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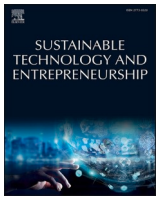

Full Length Article

Effects of competence-based sustainable entrepreneurship education on secondary school students' sustainable entrepreneurial intention

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ABSTRACT

Sustainable entrepreneurship is crucial for promoting economic growth while addressing environmental and social challenges to advance sustainable development. Sustainable entrepreneurs are driven by their intention to solve these sustainability challenges through entrepreneurial means. In higher education, sustainable entrepreneurship education is recognized as a driver of sustainable entrepreneurial intention and related antecedents, such as the attitude toward sustainable entrepreneurship.

Based on the theory of planned behavior, this study aims to examine the impact of competence-based sustainable entrepreneurship education on secondary students' sustainable entrepreneurial intention and its antecedents. Additionally, the effect of the commonly studied background factors 'gender' and 'exposure to sustainable entrepreneurial role models' is explored. A controlled pre-post research design was employed between April and May 2023 to assess changes in dependent variables. Data were collected via a questionnaire from 169 students participating in sustainable entrepreneurship interventions in Southern Germany.

The findings indicate that sustainable entrepreneurship education has a significant positive effect on secondary school students' sustainable entrepreneurial intention, attitude, subjective norm, and perceived behavioral control. The effect of the intervention on sustainable entrepreneurial intention, attitude, and perceived behavioral control is consistent across participants' genders. Sustainable entrepreneurial role models did not significantly influence the measured constructs.

These results support the implementation of sustainable entrepreneurship education already into secondary school curricula, demonstrating its potential to enhance students' sustainable entrepreneurial intention and related antecedents. This study contributes to the theoretical understanding of sustainable entrepreneurial intention formation and offers insights for educators and policymakers aiming to foster sustainable entrepreneurial intention among youth.

Introduction

Resource consumption and production are the primary drivers of the triple planetary crisis — climate change, biodiversity loss, and environmental pollution — which threaten the achievement of the Sustainable Development Goals (SDGs) for all (United Nations Environment Programme, 2024). Securing human well-being and economic growth requires reducing resource use and mitigating its negative impacts through technological innovations and new business models that close resource loops, maximize efficiency, or promote sufficiency (United Nations Environment Programme, 2024). Entrepreneurs can adopt such business models to exploit business opportunities arising from global sustainability challenges (Knudson, 2023). These sustainable entrepreneurs are crucial for the transition to a sustainable and equitable economy, as they implement innovative goods, processes, and services with an environmental, social, and economic value on the market (Cohen & Winn, 2007; Dean & McMullen, 2007; Pacheco et al., 2010; Patzelt & Shepherd, 2011; Trabattoni, 2021).

Despite the importance of sustainable entrepreneurial actions, little is known about the factors that explain and predict such behaviors

Abbreviation: SDGS, Sustainable development goals; SE, Sustainable entrepreneurship; SEE, Sustainable entrepreneurship education; TPB, Theory of planned behavior; SEI, Sustainable entrepreneurial intention; AT, Attitude toward sustainable entrepreneurship; SN, Subjective norm toward sustainable entrepreneurship; PBC, Perceived behavioral control.

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(Vuorio et al., 2018; Thelken & de Jong, 2020). Intentions in general (Armitage & Conner, 2001), and specifically entrepreneurial intentions, have been empirically identified as the most significant and reliable predictors of actual behaviors, including start-up activities (e.g., Kautonen et al., 2015, 2013; Kolvereid & Isaksen, 2006; Schoon & Duckworth, 2012; Van Gelderen et al., 2018). This principle also applies to sustainable entrepreneurship (SE), where the actions of sustainable entrepreneurs are sustained by their firm intention to solve sustainability challenges through entrepreneurial means, even without a supportive social or business environment (Muñoz & Dimov, 2015). Drawing from the concept of intention (Ajzen, 1991) and entrepreneurial intention (Thompson, 2009), sustainable entrepreneurial intention (SEI) encapsulates a person's motivation and commitment to engage in sustainable entrepreneurial activities and start a sustainable venture sometime in the future. Whereby the likelihood of performing a behavior such as sustainable entrepreneurial behavior increases with the strength of the intention regarding the behavior in question (Ajzen, 1991).

The predictive nature of SEI underscores its value for educational endeavors. Sustainable entrepreneurship education (SEE) integrates education for sustainable development and entrepreneurship education (Schadenberg et al., 2023), adopting prominent pedagogical approaches such as problem-based and experiential learning (Mindt & Rieckmann, 2017). SEE aims to foster knowledge, skills, and attitudes necessary to accomplish tasks throughout the sustainable entrepreneurial process, from opportunity recognition to venture consolidation (Foucrier & Wiek, 2019; Klapper & Fayolle, 2023). Research has shown that exposure to entrepreneurship (Zapkau et al., 2015) and participation in entrepreneurship education positively affect entrepreneurial intention (Bae et al., 2014). Studies on SEI frequently examine factors that predict SEI at the individual level, including established antecedents of intention adapted from the theory of planned behavior (TPB) and the relationship of additional background factors to Ajzen's (1991) intention model (e.g., Gimenez-Jimenez & Harc, 2024; Lopes et al., 2023; Pascucci et al., 2022; Romero-Colmenares & Reyes-Rodríguez, 2022; Thelken & de Jong, 2020; Truong et al., 2022). Empirical studies have identified SEE as a factor driving SEI, either immediately related (Thelken & de Jong, 2020) or mediated by the attention toward sustainable entrepreneurship or the perceived behavioral control (Agu et al., 2021; Romero-Colmenares & Reyes-Rodríguez, 2022; Truong et al., 2022).

Current research on SEE primarily targets university students, with little attention to secondary education (Diepolder et al., 2021). However, the scope of research on SEE, including the development, implementation, and evaluation of educational programs, should not be limited to higher education settings (Thelken & de Jong, 2020; Vuorio et al., 2018). To harmonize competing environmental, economic, and social objectives within SE, collaboration among all key stakeholders in the ecosystem—such as sustainable entrepreneurs, investors, consumers, and employees—is crucial (Chaudhary et al., 2023). Regardless of whether young people currently in school will pursue higher education, they have the potential to assume significant roles in the sustainable entrepreneurial ecosystem in the future. However, to contribute effectively, for instance as employees, they must be familiar with the new concept (Mohrman Albers & Shani, 2011).

This study seeks to expand the limited knowledge on promoting SEI at the individual level within secondary education, enhancing both the theoretical insights into the formation process of SEI and the practical design of related educational interventions.

The guiding research question is: How does participation in an intervention on sustainable entrepreneurship influence secondary school students' sustainable entrepreneurial intention?

Existing studies on SEI employ cross-sectional designs that do not manipulate variables and limit the data collection to a single point in time (e.g., Gimenez-Jimenez & Harc, 2024; Lopes et al., 2023; Pascucci et al., 2022; Romero-Colmenares & Reyes-Rodríguez, 2022; Thelken & de Jong, 2020; Truong et al., 2022). To investigate causal relationships between SEE and SEI, experimental studies with controlled pre-post designs are necessary. Accordingly, this study responds to calls for intervention studies (e.g., Sharma et al., 2020). The effects of a SEE intervention, comprising six lessons on students from five schools in Southern Germany were evaluated between April and May 2023 using a pre-post design with a waitlist control group, thus ensuring the validity of the experimental results. Research on the effectiveness of a SEE program provides guidelines for pedagogical methods and curricula that facilitate successful teaching and learning to increase sustainable entrepreneurial activity through education.

The paper is organized as follows: Section 2 reviews the literature on SEE in relation to the TPB, leading to the formulation of four hypotheses about the intervention's impact on participants' SEI. Sections 3 and 4 detail the methodology, study design, and present the results. Section 5 interprets the findings within the context of SEE and discusses implications for policymakers and educators. The paper concludes by addressing limitations and proposing directions for future research.

Theory and hypotheses

The TPB is widely employed in research on behavioral intentions across various fields, including entrepreneurship (Schlaegel & Koenig, 2014) and sustainability, in sectors like mobility (e.g., Mattia et al., 2019). Correspondingly, the TPB is the most prominent model in studies on SEI, as evidenced by extensive research (e.g., Gimenez-Jimenez & Harc, 2024; Lopes et al., 2023; Pascucci et al., 2022; Romero-Colmenares & Reyes-Rodríguez, 2022; Thelken & de Jong, 2020; Truong et al., 2022). These studies utilize the intention model to investigate the determinants of SEI and additional background factors influencing the intention formation process. The following subsections introduce the fundamentals of the TPB and the corresponding findings on SEI identified in previous research.

Sustainable entrepreneurial intention

According to the TPB (Ajzen, 2020), SEI can be defined as the intention to engage in SE or to perform sustainable entrepreneurial actions in the future. SEI, as a behavioral intention, is determined by three factors: attitude toward sustainable entrepreneurship (AT), subjective norm concerning sustainable entrepreneurship (SN), and perceived behavioral control (PBC). Positive attitudes and subjective norms provide the motivation to execute a behavior, but the intention formation depends on the strength of perceived behavioral control (Ajzen, 2020).

Intentions are not static and change can be stimulated if executing the behavior in question yields new insights that differ from initial expectations (Ajzen, 2020). This feedback effect can modify an individual's intention by altering their beliefs about the likely consequences of performing the behavior (attitude), the presence of enabling or hindering factors (perceived behavioral control), and the approval or disapproval of significant others (subjective norm) (Ajzen, 2020).

Several studies integrated the factors of entrepreneurship education or SEE to investigate the effect of educational activities on SEI. While entrepreneurship education was found to have a small negative effect on university students' AT (Goswami et al., 2024), SEE positively influences SEI (Thelken & de Jong, 2020). In SEE settings, students can engage in sustainable entrepreneurial behaviors and perform tasks within the sustainable entrepreneurial process, such as developing a business idea addressing the SDGs (Diepolder et al., 2024). Participation in SEE can provide new insights that challenge previous expectations about sustainable entrepreneurial behavior.

Empirical studies have established a positive relationship between SEE and SEI, demonstrating immediate impacts (Thelken & de Jong, 2020) and effects mediated by a heightened AT or increased PBC (Agu et al., 2021; Romero-Colmenares & Reyes-Rodríguez, 2022; Truong et al., 2022). Based on these findings, the following hypothesis is

proposed:

H1. Sustainable Entrepreneurship Education significantly increases Sustainable Entrepreneurial Intention scores.

Antecedents of sustainable entrepreneurial intention

Attitude Toward Sustainable Entrepreneurship

According to the TPB, attitudes towards a behavior reflect an individual's favorable or unfavorable evaluations of performing a specific behavior, based on their beliefs about the likely outcomes or experiences associated with that behavior (Ajzen, 2020). In the context of SE, a favorable behavioral belief would be that engaging in SE (behavior) can provide personal economic benefits while contributing to the SDGs (outcome). AT has been identified as an antecedent of SEI (e.g., Pascucci et al., 2022). Studies by Thelken and de Jong (2020), Truong et al. (2022), Romero-Colmenares and Reyes-Rodríguez (2022), and Agu et al. (2021) found that SEE positively impacts university students' AT.

Subjective Norm Concerning Sustainable Entrepreneurship

Subjective norms refer to the perceived social pressure to perform a behavior, influenced by the normative beliefs about whether significant persons, such as friends, disapprove or approve of the behavior or perform it themselves (Fishbein & Ajzen, 2010). Findings on the influence of subjective norm on SEI are inconclusive. While the majority of studies found a significant positive relationship between the two constructs (e.g., Lopes et al., 2023; Pascucci et al., 2022; Romero-Colmenares & Reyes-Rodríguez, 2022; Vuorio et al., 2018), some identified a positive but not significant influence (Agu et al., 2021; Sharma et al., 2024; Truong et al., 2022), and others found no influence at all (Thelken & de Jong, 2020). Research on the effect of SEE found a positive influence of SEE on university students' SN (Agu et al., 2021).

Perceived behavioral control

According to Ajzen (2020), PBC refers to a person's belief about the existence of factors that will enable or hinder the execution of a specific behavior. In the context of SE, an enabling factor would be the possession of competences required to balance social, economic, and environmental goals through entrepreneurial means. PBC has been identified as a driver of SEI (Lopes et al., 2023; Pascucci et al., 2022; Romero-Colmenares & Reyes-Rodríguez, 2022; Sharma et al., 2024; Thelken & de Jong, 2020; Truong et al., 2022). Research on the effect of SEE on PBC has revealed a positive influence of SEE on university students' PBC (Agu et al., 2021; Romero-Colmenares & Reyes-Rodríguez, 2022; Truong et al., 2022). Based on these findings regarding the influence of SEE on the antecedents of SEI, the following hypothesis is proposed:

H2. Sustainable Entrepreneurship Education significantly increases Attitude, Subjective Norm, and Perceived Behavioral Control scores.

Background factors

Intention models usually explain between 40 % and 60 % of the variance in entrepreneurial intention (Liñán & Fayolle, 2015). Although intention is the best predictor of behavior, Ajzen (2020) emphasizes the influence of background factors, such as values or demographic variables, which can influence a person's behavioral, normative, or control beliefs and, consequently, intention formation. Researchers have expanded the TPB by additional factors to identify the determinants of SEI. These include self-transcending or -enhancing values (Thelken & de Jong, 2020), the propensity to take risks, perceived creativity, and a proactive personality (Lopes et al., 2023), or support from family and society (Truong et al., 2022).

Sustainable entrepreneurial role models

Role models are "individuals who influence role aspirants' achievements, motivation, and goals by acting as behavioral models, representations of the possible, and/or inspirations" (Morgenroth et al., 2015, p. 4). They are the most frequently studied background factor in research on entrepreneurial intentions, with evidence indicating that familial and educationally integrated role models positively affect entrepreneurial intention and behavior (Abbasianchavari & Moritz, 2021; Liñán & Fayolle, 2015). Role models are also effectively used beyond entrepreneurship research to promote pro-environmental behavior in intervention programs (Abrahamse, 2019; Rau et al., 2022). Within the framework of the TPB, role models influence entrepreneurial intentions by affecting their antecedents (Karimi et al., 2013; Kolvereid, 1996), such as PBC towards entrepreneurial action (e.g., Fellnhofer, 2017). Role models are recommended (Gimenez-Jimenez & Harc, 2024; Lopes et al., 2023; Vuorio et al., 2018) and integrated as pedagogical instruments in SEE for higher education to enhance learning outcomes (Bernhardt et al., 2017). Diepolder et al. (2024) found indications of a positive influence of sustainable entrepreneurial role models on younger secondary school students' opportunity recognition for sustainable development. Based on these findings, the following hypothesis is proposed:

H3. Exposure to a sustainable entrepreneurial role model in Sustainable Entrepreneurship Education (Intervention B) will significantly improve Sustainable Entrepreneurial Intention, Attitude, Subjective Norm, and Perceived Behavioral Control scores compared to a control group (Intervention A).

Gender

Research investigating the impact of the background factor gender on SEI has found no significant differences in SEI scores between male and female students (Romero-Colmenares & Reyes-Rodríguez, 2022; Truong et al., 2022; Vuorio et al., 2018). This finding contrasts with studies on conventional entrepreneurship, which typically report higher entrepreneurial intentions among men than women (Haus et al., 2013) and lower startup activity by women across most countries (Hill et al., 2023). Gender differences are also evident in environmental psychology, where women demonstrate stronger pro-environmental attitudes and report more frequent pro-environmental behaviors than men (Gifford & Nilsson, 2014; Zelezny et al., 2000). The gender disparity in students' sustainability consciousness increases with each school year and is, contrary to expectations, more pronounced at schools certified in Education for Sustainable Development (Olsson & Gericke, 2017).

Consistent with these patterns, research on SEI drivers has identified higher sustainability attitudes in females and greater entrepreneurial desirability in males (Vuorio et al., 2018). Vuorio et al. (2018) suggest that educational programs can address these gender disparities by integrating entrepreneurial and sustainability elements, as practiced in SEE, to enhance SEI and facilitate sustainable entrepreneurial activities across gender boundaries. Based on the findings regarding the influence of gender on SEI, the following hypothesis is proposed:

H4. The effect of Sustainable Entrepreneurship Education on Sustainable Entrepreneurial Intention, Attitude, Subjective Norm, and Perceived Behavioral Control scores is consistent across participants' genders.

Material and methods

Treatment

To analyze the effectiveness of SEE interventions at the secondary school level, an educational intervention was developed based on the competence framework of SE by Foucrier and Wiek (2019). This intervention, first published in Diepolder et al. (2024), is designed to foster the competences necessary to accomplish tasks within the first two phases of the sustainable entrepreneurial process. Over an average period of two weeks, students in the experimental group completed six

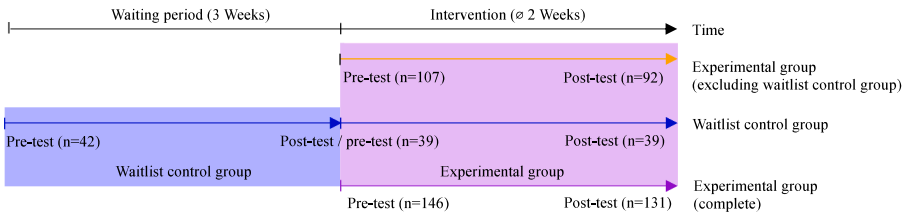

Fig. 1. Participant allocation in the waitlist control group, the experimental group excluding waitlist control group, and the complete experimental group during pre- and post-test.

45-minute school lessons, delivered by a pre-trained teacher.

To analyze the effect of the background factor 'Role Model,' two versions of the intervention were implemented: Intervention A (no role model) and intervention B (with a sustainable entrepreneurial role model). Four classes were assigned to intervention B and therefore, received guidance and support from one of four sustainable entrepreneurial role models during the final 90 mins of the intervention.

To ensure the validity of the experimental results, a waitlist control group was established. Students in this group underwent a three-week waiting period during which they received standard curriculum instruction.

Setting and sample

Eight secondary school classes, ranging from grade seven to ten, from five schools in Southern Germany volunteered to participate in the study during April and May 2023. A total of N = 169 students were enrolled. The survey was conducted anonymously, and informed consent was obtained. Questionnaires were considered completed if at least 80 % of the questions were answered. Complete questionnaires containing missing data were excluded only from specific analyses involving those incomplete items.

Two classes volunteered as a waitlist control group. In this group, $n =$ 42 students completed the pre-test, and $n = 39$ completed the post-test. One pre-test was not completed and thus excluded. Two students did not participate in the pre-test, and six students did not participate in the post-test. After the three-week waiting period, the intervention was implemented in the waitlist control group, which was then included in the experimental group.

The experimental group comprised all eight classes. In the experimental group, $n = 146$ students completed the pre-test, and $n = 131$ completed the post-test. Seven pre-tests and five post-tests were not completed and thus excluded. In total, 16 students did not participate in the pre-test, and 33 students did not participate in the post-test. Students dropped out of the experimental and the waitlist control group due to personal issues, including illness or school transfers. The described participant allocation is visualized in Fig. 1.

The average age of the students was approximately 15 years. The male-to-female ratio was nearly balanced in both groups, with a minority identifying as diverse. Most students in both groups speak German as their home language. The majority of participants' legal guardians are employed, while 13.0 % to 17.5 % are self-employed (e.g., Freelancers or Entrepreneurs). For detailed sample characteristics, refer to Table 1.

Measures

The data were collected using a questionnaire. The variables were measured during the pre- and post-tests and statistically analyzed, as described in the following sections.

Dependent variables

Behavioral intention is predicted by measuring the reflective indicators of the immediate antecedents: attitude toward the behavior, subjective norm concerning the behavior, and perceived behavioral control (Ajzen, 2020). Participants' SEI was measured using a 14-item scale adapted from the Entrepreneurial Intention Questionnaire developed by Liñán et al. (2011), employing direct measures.

Brüne and Lutz (2020) emphasize the lack of validated instruments for measuring young students' entrepreneurial intention. The Entrepreneurial Intention Questionnaire scale on entrepreneurial intention has been applied in secondary school settings (e.g., do Paço et al., 2011; Hershmann et al., 2023). The questionnaire is also used in research on sustainable entrepreneurial intention (e.g., Gimenez-Jimenez & Harc, 2024; Pascucci et al., 2022; Thelken & de Jong, 2020). To incorporate the proposed behavior of being a sustainable entrepreneur, the term 'sustainable' was prefixed to 'business' and 'entrepreneur' in the questionnaire. This modification aligns with Ajzen's (1991) requirements for accurately measuring intentions.

The scale features items on a 7-point Likert scale ranging from 1 (total disagreement) to 7 (total agreement). The scale is divided into four subscales: SEI, AT, SN, and PBC, as described below. Statistical analysis was conducted using the software SPSS version 29.0 (IBM Corp., 2022). An overall score was obtained for each sub-scale by averaging the scores

Table 1
Characteristics of the experimental and the waitlist control group recorded during the pre- and the post-test.

Variable	Pre-test		Post-test	
	Waitlist Control Group ($n =$ 42)	Experimental Group ($n =$ 146)	Waitlist Control Group ($n =$ 39)	Experimental Group ($n =$ 131)
Age (mean in years)	14.9 (SD = 1.04) ($n = 36$)	14.8 (SD =1.10) ($n = 143$)	15.0 (SD =1.01) ($n = 38$)	14.7 (SD = 0.96) ($n = 115$)
Gender (valid percent)	Male 50.0 % Female 50.0 % ($n = 36$)	Male 57.5 % Female 39.7 % Diverse 2.7 %	Male 51.3 % Female 48.7 %	Male 55.0 % Female 43.3 % Diverse 1.7 % ($n = 120$)
Language (valid percent)	German 86.1 % ($n = 36$)	German 80.1 %	German 87.2 %	German 79.5 % ($n = 117$)
Occupation legal guardians (valid percent)	Self-employed 13.0 % Employed 78.3 % Other 8.7 % ($n = 36$)	Self-employed 17.5 % Employed 70.9 % Other 11,6 % ($n = 141$)	Self-employed 13.3 % Employed 78.7 % Other 8.0 %	Self-employed 15.6 % Employed 72.9 % Other 11.5 % ($n = 131$)

SD, Standard Deviation.

Table 2
Cronbach's alpha of the dependent variables.

Variable	Pre-test		Post-test	
	Waitlist Control Group (n = 42)	Experimental Group (n = 146)	Waitlist Control Group (n = 39)	Experimental Group (n = 131)
SEI	.90 (n = 41)	.82	.87	.90 (n = 130)
AT	.80	.79 (n = 145)	.80	.78 (n = 130)
SN	.80	.84	.91	.88 (n = 130)
PBC	.77	.77	.85	.80

of the items. The Cronbach's alpha for each sub-scale is summarized in Table 2.

- SEI measures the intention to engage in behaviors aimed at starting a sustainable enterprise (Liñán et al., 2011). The subscale was measured by four items, such as "I will make every effort to start and run my own sustainable business." According to Nunnally (1978), the scale's reliability is adequate throughout the test time and across groups.
- AT is assessed with items that reflect the perception of the desirability of being a sustainable entrepreneur (Liñán et al., 2011). The subscale consists of three items, such as "Being a sustainable entrepreneur would give me great satisfaction" or "Amongst various options, I would rather be *anything but* a sustainable entrepreneur." The latter reversed item was eliminated to increase Cronbach's alpha to the reliability standard of 0.80.
- SN is assessed with items that reflect the perceived social pressure from a referent group (e.g., family) on whether the student should or should not become a sustainable entrepreneur (Liñán et al., 2011). The subscale consists of three items, such as "My classmates would approve of my decision to start a sustainable business." For better alignment with the young target group, 'classmate' replaced the term 'colleagues.'
- PBC is assessed with items that reflect the student's perception of the ease or difficulty of becoming a sustainable entrepreneur (Liñán et al., 2011). The subscale consists of four items, such as "If I tried to start a sustainable business, I would have a high chance of being successful."

The confirmatory factor analysis was conducted using the lavaan package in R, version 0.6.16 (Rosseel, 2012), on the pre- and post-test results of the experimental group. The model was estimated using the robust maximum likelihood estimation method due to the small sample size, with robust standard errors and a Satorra-Bentler scaled chi-square to account for non-normality. Despite the pre-test results indicating only an adequate fit with some areas for improvement, the model was retained because the post-test results revealed a significant improvement. The model demonstrated an acceptable fit to the observed data, shown in Table 3, supporting the structure suggested by Liñán et al. (2011).

Normality tests applied to the variable scores indicated a significant deviation from a normal distribution. Consequently, non-parametric tests were selected. A Mann-Whitney U test was calculated to identify differences in the achieved scores of dependent variables between independent samples. The data met the assumptions necessary for conducting the Mann-Whitney U test, which is suitable for small, independent samples when the assumption of normality is not satisfied and the distributions of the two samples have similar shapes (Mann & Whitney, 1947). A Wilcoxon signed-rank test was performed on the pre- and post-test scores of the dependent variables. The non-parametric test is suitable for repeated measurements on a single sample (Weaver et al., 2018). A Kruskal-Wallis H test was calculated to compare more than two independent samples. The test is appropriate when normality is not satisfied (McKight & Najab, 2010).

Control variables

Two dummy control variables were integrated to account for alternative explanations of the predicted relationships. Participants' prior experiences in formal or non-formal educational settings and their relationships with entrepreneurs were collected. Students reported whether sustainability, entrepreneurship, or SE was covered in class or encountered during participation in extracurricular events. Prior experiences with entrepreneurs were assessed according to the Entrepreneurial Intention Questionnaire (Liñán et al., 2011). Students who confirmed personally knowing an entrepreneur were prompted to detail their relationship. An additional question was included to account for SE, assessing the extent to which students perceive the entrepreneur as sustainable. Responses were recorded on a 7-point Likert scale ranging from 1 (not/nothing at all) to 7 (very much/totally). Alongside age and gender, prior experience moderates the variance in entrepreneurship education outcomes at the school level (Brüne & Lutz, 2020). Exposure to entrepreneurship may cause higher entrepreneurial intention due to effects on the attitudinal variables of the TPB (Zapkau et al., 2015).

Results

This section presents the findings of the statistical analysis, detailing evidence to support or refute the theoretical predictions.

Dependent variables

Sustainable entrepreneurial intention

The median and the interquartile range (IQR) are reported to align with the use of non-parametric tests, providing robust measures that are appropriate for data with non-normal distributions. The medians of the dependent variables for the pre- and post-test are presented in Table 4 and illustrated in Fig. 2. The pre-test results indicate no significant differences in SEI scores between the waitlist control group (n = 42) and the experimental group excluding the waitlist control group (n = 107). However, a significant difference in SEI scores between these groups is evident in the post-test results. A decrease in SEI scores is identified between the pre- and post-test in the waitlist control group.

The results of the Mann-Whitney U test confirm no significant differences in the SEI scores between the pre-test of the waitlist control group (n = 42) and the experimental group excluding the waitlist control group (n = 107), U = 1991.00, z = –1.09, p = .28 (two-tailed). Thus, preexisting differences in SEI scores between said groups are ruled out.

To ensure that changes in SEI scores reflect the intervention's effectiveness rather than the potential influence of elapsed time, the progression of the waitlist control group from pre- to post-test is analyzed with a Wilcoxon signed-rank test. Results are shown in Table 5.

The results of the Wilcoxon signed-rank test suggest that the SEI scores of the waitlist control group (n = 36) after the waiting period are significantly lower compared to the pre-test. The decrease in SEI scores

Table 3
Confirmatory factor analysis fit indices for pre- and post-test data.

Statistic	χ^2 (df=59)	p-value	Robust CFI	SMRM	Robust TLI	Robust RMSEA
Pre-test (n = 146)	130.066	< 0.001	0.909	0.061	0.880	0.100
Post-test (n = 131)	84.607	< 0.001	0.969	0.047	0.959	0.067

Table 4
Median scores of dependent variables in pre- and post-tests.

Dependent Variable	Pre-test						Post-test					
	Waitlist Control Group (n = 42)		Experimental Group excluding Waitlist Control Group (n = 107)		Experimental Group (n = 146)		Waitlist Control Group (n = 39)		Experimental Group excluding Waitlist Control Group (n = 92)		Experimental Group (n = 131)	
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR
SEI	2.50	2.82	2.25	1.75	2.25	2.00	2.00	1.75	3.25	2.00	3.25	2.00
AT	3.67	1.67	3.67	1.66	3.67	1.66	3.67	1.33	4.00	1.67	4.00	1.67
SN	4.33	2.00	4.00	2.33	4.00	2.33	4.00	3.00	4.33	2.00	4.33	2.00
PBC	3.13	1.75	2.75	1.75	2.75	1.75	2.75	1.75	3.50	1.50	3.50	1.50

IQR, Interquartile range.

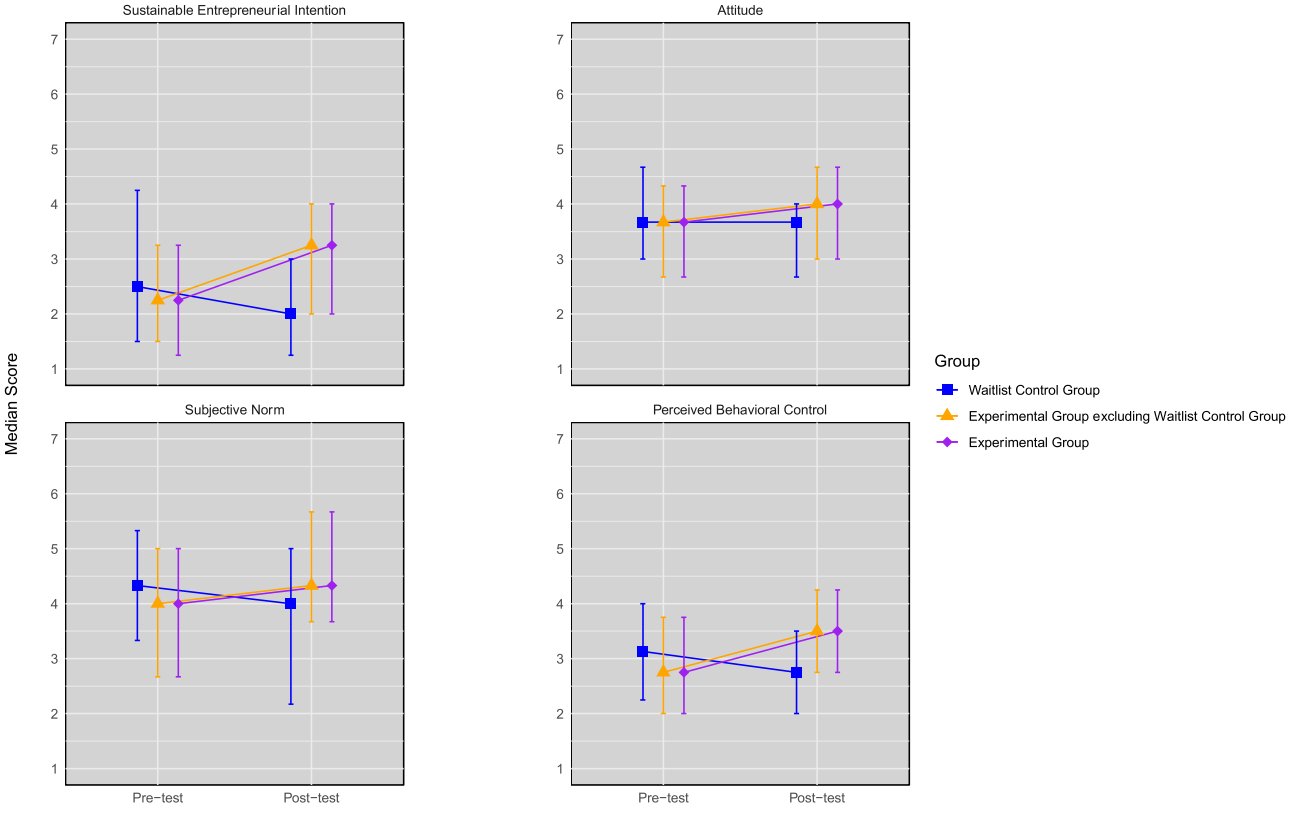

Fig. 2. Median scores of dependent variables in pre- and post-tests.

Table 5
Pair-wise comparison of the differences between the medians of the pre- and post-test scores of the dependent variables.

Dependent Variables	Waitlist Control Group (n = 36)			Experimental Group (n = 113)		
	z-value	p (two-tailed)	Effect size r (Cohen, 1988)	z-value	p (one-tailed)	Effect size r (Cohen, 1988)
SEI	–2.52	.012	.42 (medium)	–4.77	<0.001	.45 (medium)
AT	–1.35	.177	.23 (small)	–3.10	.001	.29 (small)
SN	–2.40	.017	.40 (medium)	–2.85	.002	.27 (small)
PBC	–0.98	.327	.16 (small)	–5.08	<0.001	.49 (medium)

might indicate fatigue or impatience, possibly stemming from a decrease in motivation to optimize the answers to the same questionnaire on SEI after three weeks of regular classes, which did not cover the topic in question (Krosnick, 1991).

Despite the initial decrease in SEI scores identified after the waiting period, the results of the Wilcoxon signed-rank test on the waitlist control group (n = 36) indicate a significant increase after the intervention, $z = -3.75$, $p < .001$ (one-tailed), $r = 0.63$. This positive trend is also observed for the SEI scores of the experimental group (n = 113) after the intervention, which are significantly higher compared to the pre-test, $z = -4.77$, $p < .001$ (one-tailed). According to Cohen (1988), the effect size lies between a moderate and large effect, with $r = 0.45$.

Hypothesis H1.: "Sustainable Entrepreneurship Education significantly increases Sustainable Entrepreneurial Intention scores" is supported.

Antecedents of sustainable entrepreneurial intention

The medians of the dependent variables for the pre-test, summarized in Table 4, indicate no significant differences in AT, SN, and PBC scores between the waitlist control group ($n = 42$) and the experimental group excluding the waitlist control group ($n = 107$). The results of the Mann-Whitney U test confirm no significant differences in the AT, SN, and PBC scores between the pre-test of the waitlist control group ($n = 42$) and the experimental group excluding the waitlist control group ($n = 107$), AT: $U = 2044.00$, $z = -.86$, $p = .39$ (two-tailed), SN: $U = 2001.00$, $z = -1.04$, $p = .30$ (two-tailed), and PBC: $U = 2023.00$, $z = -.95$, $p = .34$ (two-tailed). Thus, preexisting differences in AT, SN, and PBC scores between said groups are ruled out.

As observed with the SEI scores, the results of the Wilcoxon signed-rank test shown in Table 5 suggest that the SN scores of the waitlist control group ($n = 36$) after the waiting period are significantly lower compared to the pre-test. No significant differences are identified for AT and PBC scores.

Despite the initial decrease in SN scores identified after the waiting period, the results of the Wilcoxon signed-rank test suggest a significant increase in the waitlist control group ($n = 36$) after the intervention, $z = -2.65$, $p = .004$ (one-tailed), $r = 0.44$. This positive trend is also observed for the AT, SN, and PBC scores of the experimental group ($n = 113$), which are significantly higher after the intervention compared to the pre-test, with effect sizes ranging from small to medium. For details, see Table 5.

Hypothesis H2.: "Sustainable Entrepreneurship Education significantly increases Attitude, Subjective Norm, and Perceived Behavioral Control scores." is supported.

Background factor – sustainable entrepreneurial role model

A Kruskal-Wallis H test was calculated to rule out preexisting differences between the independent samples of the waitlist control group ($n = 42$), the experimental group excluding the waitlist control group assigned to intervention A ($n = 83$) and assigned to intervention B ($n = 24$). The results suggest no significant differences between these groups in the SEI, AT, and PBC pre-test scores, $H(2) = 1.57$, $p = .46$, $H(2) = 2.57$, $p = .28$, and $H(2) = 2.49$, $p = .29$, respectively. However, a significant difference was identified in the SN pre-test scores, $H(2) = 6.71$, $p = .04$. The effect size is small, with $f = 0.18$ (Cohen, 1992). The post-hoc Dunn's test with Bonferroni correction indicates significantly lower SN scores in the experimental group (excluding waitlist control group) assigned to intervention B ($n = 24$) compared to the waitlist control group, $p = .05$, $r = 0.27$.

The results of the Wilcoxon signed-rank test suggest that the SEI, AT, SN, and PBC scores of the experimental group assigned to intervention A ($n = 59$) and intervention B (54) are significantly higher after the intervention compared to the pre-test, with effect sizes ranging from small to large. For details, refer to Table 6.

The larger effect sizes for SEI, AT, and PBC in Table 6 indicate a stronger effect for intervention B ($n = 54$). However, the results of the Mann-Whitney U test comparing the post-test scores of the dependent variables between the experimental group assigned to intervention A ($n = 59$) and the experimental group assigned to intervention B ($n = 54$) are not significant, as presented in Table 7.

Table 7
Comparison of the differences in the post-test scores of the dependent variables between the independent samples of the experimental group assigned to interventions A and B.

Dependent Variables	Post-test		
	Intervention A ($n = 66$) compared to B ($n = 65$)		
	Z-value	p (one-tailed)	Effect size r (Cohen, 1988)
SEI	–0.89	.188	.08 (no effect)
AT	–1.08	.140	.09 (no effect)
SN	–1.34	.090	.12 (small)
PBC	–1.27	.102	.11 (small)

Hypothesis H3.: "Exposure to a sustainable entrepreneurial role model in Sustainable Entrepreneurship Education (Intervention B) will significantly improve Sustainable Entrepreneurial Intention, Attitude, Subjective Norm, and Perceived Behavioral Control scores compared to a control group (Intervention A)." is rejected.

Background factor - Gender

The gender-specific medians of the dependent variables measured in the experimental group during the pre- and post-test are presented in Table 8. The pre-test results indicate no significant differences in SEI, AT, and PBC scores between students identifying as female ($n = 58$) or male ($n = 84$). Due to the small sample size of students identifying as diverse, the cases were excluded from this statistical analysis.

The Mann-Whitney U test performed on the pre-test results confirms that the SEI, AT, and PBC scores between students identifying as female ($n = 58$) and those identifying as male ($n = 84$) are not significantly different. This is also evident for SEI, AT, and PBC scores between female (52) and male (66) students after the intervention. An exception is the SN score, which is significantly higher for female than male students before and after the intervention, with a small effect size. Refer to Table 9 for details.

Hypothesis H4.: "The effect of Sustainable Entrepreneurship Education on Sustainable Entrepreneurial Intention, Attitude, Subjective Norm, and Perceived Behavioral Control scores is consistent across participants' genders." is partially supported for SEI, AT, and PBC.

Control variables

Prior experiences

Over 80.0 % of the students indicated that the topic of 'SE' was not covered in class. Correspondingly, the topic of 'entrepreneurship' (e.g., student company) was not covered according to the majority of students. About 50.0 % of the students confirmed that the topic of 'sustainability' (e.g., SDGs) was not covered in class. Approximately 10.0 % of the students indicated participation in extracurricular activities related to entrepreneurship, SE, or sustainability, such as participating in a demonstration for sustainability.

A point-biserial correlation was performed to rule out the potential

Table 6
Pair-wise comparison of the differences between the medians of the pre- and post-test scores of the dependent variables measured in the experimental group before and after the intervention.

Dependent Variables	Intervention A ($n = 59$) No role models			Intervention B ($n = 54$) Sustainable entrepreneurial role models		
	z-value	p (one-tailed)	Effect size r (Cohen, 1988)	z-value	p (one-tailed)	Effect size r (Cohen, 1988)
SEI	–3.03	.001	.39 (medium)	–3.85	<0.001	.52 (large)
AT	–1.74	.041	.23 (small)	–2.64	.004	.36 (medium)
SN	–1.62	.052	.32 (medium)	–2.39	.009	.21 (small
PBC	–2.89	.002	.38 (medium)	–4.44	<0.001	.60 (large)

Table 8
Gender-specific median scores of dependent variables in pre- and post-tests for the experimental group.

Dependent Variable	Pre-test				Post-test			
	Female ($n = 58$)		Male ($n = 84$)		Female ($n = 52$)		Male ($n = 66$)	
	Median	IQR	Median	IQR	Median	IQR	Median	IQR
SEI	2.37	1.75	2.25	2.00	3.12	1.75	3.00	2.25
AT	3.67	1.33	3.33	1.33	4.00	1.34	4.00	1.67
SN	4.33	2.34	3.67	2.50	4.83	2.17	4.00	2.00
PBC	2.62	1.50	3.00	2.00	3.50	1.50	3.50	1.50

IQR, Interquartile range.

Table 9
Comparison of the differences of the pre- and post-test scores of the dependent variables between the independent samples in the experimental group separated by gender.

Dependent Variables	Pre-test			Post-test		
	Female ($n = 58$) compared to Male ($n = 84$)			Female ($n = 52$) compared to Male ($n = 66$)		
	Z-value	p (two-tailed)	Effect size r (Cohen, 1988)	Z-value	p (two-tailed)	Effect size r (Cohen, 1988)
SEI	–0.64	.523	.05 (no effect)	–0.48	.629	.05 (no effect)
AT	–1.08	.280	.09 (no effect)	–0.81	.417	.07 (no effect)
SN	–2.17	.030	.18 (small)	–2.06	.040	.19 (small)
PBC	–0.82	.411	.07 (no effect)	–0.02	.087	.00 (no effect)

effect of prior experiences on students' SEI, AT, SN, and PBC scores after the intervention. The analysis revealed no significant relationship.

Knowing entrepreneurs

About 50.0 % of the students indicated they personally know an entrepreneur, with most knowing the entrepreneur from their family. As shown in Table 1, the proportion of participants with self-employed legal guardians ranges from 13.0 % to 17.5 %, varying by group and assessment period. Most of those students who personally know an entrepreneur indicate that they know somewhat (5) to very much (7) about the entrepreneurs' actions and describe them as somewhat good (5) to very good (7) entrepreneurs. A minority of the students describe the entrepreneurs they personally know as somewhat sustainable (5) to totally sustainable (7) entrepreneurs, ranging from 15.5 % to 30.4 %, varying by group and assessment period.

A point-biserial correlation was performed to rule out the potential effect of this entrepreneurial family background on students' SEI, AT, SN, and PBC scores after the intervention. The analysis revealed no significant relationship.

Discussion

Previous studies have indicated that SEE positively affects SEI (e.g., Thelken & de Jong, 2020) and its antecedents AT, SN, and PBC (e.g., Agu et al., 2021). However, there has been a lack of experimental studies investigating said effect. The current study employed a pre-post control design to demonstrate that SEE can be effectively taught, significantly enhancing both SEI and its antecedents. Prior research on SEE has primarily focused on tertiary education (Diepolder et al., 2021). This study introduces a new demographic, showing that SEE can be successfully implemented in secondary education to increase adolescents' SEI, AT, SN, and PBC.

During the intervention, students accomplished genuine tasks from the initial phases of the sustainable entrepreneurial process. According to the TPB, the increase in SEI, AT, SN, and PBC scores can be explained by positive new experiences that diverged from existing expectations. Experiences made during the intervention changed students' beliefs about the probable outcomes of engaging in sustainable entrepreneurial behavior. For example, participants might have recognized the potential for personal economic benefits while contributing to the SDGs (AT), identified enabling factors such as skills to identify sustainable business opportunities (PBC), and received approval from significant others, such as classmates (SN).

Exposure to sustainable entrepreneurial role models is recommended (e.g., Lopes et al., 2023) and integrated as a pedagogical instrument in SEE for higher education to enhance learning outcomes (Bernhardt et al., 2017). A qualitative study by Diepolder et al. (2024) suggested their positive impact on students opportunity recognition for sustainable development. However, the present quantitative study shows that while larger effect sizes for SEI, AT, and PBC scores indicate a positive effect of sustainable entrepreneurial role models, a direct comparison revealed no significant differences between interventions with and without role models. This suggests that sustainable entrepreneurial role models are not essential for effective SEE.

The results of this study are consistent with existing findings on the background factor of gender (e.g., Truong et al., 2022), identifying no significant differences in the SEI scores between male and female students before and after the intervention. This also applies to the antecedents AT and PBC. Only the SN scores of female participants showed significant differences compared to their male counterparts before and after the intervention. Whether this is due to gender differences in pro-environmental behaviors, as identified within environmental psychology, could not be determined in this study.

Implications for theory

Previous studies using structural equation models have demonstrated the TPB's applicability in analyzing SEI drivers in higher education (e.g., Thelken & de Jong, 2020). The current results indicate that the TPB also applies in the context of promoting intentions toward SE in secondary education. Alongside increases in antecedents (AT, SN, and PBC), a corresponding rise in SEI was observed, aligning the impact of SEE with TPB predictions.

This study extends research on developing and evaluating competence-based SEE interventions. Diepolder et al. (2021) identified three SE competence frameworks rarely applied in SEE settings. The present intervention is based on the process-oriented competence framework for SE by Foucrier and Wiek (2019). The results demonstrate that SEE, integrating initial tasks of the sustainable entrepreneurial process and promoting associated competences, positively influences

SEI among secondary school students.

Most entrepreneurship education programs target students in their 20 s, starting abruptly rather than progressively building on previous programs (Ismail & Sawang, 2020). By targeting adolescents, the present intervention establishes a basis for further SEE programs at higher educational levels. In line with the process-oriented competence framework, these programs can address subsequent phases of the sustainable entrepreneurial process, such as sustainable human resources or sustainable finance, thereby fostering cumulative competence acquisition.

Implications for practice

Goswami et al. (2024) found a small negative effect of conventional entrepreneurship education on AT. This indicates that despite its aim to foster knowledge, skills, and attitudes necessary for entrepreneurial action in various contexts (Bacigalupo et al., 2016), conventional entrepreneurship education does not effectively stimulate SEI. To advance sustainable development through economic transformation, SEE should be integrated into curricula, and existing programs should be reassessed (Vuorio et al., 2018).

The present study demonstrates the effectiveness of a SEE that aligns with the sustainable entrepreneurial process and integrates sustainability not just as an add-on but as essential to accomplishing sustainable entrepreneurial tasks. Thus, this study clarifies the relationship between entrepreneurship and sustainability in SEE designs, moving beyond general recommendations for including both elements in the educational system (e.g., Lopes et al., 2023). Consequently, educators should proactively incorporate these findings into curriculum development, ensuring a competence-based SEE which embeds sustainability at the core of entrepreneurship education, thereby fostering a generation of entrepreneurs who are well-prepared to tackle global sustainability challenges.

To ensure the successful implementation, evaluation, and advancement of SEE, it is essential to consider the role of educators. Developing training programs for pre-service and in-service teachers can ensure the high-quality implementation of SEE.

Limitations and future research

The limitations outlined below provide avenues for further research. The current study does not include follow-up assessments to track long-term changes in SEI and its antecedents after the intervention, nor does it examine whether SEI leads to corresponding actions. The gap between entrepreneurial intentions and actual behaviors is well-documented (Krueger et al., 2000). While intentions are the strongest predictors of actions, their realization may fail due to constraints like limited financial resources (Ajzen, 2020). Longitudinal studies could offer insights into the persistence of intentions over time and inform the development of further educational programs to facilitate the performance of sustainable entrepreneurial actions.

The impact of the present intervention on sustainability competences and the influence of students' existing sustainability competences on SEI development remain unknown. Future studies should include these and other control variables to assess the intervention's effects and facilitate causal analysis.

It was not feasible to compare the results of this study with those from similar interventions and target groups, as research in SEE has primarily centered on higher education (Diepolder et al., 2021). Comparisons with other target groups or across different cultural backgrounds and regions were not possible because the effects of SEE on SEI have not been examined using experimental designs. Furthermore, a comparison of intervention designs proved unfeasible, as existing studies that demonstrate the effects of SEE on SEI (Agu et al., 2021; Romero-Colmenares & Reyes-Rodríguez, 2022; Thelken & de Jong, 2020; Truong et al., 2022) do not provide descriptions of the SEE interventions, unlike Diepolder et al. (2024). This lack of detail hinders the further development of programs and complicates the replication of studies. Further research is needed to assess the impact of various SEE designs on sustainable entrepreneurial competences and intentions in school settings.

Conclusions

This study addresses the research gap in SEE for secondary schools by analyzing the effect of a competence-based intervention, integrating sustainable entrepreneurial role models. The experimental research design provides initial evidence that SEE can be successfully implemented at the secondary school level. The significant positive effect of the intervention on SEI and its antecedents AT, SN, and PBC supports the relevance and predictive power of the TPB in the context of SEE.

Although interventions with sustainable entrepreneurial role models show stronger effects, their presence is not essential for the success of SEE at the secondary school level. Further research is required to explore how different types of role models can enhance learning outcomes as pedagogical tools in SEE. The intervention's gender-neutral impact on SEI, AT, and PBC highlights the potential of SEE to narrow the gender gap in entrepreneurial intentions and ultimately increase female entrepreneurship. Additional research is needed to explore gender differences in SN and understand why the intervention does not equally enhance SN in male students to the same extent as in female students. SEE can enhance sustainable entrepreneurial ecosystems by targeting secondary school students and empowering youth to adopt crucial roles in the future.

Data Availability Statement: The data presented in this study are available upon request from the corresponding author. The data are not publicly available due to the ongoing study.

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During the preparation of this work the authors used ChatGPT in order to improve the readability and language. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

Charlotte Sophia Diepolder: Writing – original draft, Visualization, Validation, Project administration, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Johannes Huwer:** Writing – review & editing, Supervision, Resources, Funding acquisition, Conceptualization. **Holger Weitzel:** Writing – review & editing, Supervision, Resources, Funding acquisition, Conceptualization.

Declaration of competing interests

The author is an Editorial Board Member/Editor-in-Chief/Associate Editor/Guest Editor for *[Sustainable Technology and Entrepreneurship]* and was not involved in the editorial review or the decision to publish

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