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Fostering secondary school students' attitudes toward sustainable development and their individual entrepreneurship orientations through a STEM + activity

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Abstract

Today, problems such as climate change, drought, food crises, and pandemics have once again brought the effective use of natural resources back on the agenda. With STEM + based activities, an interdisciplinary learning approach, students are expected to design a product that will solve a problem from daily life and add value to it. Based on these thoughts, this study aims to present a STEM + entrepreneurship activity for secondary school students to design cologne using lavender oil, a natural product. Also, the study aims to determine the impacts of the activity on students' attitudes toward sustainable development and individual entrepreneurship orientations. In this direction, a single-group pre–test–post–test study was conducted with the attendance of 20 tenth-grade secondary school students. Data was collected with the *Individual Entrepreneurship Orientation Scale* and *Attitudes toward Sustainable Development Scale*. The activity was developed according to the engineering design process steps, and a worksheet was used in the implementation, which lasted for four course hours. According to the results, a significant differentiation was determined both in the attitudes toward sustainable development and individual entrepreneurship orientations of the students in favour of post-tests. It is recommended to broaden the context of the activity in future studies.

Keywords Entrepreneurship, Lavender oil, STEM, Sustainable development

1 Introduction

The depletion of natural resources affects societies negatively. In addition, human beings face some challenges such as drought, climate change, and food crises. So, all resources should be consumed efficiently and not be wasted. Accordingly, the United Nations has introduced 17 sustainable development goals (SDGs) as the 2030 agenda as an action plan for the people, planet and prosperity [1]. Hence, the concept of sustainable development needs to be effectively applied in daily life nowadays.



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The role of education is stated as a key factor to raise awareness on sustainable development in the young generation [2]. Since the issues related to sustainable development have interdisciplinary foundations, STEM (Science, Technology, Engineering, and Mathematics) education is followed in this respect. Gamage et al. [3] explain STEM education as the teaching and learning method that integrates the content and skills of science, technology, engineering, and mathematics while providing students with opportunities to become problem solvers, innovators, inventors, logical thinkers, and technology literates. Thus, STEM education is more than mere transfer of knowledge, but also develops the next generation of innovators required to succeed in the current dynamic, globalised and competitive work environment [4]. However, recent critiques have emphasised the limitations of STEM education in addressing long-term sustainability challenges, especially concerning its scalability, inclusivity, and real-world applicability in under-resourced educational settings [5, 6]. Moreover, many STEM+ educational models, although promising in theory, often lack empirical validation and do not consistently demonstrate sustained behavioural change among learners in relation to sustainable development practices [7]. Yet, it is believed that proper studies should be designed to obtain efficient results and maintain their positive influences on the students.

In today's world, the economic and business development of a country is very important. Therefore, this situation demands the emergence of young entrepreneurs to join business life, which is imperative to decrease employment and poverty issues while giving rise to economic growth [8]. It is highlighted that as a result of attaining STEM jobs, these people should have the ability to turn their ideas into products, i.e. to be entrepreneurs to drive a country's innovation economy [9]. Hence, it is believed that STEM education can be utilised in training students who are aware of sustainable development and equipped with entrepreneurship orientations. Also, natural resource sustainability is one of the contemporary subjects which can be focused on in terms of STEM education [7]. Thus, this study aims to contribute to the existing literature by proposing a novel STEM+ activity that not only integrates sustainability and entrepreneurship but also seeks to address gaps related to experimental, hands-on learning approaches in the context of SDGs, using lavender oil cologne production as a real-world application.

1.1 The aim and significance of the study

The purpose of this research is to present a STEM+ entrepreneurship activity for secondary school students using lavender oil, a natural substance and foster their attitudes toward sustainable development, and individual entrepreneurship orientations with a weak experimental study. On the other hand, the systematic review of Concina and Frate [10] indicates the insufficiency of the studies regarding quantitative experimental studies regarding sustainable development when compared to the quantitative correlational and quantitative descriptive studies. With the study, it is expected to raise awareness about turning lavender that can be found in abundance into a useful product without being wasted. Thus, the study considers the importance of sustainable development and this aim is intended to be reflected in the students' attitudes. Moreover, it is believed that the activity carries significance in terms of its entrepreneurship aspect. As a matter of fact, it is noteworthy that there is a gap in the studies on the development of entrepreneurial skills of secondary school students. On the other hand, it is thought that these skills of young individuals who are expected to be entrepreneurs in the future should be

developed during secondary school. Therefore, it is intended to provide students with positive orientations towards their careers after their current level of education. Thus, the study is expected to make several contributions to the literature.

1.2 The research questions

The research questions are as follows:

- Does the STEM+activity proposed in this study have a significant effect on secondary school students' attitudes toward sustainable development?
- Does the STEM+activity proposed in this study have a significant effect on secondary school students' individual entrepreneurship orientations?

2 Literature review

Sustainable development has become an important concept for the world, considering today and the future. This concept is based on the idea of protecting our planet from any developments which could cause harm to the people and the environment [11]. When the literature is examined, it is seen that the definition and context of this concept are observed to change in the international policy documents [12]. The concept is dynamic, complex and connected with various interpretations [13, 14]. In addition, it is indicated that there is no well-defined path to sustainable development, nor is there a well-defined endpoint [14]. Robert et al. [15] assert that the original emphasis of this concept was on economic development and environmental protection, whereas later on, the context of it extended to cover human and social development in addition to alternative views of nature. Besides, as a result of his analysis, Jabareen [16] has introduced seven concepts (ethical paradox, natural capital stock, equity, eco-form, integrative management, utopianism, and political global agenda) which compose the theoretical framework of sustainable development. Thus, sustainable development addresses various aspects in an integrated manner to provide a better life for the generations. To solve the issues encountered in daily life and in the future, awareness should be created in students about this concept [17].

The 17 SDGs put forward by the United Nations begin with *no poverty* and continue with *zero hunger* and *good health and well-being* [1]. The 12th of these goals is *responsible consumption and production*. Today, this goal is important for the effective use of resources. In order for resources to be distributed equally among people in the world and to be transferred to future generations, it is necessary to avoid excessive consumption and transform them into different usable forms. The report published in 2024 draws attention to the worldwide crisis of nature loss and states that domestic material consumption and material footprint continue to increase [18]. Hence, the education given to children from an early age might create a difference in achieving these SD-related goals.

The literature includes studies which were conducted with different age-group samples regarding attitudes toward sustainable development. A study conducted in Mexico revealed that undergraduate students possessed a moderate level of knowledge and attitudes regarding sustainable development [19]. Besides, as a result of their survey study conducted with adults and students who were studying at grades 6–12 in Canada, Michalos et al. [20] explained that sustainable development favourable attitudes were more significant than age, levels of education, and knowledge for sustainable development favourable behaviours. In addition, the study of Nikolic et al. [21] showed that university

students had partially positive attitudes toward sustainable development. The students understood the basic characteristics of the concept, whereas they did not possess a differentiated opinion of the way in which sustainable development was implemented. Furthermore, Balakrishnan et al.'s [11] research indicated positive perceptions and attitudes of Malaysian undergraduate students about sustainable development in all dimensions. However, social and economic dimensions were reported to have lower scores when compared to the environmental dimension. A similar result was also concluded from the findings of Kougias et al. [22]. These researchers reported that natural science teachers in Greece perceived the most important dimension as environment, whereas social science teachers mentioned well-being in this respect. So, an integrated approach is necessary to enhance students' attitudes toward sustainable development.

It is seen that sustainable development cannot be achieved through isolated initiatives, but it requires integrated efforts at multiple levels, such as social, environmental and economic aspects [23]. STEM education brings various advantages to the field in this respect. As a result of a systematic review, it is stated that STEM studies are mostly carried out with simple tools and equipment, increase student success and develop 21st century skills [7]. On the other hand, there are some criticisms of STEM education. For instance, although teachers find STEM education valuable, they believe that pedagogical challenges, curriculum challenges, structural challenges, concerns about students, concerns about assessments, and lack of teacher support pose serious obstacles to STEM education [5]. In addition, other criticisms include that STEM education directs students to develop products rather than focusing on the problem situation [24] and limits students' scientific concept development [25].

As STEM fields have remained insufficient in several subjects, researchers have integrated different fields such as art and environment into STEM [26]. Thus, new approaches such as STEAM or STEM+A (A for Art), STEM+C (C for Computing), STREAM (R for Reading and A for Art) and ESTEM (E for Environment) have emerged. For example, Park and Ko [27] underline the importance of art in STEAM education, which provides a competitive and innovative field as STEM in creativity. One of the approaches that emerged as a result is STEM and entrepreneurship education (STEM+ entrepreneurship). Shane and Venkataraman [28] explain entrepreneurship as a field of business which seeks to understand how opportunities create something new. Also, entrepreneurship enables knowledge of individuals to gain value for the future by applying it to real-life situations [29]. Therefore, it can be asserted that entrepreneurship is connected to creativity, productivity, daily life, using theoretical knowledge, and solving problems. In this respect, the STEM approach and entrepreneurship complement each other.

Entrepreneurship involves the process of achieving goals by combining an individual's creativity, innovation and risk-taking skills with planning and project management competencies [30]. In this context, a chemistry course is believed to supply an appropriate background to improve such skills of the students. Students are expected to use their knowledge and skills they have acquired in the chemistry course to explain situations related to daily life, health, industry, and the environment, and to be willing to produce new ideas and carry out original studies that will benefit humanity. A longitudinal study implies that the combination of having an entrepreneurial environment and

entrepreneurial education is necessary for STEM students to achieve the highest level of entrepreneurial readiness [31].

In the literature, several studies have been carried out within the scope of STEM+entrepreneurship. For instance, in Aydın-Günbatar's [32] STEM+activity-based study, pre-service chemistry teachers designed pH indicator sticks with daily life materials. In another STEM activity carried out by Pabuçcu Koşu and Demirer [33], secondary school students produced their own hand disinfectants using different natural substances. In this activity, the students prepared labels for the products they developed, thus adding a brand advertising dimension to the activity. In addition, as a result of the green entrepreneurship-based STEM education that Dahl and Grunwald [34] gave to lower secondary school students; the students introduced products such as a protein tablet to replace meat consumption, bottle caps made of bamboo, straws made of palm leaves, and a filter made of linen and natural rubber to capture microplastics in the kitchen sink. On the other hand, in a study of Nikitina et al. [35], STEM students were found to be lower risk-takers and innovators when compared to the business students. However, the researchers concluded that STEM students were significantly more proactive than the other participants, and the field of study was asserted to be influential in this regard. Accordingly, it is thought that the STEM+entrepreneurship approach can be used to help students from different age groups find solutions to environmentally related problems and develop their abilities and attitudes in this respect.

As in this study, it is seen that the focus in the literature involves developing student attitudes within the scope of STEM education. Significant increases in students' entrepreneurial attitudes [36], STEM attitudes [37–39], and STEM-project-based learning attitudes [40] have been determined with STEM education. Among these studies, there are relatively long-term studies conducted for seven to eight weeks [38, 39] as well as shorter-term studies based on only one activity implementation [36, 37, 40]. However, positive attitude development studies are time-consuming [41–43], and different results are obtained in terms of the sub-dimensions of the attitudes. Indeed, Chaiwongsa et al.'s [37] study showed that the increase in the value sub-dimension of students' attitudes, which they gave to science, technology and engineering, was lower than the increase in the average attitudes in this sub-dimension. However, these researchers also determined that there was a greater improvement in students' attitudes towards the ability sub-dimension than the average attitudes.

In addition to the aforementioned problems, as pointed out in the SDGs, such as hunger, another great challenge that humanity has recently experienced is the COVID-19 Pandemic. In this process, people have also looked for ways to protect their personal hygiene while fighting against the virus. Alcohol-based hand disinfectants are among the most used products for this purpose since these products offer advantages such as being convenient and ensuring personal hygiene when hand washing is not possible [44]. On the other hand, in a survey study aiming to reveal the difficulties encountered in the process of using hand disinfectants, more than half of the participants claimed that they had difficulty accessing such products and that these products were expensive [45]. However, these products can be easily prepared using various natural resources such as lemon and lavender. In Türkiye, liquid mixtures prepared using ethyl alcohol with different natural aromas for both providing hygiene and benefiting from its pleasant smell are called

cologne and are widely used in daily life. This study focused on lavender, one of these natural substances.

Due to its value, lavender is widely cultivated in Türkiye and worldwide [46]. Although the essential oil produced from lavender is used in many areas, the most important of these is the cosmetics industry, where various products such as perfumes are produced by making use of its pleasant scent [47]. Additionally, lavender oil reduces anxiety [48], facilitates sleep [49], and has an antimicrobial effect [50]. Lavender oil is also utilised in the treatment of anxiety, stress, and sleep disorders [51], burns and insect bites [52], and dealing with the pathogens in foods as antimicrobial agents [53]. Therefore, to effectively benefit from lavender, it is important to turn it into a product. This paper focuses on the utilisation of lavender oil to design cologne.

3 Method

3.1 Study design

In this study, a quantitative research method consisting of a single-group pre-test-post-test weak-experimental design was used. Measurements using the same data collection instruments on a single group as the study sample before and after the implementation process are used to evaluate the impact of the experimental method carried out in the study [54]. Thus, using this method, it is possible to show the effect of a particular application on the dependent variable investigated in the study sample [55]. Although the absence of a control group limits the ability to make strong causal inferences, single-group designs are commonly used in the initial exploratory phases of intervention development, particularly in educational contexts where randomised control is not feasible due to ethical or logistical constraints [56, 57]. Several recent studies employing STEM-based educational interventions have utilised a single-group pre-test-post-test model to examine attitudinal or behavioural shifts, especially in pilot implementations [58, 59].

3.2 Study sample

The study sample consisted of 20 students who were studying in the tenth grade at a secondary school in the western part of Türkiye. Eleven of the students were female, whereas nine of them were male. The average age of the students was 16. All of the students were taking a tenth-grade chemistry course. Thus, the study sample was formed via a purposive sampling method. Purposive sampling is used to select participants who are most likely to generate relevant and useful information [60] and is a way to identify and choose cases that will effectively utilise limited research resources [61]. While the purposive selection of chemistry students may imply pre-existing interest in STEM, this approach is justifiable in intervention-based studies aiming for contextual relevance and feasibility in early-stage implementations [61]. Moreover, the goal of this study was not generalizability, but rather to observe changes within a defined population who are reasonably assumed to engage meaningfully with the experimental activity [62].

3.3 Data collection instruments

The data of the study were collected with the help of two instruments, both of which are 5-point Likert-type scales. The first of these is the *Attitudes toward Sustainable Development Scale (ASDS)* developed by Kaya [63]. It was stated that the scale could be used for determining the attitudes of secondary school students toward sustainability. This

scale has 21 items collected under three sub-scales. The sub-scales are *social sustainability* (items 1–8), *sustainable environment* (items 9–14), and *sustainable economy* (items 15–21). The Cronbach's alpha coefficient of the scale was reported to be 0.93 by Kaya [63]. The second scale is the *Individual Entrepreneurship Orientation Scale (IEOS)*, which was originally developed by Bolton and Lane [64] and then adapted to the Turkish language by Ercan and Yıldırım [65]. This scale involves 10 items under three sub-scales. The sub-scales are *risk-taking* (items 1–3), *innovativeness* (items 4–7), and *proactiveness* (items 8–10). A Cronbach's alpha coefficient of 0.80 was calculated for the total scale by the researchers [65]. The items in both scales are rated as “1” to “5” points for “totally disagree” to “totally agree”.

In the study, to minimise the influence of social desirability bias, the participants were assured of complete anonymity and confidentiality, and the data were collected without the presence of authority figures. Additionally, both scales have been used in recent research involving adolescents or university students in Türkiye [66–69], suggesting a contextual relevance despite limited longitudinal validation. Although the original scales were not developed specifically for intervention studies, recent findings [70] demonstrate their responsiveness to short-term educational programs aimed at enhancing sustainability awareness and entrepreneurial orientation. Furthermore, expert reviews were taken prior to the application to ensure content validity in the specific context of this study.

3.4 Implementation process

Figure 1 shows the flow of the implementations conducted regarding the study.

The activity proposed in this study aims to teach sustainable development and entrepreneurship to the secondary school students by making them turn lavender oil, a natural source into a valuable product through a STEM + activity. In this direction, the activity is implemented to the students working in groups with the use of the worksheet developed by the researchers. This study was conducted with five groups involving four students in each group. The activity lasted about four course hours (4 × 40 min).

The materials used in the activity are as follows and shown in Fig. 2:

- Lavender oil (max 40 drops).
- 80 mL of ethyl alcohol (96% purity).
- 18 mL of deionized water.
- Graduated cylinder.
- Conical flask.
- Beaker.
- Dropper.

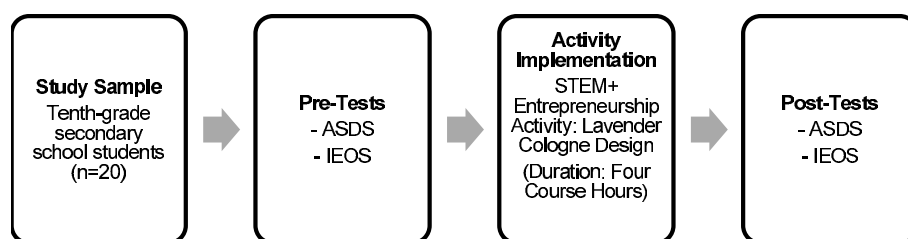


Fig. 1 The flow of the study implementations



Fig. 2 The laboratory materials used in the activity

- Old cologne bottles.
- Computer and printer.

The safety precautions to be taken during the activity are as follows:

- While working in the laboratory, a suitable lab coat and safety glasses should be worn.
- While using alcohol, open flames or heat sources should be avoided.
- Lavender oil, an essential oil, is concentrated and should not be brought closer directly to the nose or eyes.

This activity is designed according to the engineering design process steps. Within this scope, the activity is implemented based on the model proposed by Wendell et al. [71], which consists of five steps as finding the problem, researching possible solutions, choosing the best solution, building a prototype, and testing the prototype. Ethical research standards were followed in the implementations.

The details of the engineering design steps are explained below.

3.4.1 Finding the problem (15 min)

The activity starts by first attracting students' attention to the subject. In this context, the teacher asks the students whether they have been to a lavender field before or whether they have seen a lavender field on television or social media. S/he asks the students who have had experiences in the lavender field about their observations and whether they know about products made from lavender. After the introduction, the teacher gives the problem situation (Fig. 3) by distributing the worksheet in Appendix 1 to the students.

The teacher asks the students to express the problem situation in the paragraph given to them.

3.4.2 Researching possible solutions (25 min)

In the second stage, students do a short research on the uses of lavender from the internet. As a result of this research, they list possible solution suggestions for the utilisation of lavender oil. These suggestions are discussed in class. In this context, students put forward suggestions such as making soap, wet wipes, and cologne.

3.4.3 Choosing the best solution (10 min)

Following the solution suggestions, the teacher presents the materials to be used in the activity to the class. Thus, s/he limits the solution. Considering the situation, students turn to cologne design as the best solution. Then, the teacher states three criteria for students' cologne design:

- The cologne should be clear.
- The cologne should consist of a single phase.
- The cologne bottle should be creative, functional, and possess a logo and QR code showing its components.

3.4.4 Building a prototype (30 min)

At the fourth stage, students are expected to use the worksheet and make their designs using appropriate amounts of alcohol, water, and lavender oil. For this reason, they are asked to mix all the ingredients in two steps rather than mixing all of them at the same time. Also, the students are reminded to add lavender oil drop by drop. Figure 4 shows photos of students' cologne designs according to the three stages structured in the worksheet.

According to Fig. 4, in the first design, students first mix 18 mL of water and 2 mL of oil (approximately 40 drops) and then add 80 mL of ethyl alcohol. However, they notice that the product they obtain does not meet the first and second criteria introduced in the activity. In the second design, the students mix 18 mL of water and 80 mL of ethyl alcohol, and then drop 2 mL of oil onto it. As a result, they realise that this design is not

Lavender cultivation has become popular in different parts of our country in recent years. One of the products made from lavender is lavender oil. The important thing is to continue to provide benefits by transforming this oil into ways that can be useful to people. If you consider infectious diseases such as flu, which have become widespread in recent years, how can you find a solution to this problem with lavender oil?

Fig. 3 The problem situation of the activity

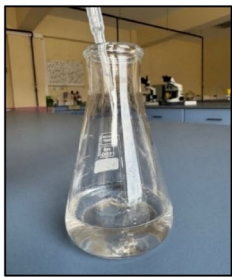
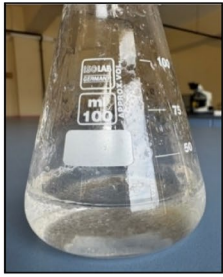
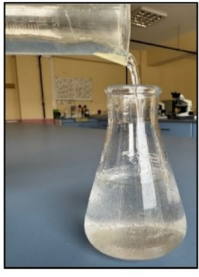
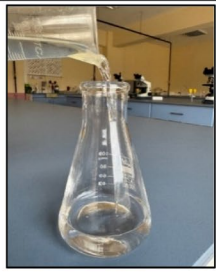
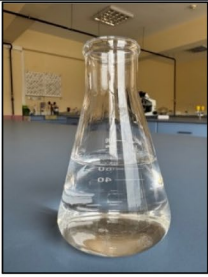
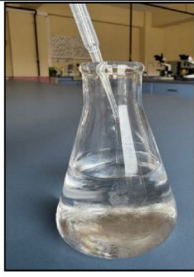
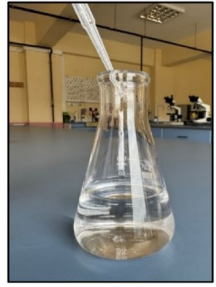


Design 1			
	oil is dropped into water	oil + water mixture	ethyl alcohol is added to the mixture
Design 2			
	water is added into ethyl alcohol	water + ethyl alcohol mixture	oil is dropped into the mixture
Design 3			
	oil is dropped into ethyl alcohol	oil + ethyl alcohol mixture	water is added to the mixture

Fig. 4 Photos from three different cologne designs

clear either. In the final design, students dissolve 2 mL of oil in 80 mL of ethyl alcohol and then add 18 mL of water. It is seen that this design is single-phase and clear.

3.4.5 Testing the prototype (80 min)

Students examine their designs in terms of their appearance and redesign them if they are not appropriate. In this way, they finalise their products and define the amounts of the substances in the product's composition as a QR code. Also, they prepare a logo for their cologne.

After the students test their prototypes and obtain the final version of their products, each group introduces their design to the class. Additionally, the cologne design made by each group is evaluated by the teacher according to the rubric in [Appendix 2](#).

3.5 The connections of the activity

The activity makes a connection to Goal 12 of SDGs, responsible production and consumption, which ensures sustainable consumption and production patterns [1]. The activity is also related to the subject of “Homogeneous and Heterogeneous Mixtures” in the tenth-grade Chemistry course program implemented in Türkiye, as declared by the Ministry of National Education [72].

3.6 Data analyses

In data analyses, first, the normality of data sets was examined for both scales' scores. Accordingly, the normality of the scores obtained from the pre- and post-test applications was analysed with the Shapiro-Wilk test since the sample size was below 50 [73]. Table 1 shows the normality analysis results at $\alpha = 0.05$ significance level.

According to Table 1, it was determined that the data sets showed normal distribution for both pre- and post-test applications of the scales. For this reason, the t-test for related-samples from parametric tests was used in the comparison of the data. To control the increased risk of Type I error associated with conducting multiple t-tests, a Bonferroni adjustment was applied by dividing the conventional α level (0.05) by the number of comparisons. The adjusted significance level was set at 0.0125. All results retained their statistical significance after the correction, confirming the robustness of the findings.

To identify the effect size of the implementation for meaningful differences on students' attitudes and orientations, Cohen's [74] d statistics were calculated. Cohen [74] defined d values as 0.2, 0.5 and 0.8 to indicate small, medium and large effects, respectively.

The reliability of data was evaluated with Cronbach's alpha coefficient. It was determined to be 0.705 for pre- and 0.710 for post-test application of *ASDS*. Besides, a value of 0.906 for pre- and 0.855 for post-test application was detected for the application of the *IEOS*. Generally, an alpha value between 0.60 and 0.80 indicates that the data analysis is quite reliable [75]. A higher Cronbach's alpha coefficient indicates reliability and shows that the items are compatible with each other [76].

4 Findings

4.1 Findings regarding the attitudes of the students toward sustainable development

The findings obtained from the t-test for related samples for the attitudes of the students toward sustainable development are shown in Table 2.

As shown in Table 2, the results of the t-test for related samples indicate that the mean scores obtained by the students from the *ASDS* demonstrated a significant differentiation between pre- and post-test applications in favour of the post-test ($t(19) = 17.57$, $p = .0001$). Considering the mean scores, there is a significant increase from pre- ($M = 51.80$, $SD = 6.91$) to the post-test application ($M = 88.35$, $SD = 5.82$). Besides, the

Table 1 Shapiro-Wilk test results of data sets

Application	Sustainable Development Attitude Scores			Individual Entrepreneurship Orientation Scores		
	statistic	df	p	statistic	df	p
Pre-test	0.939	20	0.234	0.924	20	0.121
Post-test	0.981	20	0.941	0.968	20	0.714

Table 2 The analysis results of the attitudes of the students toward sustainable development

Scale/Sub-Dimension	Pre-test M(SD)	Post-test M(SD)	t	p	Bonfer- roni Adj. α	Signifi- cant after Bonferroni	Co- hen's d
Total Scale	51.80 (6.91)	88.35 (5.82)	17.57	0.0001	0.0125	True	3.93
Social Sustainability	19.15 (4.07)	33.75 (2.38)	14.82	0.0001	0.0125	True	3.32
Sustainable Environment	15.40 (3.35)	25.85 (2.54)	9.93	0.0001	0.0125	True	2.22
Sustainable Economy	17.25 (2.31)	28.75 (3.40)	11.83	0.0001	0.0125	True	2.65

M: Mean, SD: Standard Deviation

Table 3 The analysis results of individual entrepreneurship orientations of the students

Scale/Sub-Dimension	Pre-test M(SD)	Post-test M(SD)	t	p	Bonfer- roni Adj. α	Signifi- cant after Bonferroni	Co- hen's d
Total Scale	22.50 (8.11)	40.20 (5.18)	7.18	0.0001	0.0125	True	1.61
Risk-Taking	6.10 (3.16)	11.50 (2.37)	5.64	0.0001	0.0125	True	1.26
Innovativeness	9.85 (3.29)	15.95 (2.06)	5.96	0.0001	0.0125	True	1.33
Proactiveness	6.55 (2.19)	12.75 (1.45)	9.51	0.0001	0.0125	True	2.13

M: Mean, SD: Standard Deviation

t-test results related to the data obtained from the sub-dimensions also imply significant increases in all sub-dimensions (social sustainability: $t(19) = 14.82$, $p = .0001$; sustainable environment: $t(19) = 9.93$, $p = .0001$; sustainable economy: $t(19) = 11.83$, $p = .0001$). Also, d statistics showed a large effect of the implementation on students' attitudes, both in the total and sub-dimensions.

4.2 Findings regarding the individual entrepreneurship orientations of the students

The findings obtained from the t-test for related samples for the individual entrepreneurship orientations of the students are demonstrated in Table 3.

According to Table 3, the results of the t-test for related samples reveal that the mean scores obtained from the *IEOS* showed a significant difference from pre- to post-test application ($t(19) = 7.18$, $p = .0001$). It is noticed that the mean score obtained by the students as a result of the post-test ($M = 40.20$, $SD = 5.18$) increased significantly when compared to the pre-test application ($M = 22.50$, $SD = 8.11$). In addition, the t-test results related to the data obtained from all three sub-dimensions also improved significantly (risk-taking: $t(19) = 5.64$, $p = .0001$; innovativeness: $t(19) = 5.96$, $p = .0001$; proactiveness: $t(19) = 9.51$, $p = .0001$). Similar to the previous findings, a large effect was determined on students' individual entrepreneurship orientations both in the total and sub-dimensions considering d values in Table 3.

5 Discussion and conclusions

This study was based on an activity suggestion that can be used in the STEM+ entrepreneurship education of secondary school students. The duties and responsibilities assumed by individuals from all segments of society play a critical role in achieving SDGs [77]. In this STEM+ entrepreneurship activity, Goal 12 of the SDGs creates a basis for the students. The literature involves several studies which focus on teaching SDGs with hands-on applications, considering STEM education for primary school students [78] and pre-school level students [79]. These studies also conclude positive consequences for the literature. However, unlike the current study, one of these studies had a

qualitative nature [78], whereas the other one was a mixed-type study [79]. They focused on students' attainment of SDGs. On the other hand, the present study had a quantitative approach.

The results of the current study revealed a significant increase in secondary school students' attitudes toward sustainable development. According to Michalos et al. [20], having attitudes favourable to education for sustainable development/sustainable development is relatively more influential than age, levels of education and knowledge for behaviours favourable to education for sustainable development/sustainable development. Also, Berglund et al.'s [14] research produced a significant increase in the sustainability consciousness of upper secondary students as a result of the education they gave to the students. The increase in the current study, as observed in the overall scale, also manifested itself clearly in environmental, economic and social dimensions of the students' attitudes. These results are important when it is considered that there is a need for higher education institutions to integrate sustainable development into curricular and extracurricular activities for university students, as highlighted by Wendlandt Amézaga [19]. On the other hand, Balakrishnan et al.'s [11] study showed that university students had relatively lower attitudes in the dimensions of social and economic issues when compared to the environmental issues. Also, the results of Berglund et al.'s [14] research indicated a significant impact of the sustainable development education on the economic dimension of sustainability consciousness, whereas no significant differences were determined between sustainable education and control group students in terms of the environmental and social dimensions. It is thought that these results might be related to the background and culture of the students. Besides, Kougiyas et al. [22] reported various misconceptions of teachers about sustainable development, which can also hinder students' understanding and perceptions of this concept.

In this activity, students' entrepreneurial skills were improved with the help of a plant. Accordingly, it is pointed out that environmental issues are among the main issues that initiate entrepreneurship in higher education institutions that provide STEM education [80]. In another study, Amri [36] utilised another plant, the banana, for the high school students to convert into a value-added product in terms of a STEM activity. Therefore, such activities applied to students in the pre-university period may be effective in their career orientation. On the other hand, these studies are relatively short-term implementations. As a result of a longer period of implementation, Karpova et al. [81] found that a STEM science camp program applied to secondary school students increased students' knowledge, interest, and intentions to attend a university that provides education in STEM fields.

The current study indicated that the scores of innovativeness, risk-taking and proactiveness, which were sub-dimensions of the *IEOS*, also increased significantly. Similarly, another research based on STEM and entrepreneurship education conducted with middle school students showed that students' entrepreneurial skills improved in all sub-dimensions [39]. On the other hand, Şirin et al.'s [82] study indicated that there was no significant difference between the entrepreneurial attitudes of high school students who took and did not take entrepreneurship courses. In the current study, a significant increase was observed in the innovativeness dimension, which shows students' ability to develop and implement new ideas. This increase contributes to the emergence of innovative products and services that can provide a competitive advantage in the market

[83]. However, the students might also experience difficulties in the activity process. The lack of one-to-one interviews in this study prevented the collection of data on this issue. Yazıcı et al. [39] report that design issues constitute a major problem in STEM + entrepreneurship education.

In the risk-taking dimension, it was determined that students exhibited more courageous and determined behaviour in the face of uncertainty and potential dangers. This allows faster and more effective decisions to be made in evaluating opportunities and entrepreneurial activities [84]. On the other hand, Ferreira et al.'s [85] study shows that STEM PhD students and graduates report various barriers regarding starting up. Financial issues were determined to be significant in this respect. So, this result might be associated with the age of the participants. It can be asserted that students get economic worries as they grow up, which might negatively influence their risk-taking characteristics. In the proactiveness dimension, it was determined that there was a significant increase in students' tendency to foresee future opportunities and take action to evaluate these opportunities. This increase enhances the capacity of entrepreneurs to quickly adapt to changing market conditions and find solutions before problems arise [86]. However, Yazıcı et al. [39] remark that a participant in their study mentioned mission conditions' difficulty, although a significant improvement was obtained among students in all sub-dimensions of entrepreneurship skills.

In this study, the effect sizes– Cohen's *d* statistics were calculated to be over 1.0. The values over 0.80 are considered large according to Cohen [74]. On the other hand, such high values are not so common in the literature but are encountered in the experimental studies [87, 88]. This result might stem from short-term but content-intensive and goal-oriented training programs, which give rise to dramatic changes, especially at behavioural and attitudinal levels [87]. Besides, if the sample size is small as in this study ($n = 20$) and the within-group variance is low, it is stated that Cohen's *d* can grow very quickly [88].

In the literature, another cologne design activity is also encountered in the work of Pabuçcu Akiş and Demirer [33]. However, these researchers presented students with different types of essential oils (such as jasmine, magnolia, lavender, and apple) for their cologne designs and used 3D printers to design their cologne bottles. The current activity is based on designing a cologne from a single natural source and focuses on the concept of recycling by making use of old cologne bottles, which are abundantly available in daily life at home. The students are expected to specialise these bottles by using technology. Additionally, the current activity is supported by the worksheet developed by the researchers, aiming to effectively implement the prototype development, testing, and revision steps of the engineering design process. In the worksheet, the volumes of ethyl alcohol (80 mL) and water (18 mL) were given to the students. Thus, it was intended to help students produce an effective antimicrobial cologne, which is an alcohol-based hand sanitiser. Research states that higher alcohol concentrations are necessary to inactivate virus activity [89, 90]. Alcohol-based hand sanitisers can include 60–95% (v/v) alcohol, such as ethanol, isopropyl alcohol [91], and they reduce the microbial burden [92]. On the other hand, the exact mechanism beyond this process against viruses compared to bacteria is not well-known, but ethanol is reported to be more effective than propanol in this regard [93]. Hence, in this study, 80 mL of ethyl alcohol was utilised to make 80% cologne.

In the worksheets, the students were given three alternative ways to produce their cologne. Consequently, they could discover the best way to produce their cologne. In the first and second designs given in Fig. 4, it is realised that students could not obtain a product that met the criteria. Therefore, the reasons for these findings were discussed in the class, considering the homogeneous and heterogeneous mixtures as explained in the chemistry course program [72]. Thus, students were assisted in understanding these concepts. Besides, the reasons for the compliance of the third design made by the students with the criteria were explained to the students by creating a discussion environment based on the correct establishment of solvent and solute relationships specified in the course objectives. On the other hand, conceptual understanding levels or academic achievements were not handled in the study. The effectiveness of the activity was measured only in terms of quantitative methods regarding two variables. Also, the analysis of students' worksheets, which might provide qualitative data, was excluded from the study. So, in further studies, more enriched results might be obtained by means of diversifying the data collection methods (such as observations, open-ended questions) and considering the conceptual understanding of the students.

6 Limitations and suggestions

In future research, the following are suggested to broaden the context of the activity:

- Different aromatic oils, such as orange oil and lemon oil, can be presented to the students for their cologne designs.
- Problem situations which are used in the first step of the activity can be generated by using actual media news about the excessive amount of products (such as lemons) remaining in the hands of the producer being wasted due to their inability to find a market.
- The students in groups can prepare a short advertisement video marketing their product, to include technology more comprehensively in their studies.
- Data triangulation can be made by using both qualitative and quantitative methods to obtain more detailed results.
- Criticisms regarding the size of the d coefficient can be eliminated by performing the activity on larger samples.

Appendix 1

Worksheet for lavender cologne design.

Group Name:

Part 1: Lavender cultivation has become popular in different parts of our country in recent years. One of the products made from lavender is lavender oil. The important thing is to continue to provide benefits by transforming this oil into ways that can be useful to people. If you consider infectious diseases such as flu, which have become widespread in recent years, how can you find a solution to this problem with lavender oil?:

Problem Statement:

Possible Solutions:

Best Solution:

Part 2: Here, you have the substances (80 mL of ethyl alcohol and 18 mL of water) to design your cologne. Remember to add lavender oil in the form of droplets (max 40 droplets). Note down the amount of substance you use in your designs. Test your design until you get the best results in terms of the phase and clarity.

Design 1:

Design 2:

Design 3:

Group Name:		
• I mix &	• I mix &	• I mix &
• Then, I add	• Then, I add.....	• Then, I add.....
<i>My Observations (✓ or X)</i>	<i>My Observations (✓ or X)</i>	<i>My Observations (✓ or X)</i>
- One phase	- One phase	- One phase
- Clarity	- Clarity	- Clarity
• Do you want to change the amounts and redesign it? ?.....	• Do you want to change the amounts and redesign it?.....	• Do you want to change the amounts and re-de- sign it?.....
Part 3: Results & Conclusions		
• What are your conclusions about your cologne designs?		
• Which design is the best one? Why?		

Appendix 2

Rubric for evaluating lavender cologne designs.

Criteria	Scores				
	Very Good (5)	Good (4)	Needs to be developed (3)	Insufficient (2)	Very Insufficient (1)
Scent					
Colour					
Clarity					
Active substance content					
Package and presentation					

Author contributions

HÜ: designed the study, wrote the manuscript. NK: conducted the study, collected and analyzed data. GD: supervised the study, edited the manuscript.

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Data availability

Data and material related to the study are available upon request.

Declarations

Ethics approval and consent to participate

All methods were carried out in accordance with relevant guidelines and regulations. Ethical approval was taken from Social Sciences and Humanities Ethical Board of Bandırma Önyedi Eylül University. Informed consent was obtained from a parent and/or legal guardian for the participants since they are under 18.

Consent for publication

All authors consent to the publication of this manuscript.

Competing interests

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