; rather we agreed to report only themes and aggregate results.

Submission declaration

This manuscript has not been published elsewhere and is not under consideration by any other journal. All authors have approved the manuscript and agree with its submission to Sustainable Technology and Entrepreneurship.

CRediT authorship contribution statement

Antonia Christou: Writing – original draft, Methodology, Investigation, Data curation. **Stylianos Yiatros:** Writing – review & editing, Supervision. **Andri Ioannou:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Annex 1: Rubric with indicators for pitchdeck analysis

Framework	Area	Competence	Indicators/Questions
EntreComp	Ideas & Opportunities	1. Spotting Opportunities	Did the team identify a clear need or opportunity their solution responds to?
		2. Creativity	Did the team present an innovative or original idea?
		3. Vision	Is the vision for the future clearly communicated and inspiring?
		4. Valuing Ideas	Did the team reflect on idea value in environmental, social, and economic terms?
		5. Ethical and Sustainable Thinking	Were sustainability or ethical impacts considered in the decision-making process?
	Resources	6. Self-awareness and Self-efficacy	Did the team members demonstrate awareness of their individual strengths and limits?
		7. Motivation and Perseverance	*Not applicable*

(*continued on next page*)

(*continued*)

Framework	Area	Competence	Indicators/Questions
		8. Mobilizing Resources	Did the team efficiently organize and manage the resources needed for the project?
		9. Financial and Economic Literacy	Are financials realistic, and is there a clear go-to-market plan?
		10. Mobilizing Others	Did the team effectively communicate and inspire support for their idea?
	Into Action	11. Taking the Initiative	Did the team demonstrate leadership and take ownership of the project tasks?
		12. Planning and Management	Did the team set clear goals and outline steps to achieve them?
		13. Coping with Uncertainty, Ambiguity and Risk	*Not applicable*
		14. Working with Others	Did the team have defined roles for each one of the team members?
		15. Learning through Experience	Did the project show progression from idea to implementation?
GreenComp	Embodying Sustainability Values	16. Valuing Sustainability	Are sustainability principles embedded in the product and decision-making?
		17. Supporting Fairness	Did the team consider how their solution promotes fairness and inclusion?
		18. Promoting Nature	Did the team demonstrate an effort to protect, restore, or positively engage with nature?
	Embracing Complexity in Sustainability	19. Systems Thinking	Did the team demonstrate understanding of the interconnected impacts of their solution?
		20. Critical Thinking	Did the team critically reflect on trade-offs and underlying assumptions?
		21. Problem Framing	Did the team define and structure a real-world sustainability problem?
	Envisioning Sustainable Futures	22. Futures Literacy	Did the team propose a solution with long-term sustainability impact?
		23. Adaptability	*Not applicable*
		24. Exploratory Thinking	Did the team explore novel, interdisciplinary or unconventional approaches?
	Acting for Sustainability	25. Political Agency	Did the project empower others or advocate for broader sustainable change?
		26. Collective Action	Did the team collaborate with stakeholders or communities in developing their idea?
		27. Individual Initiative	*Not applicable*

Annex 2: Examples of coding for each pitchdeck

Pitchdeck	Competence	Pitchdeck excerpt	Coding decision	Comment
FunginEering	GreenComp: Futures Literacy	"With 20 % of the beachhead market, we save 3855 tn CO_2-eq emissions per year."	5/5	The team quantified projected environmental impact and explicitly linked their solution to long-term climate goals, demonstrating strong futures thinking.
Honest Furniture	EntreComp: Financial and Economic Literacy	*"Monthly income of €5000; Break even within the first 5 years; Expansion to outdoor furniture in phase two."*	2/5	The financial claims were presented in broad terms without detailed calculations or evidence to support their feasibility. While the idea of revenue generation was acknowledged, the lack of a structured go-to-market plan or realistic financial modeling justified a low score.
MagnetMorph	GreenComp: Critical Thinking	*"The magnetic simulator is infinitely recyclable, unlike 3D printing which consumes non-renewable materials and generates non-recyclable waste."*	3/5	The team demonstrated some critical reflection by contrasting their solution with existing alternatives and highlighting sustainability trade-offs. However, the analysis remained surface-level and did not fully engage with underlying assumptions (e.g., energy use, supply chains), which limited the depth of critical reasoning.
AsfaMax	EntreComp: Planning and Management	"Goals: implement mass production of the product by 2026; increase recycled asphalt use in Cyprus by 2029; reduce fuel and chemical inputs in asphalt production by 40 %; expand to the Greek market by 2033	4/5	The team outlined concrete objectives and a clear timeline for scaling their innovation, demonstrating strong planning and management skills. While ambitious, some milestones lacked detailed operational strategies or contingency plans, which prevented a full score.

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