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Teaching Factory Based on Scientific Creativity to Enhance Students' Soft Skills and Sustainable Entrepreneurship

Taufik Samsuri [1]*, Habibi [2], Muhammad Ikhsan [3]

[1] Department of Biology Education, Universitas Pendidikan Mandalika, Mataram, Indonesia.
[2] Department of Physics Education, Universitas Negeri Surabaya, Surabaya, Indonesia.
[3] Department of Sports Education and Health, Universitas Pendidikan Mandalika, Mataram, Indonesia.

*Correspondence: taufiksamsuri@undikma.ac.id

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Abstract

This study aimed to assess the validity and effectiveness of a Teaching Factory (TEFA) model based on scientific creativity in enhancing students' soft skills and fostering sustainable entrepreneurship. The TEFA approach was validated through expert evaluations and tested through two production processes involving 15 university students. The research focused on improving soft skills such as communication, teamwork, creativity, leadership, and time management, alongside sustainable entrepreneurship skills like opportunity identification, resource utilization, and entrepreneurial action. Data were collected using observation sheets and analyzed through descriptive statistics and ANOVA to compare students' performance across the two production processes. The results showed significant improvements in students' soft skills and sustainable entrepreneurship, with the TEFA approach based on scientific creativity proving highly effective. Average soft skill scores increased from "Poor" to "Good" after the intervention, and similar improvements were observed in sustainable entrepreneurship scores. The structured pedagogical cycle employed—encompassing need identification, curriculum development, implementation, evaluation, and reflection—successfully bridged the gap between theoretical knowledge and practical application in entrepreneurship education. However, a limitation of the study was its small sample size, indicating the need for further research with larger and more diverse populations. These findings suggest that the TEFA approach based on scientific creativity can be a valuable addition to university entrepreneurship programs, better preparing students for the challenges of the global business landscape.

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INTRODUCTION

The increasing emphasis on university entrepreneurship programs aligns with the evolving demands of contemporary educational landscapes, which require more dynamic teaching approaches. The primary objective of these programs is to develop students' soft skills, which are necessary for thriving in competitive business environments, and to create a space for fostering sustainable entrepreneurship. Sustainable entrepreneurship is essential for

long-term business success and economic resilience, as it integrates environmental, social, and economic considerations into entrepreneurial practices. However, previous studies have highlighted numerous challenges impeding the effectiveness of entrepreneurship education in higher education institutions, indicating the need for more innovative pedagogical interventions (Liu, 2023). These challenges include gaps in soft skill acquisition and limited opportunities for students to apply entrepreneurial concepts in real-world contexts.

Research in higher education settings has revealed that the current entrepreneurship programs have not been adequately implemented, particularly in preparing students for real-world entrepreneurial endeavors (Samsuri et al., 2023). In many cases, university curricula prioritize academic achievement over the development of soft skills, such as creativity, critical thinking, and problem-solving, which are essential for entrepreneurship (Bhakti et al., 2022). Additionally, the pedagogical strategies employed in entrepreneurship education often fail to provide students with the necessary tools to succeed in business ventures. This pedagogical gap has contributed to low levels of entrepreneurial interest among university students, as evidenced by recent studies (Setyawati et al., 2021).

One of the most important soft skills for students to acquire as a foundation for entrepreneurship is creativity (Sanda, 2024). Creativity is vital for identifying opportunities, developing innovative solutions, and adapting to changes in the marketplace. Previous research has demonstrated a positive association between creativity and entrepreneurial mindset, highlighting the role of creative thinking in driving business success (Machali et al., 2021; Škare et al., 2022). However, creativity and entrepreneurship cannot fully develop in students without innovative interventions in the educational systems of universities. Current entrepreneurship programs are often too theoretical and lack practical applications that would allow students to hone their creative skills and apply them to entrepreneurial contexts (Kakouris, 2021). Several studies have recommended the implementation of educational systems that promote creativity as a key to developing sustainable entrepreneurship (An et al., 2018; Hulyadi et al., 2022; Sarooghi et al., 2015).

Universities are uniquely positioned to act as hubs for entrepreneurship, especially when they adopt innovative educational models that foster creativity and entrepreneurial skills. By creating an ecosystem that nurtures creativity and provides students with the opportunity to apply their skills in practical settings, universities can significantly enhance the entrepreneurial capabilities of their students (Allahar & Sookram, 2019; Samsuri et al., 2023; Wang & Ma, 2022). The motivation for students to develop their entrepreneurial potential is further amplified when the learning environment encourages experimentation, creativity, and the application of skills to real-world problems (Subari et al., 2022). In this regard, the TEFA emerges as a promising educational model that can bridge the gap between theoretical knowledge and practical application, thereby supporting the development of sustainable entrepreneurship.

In the context of innovation strategies, TEFA offers a framework for integrating students' disciplinary knowledge with the soft skills and industry needs required for entrepreneurship (Mashur et al., 2022; Xu, 2022). This educational model aligns with the demands of Industry 4.0, where the integration of theoretical knowledge, creativity, and practical application is critical for preparing students for the challenges of the modern business world (Mourtzis et al., 2023). TEFA has been recognized as a best practice in industrial education, providing students with hands-on experiences that reflect the realities of industrial processes and entrepreneurial ventures. Despite its potential, there has been little effort to develop TEFA programs that incorporate scientific creativity as a core element for enhancing students' soft skills and sustainable entrepreneurship.

Research Problem

Despite the growing implementation of entrepreneurship programs in universities, several challenges persist in cultivating the soft skills required for sustainable entrepreneurship. Research has shown that these programs often focus more on academic achievement than on developing the practical skills students need to succeed in entrepreneurial ventures (Samsuri et al., 2023). This imbalance limits the students' ability to adapt to real-world business challenges, particularly in areas requiring creativity and innovation (Bhakti et al., 2022).

Furthermore, entrepreneurship education in universities is frequently not supported by pedagogical innovations that would allow students to develop essential skills like creativity and problem-solving, which are crucial for successful entrepreneurship (Setyawati et al., 2021). As a result, students often graduate without the necessary capabilities to pursue entrepreneurship in a sustainable manner. The limited integration of practical skills, creativity, and real-world applications within entrepreneurship programs continues to be a significant barrier to the effectiveness of these programs (Sanda, 2024).

Thus, the need arises to explore innovative teaching methods, such as the TEFA, that can integrate scientific creativity into entrepreneurship programs to enhance soft skills and support sustainable entrepreneurship development. By bridging the gap between theory and practice, TEFA has the potential to address these challenges and provide students with the tools they need to succeed in the modern entrepreneurial landscape (Mourtzis et al., 2023).

Problem Solving Approach

The primary issue in the failure of university entrepreneurship programs to foster soft skills and sustainable entrepreneurship stems from inadequacies in their infrastructure. Specifically, traditional pedagogical methods have not been successful in aligning with the modern needs of the industry. As a solution, this study proposes the implementation of a TEFA pedagogical model integrated with scientific creativity. TEFA, a pedagogical approach designed to synchronize teaching and learning processes with industrial manufacturing practices, has gained recognition as an effective means to address the mismatch between academic training and industry demands (Chryssolouris et al., 2016; Weyand et al., 2023). However, TEFA alone is insufficient for the development of soft skills and sustainable entrepreneurship among students. The integration of scientific creativity into this model is crucial for achieving these educational objectives.

Scientific creativity, as defined in educational and entrepreneurial research, is a form of innovative thinking that encourages the design of creative products and solutions (Wahyudi et al., 2019). It has been shown to mediate the development of entrepreneurial skills, fostering a mindset that is capable of navigating the complexities of modern markets (Barnard & Herbst, 2019; Kumar & Shukla, 2022; Zhou & Verburg, 2020). By incorporating scientific creativity into TEFA, students are not only exposed to hands-on industrial experience but are also encouraged to develop innovative problem-solving abilities. This combination is expected to produce graduates who are well-equipped with the soft skills necessary for sustainable entrepreneurship.

A bibliometric analysis by Jing et al. (2023) highlighted the potential of TEFA to produce human resources with the necessary soft skills to achieve sustainable development goals. Similarly, the implementation of TEFA in vocational education has been linked to successful entrepreneurship training (Hasanah & Malik, 2018). However, the lack of scientific creativity in many of these programs remains a significant limitation. Scientific creativity is not merely about innovation in product design but encompasses broader skills such as negotiation,

problem-solving, and the ability to adapt to changing industrial landscapes (Rua & Maia, 2023). Prior studies have already demonstrated the effectiveness of creative techniques in stimulating these soft skills, which are essential for both individual and organizational success in entrepreneurship (Kumar & Shukla, 2022; Zhou & Verburg, 2020).

The pedagogical model of TEFA integrated with scientific creativity, as adapted from Chryssolouris et al. (2016), follows a structured cycle, which can be divided into five distinct phases (see Figure 1). These phases ensure a comprehensive approach to education, from problem identification to continuous improvement, thereby addressing the current shortcomings of entrepreneurship programs.

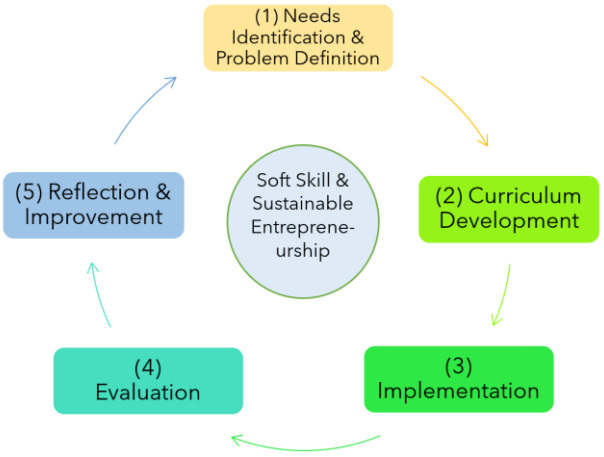

Figure 1. Teaching factory cycle

Phase 1: Need Identification and Problem Definition

The first phase involves identifying industry and societal needs, which forms the basis for the definition of the problems that the educational program aims to address. This step is critical for aligning educational goals with real-world challenges, ensuring that students are prepared to tackle contemporary issues in their respective fields. By analyzing industrial and societal needs, universities can determine the specific skills and knowledge that are most relevant. This phase ensures that the focus of the educational experience is on solving pressing industrial problems, thus enhancing the practical relevance of the curriculum.

Phase 2: Curriculum Development

In the second phase, the curriculum is developed based on the needs identified in the first phase. This involves creating a lesson plan that integrates academic theory with practical application in an industrial context. The curriculum is designed around creatively oriented project work, which is both realistic and aligned with the demands of modern industries. By integrating theory with practice, students are given the opportunity to apply their knowledge in real-world settings, thereby developing the critical soft skills required for sustainable entrepreneurship. This phase also emphasizes the importance of scientific creativity, which is woven into the curriculum to encourage students to approach problems from innovative perspectives.

Phase 3: Implementation

The third phase is the implementation of the curriculum, where students engage in hands-on learning through collaborative projects. This phase is characterized by the organization of practical, real-world projects that are closely linked to industrial needs. During this phase, students work under the guidance of expert mentors from the industry,

who provide feedback and insights into the practical aspects of the projects. This collaboration ensures that the learning process is deeply connected to the realities of industrial practices. The end goal of this phase is for students to produce small-scale creative products that have the potential to be commercialized. The development of these prototypes allows students to gain practical experience in entrepreneurship, while also encouraging innovation and creativity.

Phase 4: Evaluation

The fourth phase involves the evaluation of student performance. This evaluation is based on both practical skills and theoretical knowledge, ensuring that students are assessed holistically. The evaluation process focuses on how well students have been able to apply their learning to solve real-world problems. It also includes a performance assessment that measures the effectiveness of their creative solutions and entrepreneurial mindset. The inclusion of practical, performance-based assessments in this phase ensures that students' soft skills, such as negotiation and problem-solving, are also evaluated. This approach aligns with previous research that has shown the importance of soft skills in entrepreneurial success (Rua & Maia, 2023).

Phase 5: Reflection and Improvement

The final phase is reflection and improvement, which involves a feedback loop based on the results of the evaluations conducted in the fourth phase. This phase collects feedback from both students and industry partners to identify areas for improvement in the curriculum. Continuous improvement is a key component of this phase, as it ensures that the educational program remains relevant to the evolving needs of industry and society. By incorporating feedback from both students and industry experts, the curriculum can be continuously refined to better meet the needs of future cohorts. This phase also serves as an opportunity to reinforce the importance of scientific creativity in solving industrial problems and fostering entrepreneurship.

In summary, the proposed solution to the problem of inadequate entrepreneurship education in universities involves the implementation of a TEFA pedagogical model integrated with scientific creativity. This approach not only addresses the shortcomings of current programs but also provides a comprehensive framework for developing students' soft skills and fostering sustainable entrepreneurship. Through a structured cycle of need identification, curriculum development, implementation, evaluation, and continuous improvement, this model ensures that students are well-prepared for the challenges of modern entrepreneurship. By integrating scientific creativity into TEFA, universities can create a more dynamic and effective learning environment that equips students with the skills they need to succeed in today's competitive business world.

Research purposes

This study aims to assess the validity and effectiveness of a Teaching Factory (TEFA) model based on scientific creativity to improve students' soft skills and foster sustainable entrepreneurship within university-level entrepreneurship education. The objective is to determine how the integration of scientific creativity into the TEFA model can enhance students' practical skills, bridging the gap between theoretical knowledge and real-world application.

Research Novelty

The novelty of this research lies in the integration of scientific creativity within the TEFA framework for entrepreneurship education. While TEFA has been widely recognized for its

ability to align educational practices with industry demands, the incorporation of scientific creativity represents a novel approach aimed at enhancing the development of soft skills and sustainable entrepreneurship. Previous studies have primarily focused on TEFA's role in vocational education and its contribution to hands-on learning, but there has been limited exploration of how scientific creativity can be systematically embedded within this model to foster innovative thinking and entrepreneurial capabilities among university students.

Furthermore, this research introduces a unique pedagogical cycle that blends creative project-based learning with real-world industrial challenges, promoting sustainability as a core element of entrepreneurship education. This approach transcends traditional entrepreneurship training by encouraging students to think beyond immediate market demands and focus on long-term business viability that aligns with societal and environmental goals. By combining the practical, hands-on experience of TEFA with the innovative mindset fostered by scientific creativity, this study contributes to the creation of an educational model that prepares students for the complexities of modern entrepreneurship, emphasizing both economic and sustainable development.

METHOD

This study employed a modified research and development methodology, based on the TEFA pedagogical cycle, as adapted from Tisch et al. (2019), to assess the validity and effectiveness of a TEFA enhanced with scientific creativity. The purpose of this approach was to evaluate the potential of the TEFA model based on scientific creativity to improve students' soft skills and foster sustainable entrepreneurship. The research was conducted in two stages: validation of the TEFA model and empirical testing through two production processes, where the first cycle (production process I) acted as an empirical trial and the second cycle (production process II) served as the implementation phase.

Design and Validation of the TEFA Model

The first step in the research was to design the pedagogical framework of the TEFA model, as described in Figure 1, integrating scientific creativity into the traditional TEFA cycle. This framework was designed to support students' development of soft skills such as communication, teamwork, creativity, leadership, and time management. Additionally, it aimed to enhance sustainable entrepreneurship skills, focusing on opportunity recognition, resource utilization, and entrepreneurial action.

The TEFA model's validity was assessed by involving six expert validators in two domains: content validity and construct validity. Content validity refers to how well the model represents the key aspects of TEFA and scientific creativity relevant to the research objectives. Construct validity was used to ensure that the model adequately measured the constructs it was designed to assess, namely the soft skills and sustainable entrepreneurship of students. Validation data were collected using validation sheets that were structured according to pre-established criteria. The experts evaluated the TEFA model based on the appropriateness, comprehensiveness, and clarity of its components, including the integration of scientific creativity and the practical application of entrepreneurship education. The evaluation results were analyzed descriptively, with the mean validation scores calculated to determine the overall validity of the model. The scoring criteria were based on standards set by previous studies (Prayogi et al., 2018).

Testing the Effectiveness of the TEFA Model

Once the TEFA model was validated, its effectiveness in enhancing students' soft skills and fostering sustainable entrepreneurship was tested in two cycles of production-based

learning. A total of 15 students from Universitas Pendidikan Mandalika participated in this phase. The participants were actively involved in the TEFA-based learning process, which focused on hands-on, project-based activities that simulated real-world industrial production and entrepreneurial challenges.

During both the first and second production processes, students engaged in various tasks designed to foster creativity, teamwork, and entrepreneurial thinking. Each production process lasted for approximately 6 weeks, during which students worked in teams to design and develop a product that addressed a specific market need. The process required students to apply both their disciplinary knowledge and the soft skills necessary for successful entrepreneurship.

The aspects of soft skills measured in this study included communication, teamwork, creativity, leadership, and time management. Meanwhile, sustainable entrepreneurship was evaluated through indicators such as identifying opportunities, resource usage, and entrepreneurial actions. Data collection for these aspects was conducted using observation sheets filled out by trained observers who monitored students' participation and performance throughout the learning activities.

The students' soft skills and sustainable entrepreneurship were scored on a scale from 1 to 5, with 1 being the lowest and 5 the highest. The criteria for evaluating student performance are detailed in Table 1, where scores greater than 4.21 were categorized as "Very Good," 3.40 to 4.21 as "Good," 2.60 to 3.40 as "Fair," 1.79 to 2.60 as "Poor," and scores below 1.79 as "Very Poor."

Table 1. Criteria for evaluating soft skills and sustainable entrepreneurship

No	Interval	Calculating	Criteria
1.	$X > X_i + 1{,}8\ Sbi$	$X > 4{,}21$	Very Good
2.	$X_i + 0{,}6\ Sbi < X \leq X_i + 1{,}8\ Sbi$	$3{,}40 < X \leq 4{,}21$	Good
3.	$X_i - 0{,}6\ Sbi < X \leq X_i + 0{,}6\ Sbi$	$2{,}60 < X \leq 3{,}40$	Fair
4.	$X_i - 1{,}8\ Sbi < X \leq X_i - 0{,}6\ Sbi$	$1{,}79 < X \leq 2{,}60$	Poor
5.	$X \leq X_i - 1{,}8\ Sbi$	$X \leq 1{,}79$	Very Poor

Annotation: x (empirical score), Xi (ideal mean), Sbi (ideal standard deviation),

Data Analysis

The data collected during both production processes were analyzed to evaluate the effectiveness of the TEFA model. First, descriptive statistics were employed to calculate the average scores for each soft skill and sustainable entrepreneurship indicator. These average scores were used to classify the students' performance into the appropriate criteria (as shown in Table 1). To assess the improvement in soft skills and sustainable entrepreneurship from the first to the second production cycle, a comparative analysis was conducted. The mean scores from production process I and production process II were compared using a one-way Analysis of Variance (ANOVA) test, with a significance level set at 0.05. This statistical test was chosen to determine whether the differences in the mean scores between the two production processes were statistically significant, indicating an improvement in student performance after implementing the TEFA model based on scientific creativity.

The effectiveness of the model was judged based on the extent of improvement in students' scores between the two production cycles. A significant increase in the scores would suggest that the TEFA-based pedagogical model, with its integration of scientific creativity, effectively enhanced the soft skills and sustainable entrepreneurship of the students.

RESULTS AND DISCUSSION

The results of the validation for the TEFA model based on scientific creativity are presented in Table 2, outlining the validation outcomes in terms of content validity (including needs and state of the art) and construct validity.

Table 2. Validation data for the TEFA model based on scientific creativity

Validation aspect	Validation score	Criteria
Content Validity- Needs	4.57	Very Valid
Content Validity- State of the Art	4.60	Very Valid
Construct Validity	4.53	Very Valid
Average score	4.57	Very Valid

The results of the validation for the TEFA model based on scientific creativity, presented in Table 2, show that all evaluated aspects received very high average scores. For content validity in terms of needs, the average score was 4.57, while the score for the state of the art was also very high at 4.60. The construct validity aspect received a score of 4.53. Overall, the average total score for the validation of the TEFA model based on scientific creativity was 4.57, indicating that this pedagogy was considered highly valid by expert validators. This strong validation suggests that the TEFA model has high relevance and feasibility in terms of both content and conceptual framework for enhancing students' soft skills and sustainable entrepreneurship within university entrepreneurship programs.

The effectiveness test was measured across two processes: an empirical trial (production process I) and implementation (production process II). These processes assessed students' soft skills and sustainable entrepreneurship. The results of the soft skills data analysis are presented in Table 3 and Figure 2, followed by the ANOVA test results in Table 4.

Table 3. Results of students' soft skills data analysis

Aspects	Group	N	Mean	SD	Criteria
a. Communicatin	Production-I	15	2.133	0.640	Poor
	Production-II	15	4.267	0.799	Very Good
b. Teamwork	Production-I	15	2.067	0.799	Poor
	Production-II	15	4.467	0.834	Very Good
c. Creativity	Production-I	15	1.333	0.488	Very Poor
	Production-II	15	4.133	1.060	Good
d. Leadership	Production-I	15	2.267	0.704	Poor
	Production-II	15	3.800	1.082	Good
e. Time management	Production-I	15	2.200	0.676	Poor
	Production-II	15	4.000	0.845	Good
Average score	Production-I	15	2.000	0.330	Poor
	Production-II	15	4.133	0.816	Good

Table 3 shows significant differences in students' soft skills between production process I and production process II. In production process I, students' communication skills were categorized as "Poor," with an average score of 2.133, while in production process II, these skills improved to "Very Good," with a score of 4.267. Similarly, students' teamwork skills increased from "Poor" (2.067) in production process I to "Very Good" (4.467) in production process II. Creativity, which was initially categorized as "Very Poor" in production process I with a score of 1.333, improved to "Good" in production process II (4.133). Leadership skills also showed improvement, rising from "Poor" (2.267) to "Good" (3.800). Additionally, time

management skills improved from "Poor" (2.200) to "Good" (4.000). Overall, the average soft skills score for students in production process I was 2.000 ("Poor"), which increased to 4.133 ("Good") in production process II.

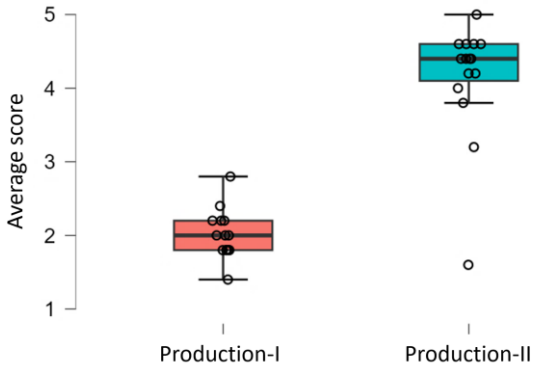

Figure 2. Descriptive plot of students' soft skills assessment

The descriptive plot in Figure 2 shows significant differences in the average soft skills of students between production process I and production process II. In production process I, the average soft skills scores ranged from 1 to 3, indicating low performance. However, in production process II, the average scores increased significantly, with many students achieving scores in the 4 to 5 range. This indicates a clear improvement in students' soft skills after the second learning process, including communication, teamwork, creativity, leadership, and time management.

Table 4. ANOVA test results for soft skills

Cases	Sum of Sqrs.	df	Mean Sqr.	F	p	η^2
Group	34.133	1	34.133	88.059	< .001	0.759
Residuals	10.853	28	0.388			

between production process I and production process II ($F = 88.059$, $p < 0.001$, $\eta^2 = 0.759$). With a very small p-value (< 0.001), it can be concluded that the improvement in soft skills between the two groups (production process I and II) was not due to chance but resulted from a significant intervention. The eta-squared value ($\eta^2 = 0.759$) shows that the effect size was large, with 75.9% of the variance in the data explained by the differences between the production groups.

Next, the results of the students' sustainable entrepreneurship data analysis are presented in Table 5, Figure 3, and the ANOVA test in Table 6.

Table 5. Data results of students' sustainable entrepreneurship assessment

Aspect	Group	N	Mean	SD	Criteria
a. Opportunity identification	Production-II	15	3.373	0.271	Fair
	Production-I	15	1.467	0.247	Very Poor
b. Resource utilization	Production-II	15	3.501	0.378	Good
	Production-I	15	1.445	0.163	Very Poor
c. Entrepreneurial action	Production-II	15	3.166	0.251	Fair
	Production-I	15	1.377	0.147	Very Poor
Average score	Production-II	15	3.346	0.104	Fair
	Production-I	15	1.430	0.111	Very Poor

The results in Table 5 show a significant improvement in students' sustainable entrepreneurship aspects between production process I and production process II. In production process I, the aspect of "Identifying Ideas and Opportunities" received an average score of 1.467, categorized as "Very Poor," but this increased to 3.373, categorized as "Fair," in production process II. Similarly, the "Resource Utilization" aspect improved from "Very Poor" in production process I, with a score of 1.445, to "Good" in production process II, with a score of 3.501. Additionally, the "Entrepreneurial Action" aspect, which initially scored 1.377 ("Very Poor") in production process I, increased to 3.166 ("Fair") in production process II. Overall, the average score for students' sustainable entrepreneurship increased from 1.430 ("Very Poor") in production process I to 3.346 ("Fair") in production process II.

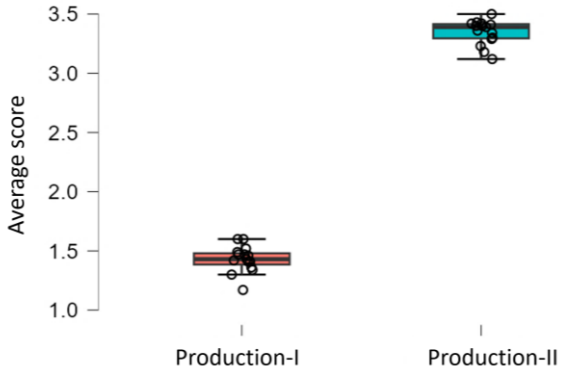

Figure 3. Descriptive plot of students' sustainable entrepreneurship assessment

Figure 3 presents a descriptive plot showing a significant increase in the average scores of students' sustainable entrepreneurship between production process I and production process II. In production process I, the average scores ranged from 1 to 1.5, indicating low performance in sustainable entrepreneurship aspects. However, in production process II, the average scores increased significantly to a range of 3 to 3.5, reflecting a substantial improvement in students' sustainable entrepreneurship abilities after the learning intervention, particularly in idea generation, resource utilization, and entrepreneurial actions.

Table 6. ANOVA test results for sustainable entrepreneurship

Cases	Sum of Sqrs.	df	Mean Sqr.	F	p	η^2
Group	27.533	1	27.533	2385.573	< .001	0.988
Residuals	0.323	28	0.012			

The ANOVA test results indicate a significant difference between production process I and II in students' sustainable entrepreneurship ($F = 2385.573$, $p < 0.001$, $\eta^2 = 0.988$). The very low p-value (< 0.001) suggests that the improvement in students' sustainable entrepreneurship between the two groups (production process I and II) resulted from a significant learning intervention. The eta-squared value ($\eta^2 = 0.988$) indicates a very large effect size, with 98.8% of the variance in the data explained by differences between the production groups.

The validation results of the TEFA model based on scientific creativity show that this model is highly valid and relevant for university entrepreneurship programs. Expert validation yielded very high average scores for both content validity and construct validity, indicating that this model effectively meets students' needs in enhancing soft skills and sustainable entrepreneurship. This strong validation aligns with previous literature, which emphasizes that practice-based pedagogy like TEFA is an effective educational approach for

bridging the gap between theoretical knowledge and the practical skills needed in the industry (Chryssolouris et al., 2016; Rentzos et al., 2015). With adequate validation, this pedagogy holds potential for increasing the relevance of higher education to the needs of business and industry, as suggested by previous studies (Allahar & Sookram, 2019).

The effectiveness of the TEFA model based on scientific creativity in enhancing students' soft skills is also clearly demonstrated by the research findings. Prior to implementation, students' abilities in various soft skill aspects were categorized as "Poor" and "Very Poor." However, after the application of this pedagogy, students' skills in communication, teamwork, creativity, leadership, and time management significantly improved, with most aspects categorized as "Good" and "Very Good." This improvement reflects the effectiveness of the TEFA model in encouraging students to work in collaborative and creative environments, which are crucial in modern industry contexts (Hasanah & Malik, 2018). Other studies have also shown that experiential learning approaches like TEFA help students develop essential soft skills, such as communication, time management, and collaboration, which are critical in the workplace (Wagner et al., 2012).

The ANOVA test results show significant differences between production process I and II in students' soft skills, with an eta-squared value ($\eta^2 = 0.759$) indicating a large effect of the intervention. These findings align with Kolb's experiential learning theory, which suggests that direct experience-based learning helps students apply theoretical knowledge in practical contexts, thereby strengthening skill mastery (Monetti et al., 2023). Furthermore, project-based TEFA model aligns with the "learning by doing" approach, which is highly effective in equipping students with industry-relevant skills (Müller et al., 2017). By placing students in situations that simulate real industry conditions, they develop practical skills that cannot be fully taught through conventional classroom learning (Kusmintarti et al., 2021).

In the aspect of sustainable entrepreneurship, the research shows significant improvement after the implementation of the TEFA model based on scientific creativity. Aspects such as identifying ideas and opportunities, resource utilization, and entrepreneurial actions, which were initially categorized as "Very Poor," improved to "Fair" and "Good" after the intervention. This is consistent with literature stating that entrepreneurship not only depends on understanding theoretical concepts but also on practical skills in identifying opportunities and effectively utilizing resources (Bacigalupo et al., 2016). Practice-based approaches to entrepreneurship education have been shown to improve students' entrepreneurial competencies, as demonstrated by research conducted by Fortunato & Alter (2017).

The integration of scientific creativity in TEFA model also plays an important role in enhancing students' sustainable entrepreneurship abilities. Scientific creativity enables students to develop new and innovative ideas that can be applied in entrepreneurial contexts (Kharkhurin, 2014). This is consistent with research that suggests creativity is a key element in entrepreneurial development, as it allows students to adapt to changes and tackle complex challenges in the business world (Kumar & Shukla, 2022). Thus, the TEFA model based on scientific creativity not only enhances students' technical skills but also helps them develop a creative and innovative entrepreneurial mindset (Sternberg & Karami, 2022).

The ANOVA test results for the sustainable entrepreneurship aspect also show a highly significant difference between production process I and II, with an eta-squared value ($\eta^2 = 0.988$) indicating a very large effect. This means that nearly all the variation in the improvement of students' entrepreneurship skills can be explained by the differences in the interventions provided. These findings support the literature, which suggests that creativity plays a mediating role in entrepreneurship development, where creative thinking is essential

for identifying opportunities and developing innovative products or services (Zhou & Verburg, 2020). In the context of higher education, integrating scientific creativity with sustainable entrepreneurship through the TEFA model can be an effective strategy for equipping students with skills relevant to the demands of the modern job market (Wang & Ma, 2022).

Overall, this study demonstrates that the TEFA model based on scientific creativity can be an effective model for enhancing students' soft skills and sustainable entrepreneurship. These findings are consistent with previous research suggesting that practice-based and creativity-driven learning approaches can help students develop the skills required in the workplace and entrepreneurship contexts (Bhakti et al., 2022; Sarooghi et al., 2015). With strong empirical evidence, universities in Indonesia can consider adopting this model as part of their entrepreneurship curriculum, particularly in entrepreneurship programs. The broader implementation of the TEFA model based on scientific creativity could help create graduates who are not only technically competent but also possess the creative and innovative thinking skills needed to address global challenges in the era of Industry 4.0 (Mourtzis et al., 2023).

In conclusion, the prototype of the TEFA model based on scientific creativity has been successfully developed, validated, and effectively tested in the context of teaching entrepreneurship programs. This pedagogical model was designed with a learning cycle approach consisting of five key phases: need identification and problem definition, curriculum development, implementation, evaluation, and reflection and improvement. The validation results show that this pedagogy is highly relevant and has strong validity, both in content and concept, supporting its feasibility for widespread implementation in higher education.

The effectiveness tests of this TEFA model also showed significant improvements in students' mastery of soft skills such as communication, teamwork, creativity, leadership, and time management. After participating in this learning cycle, students' performance in these aspects significantly improved from the "Poor" category to the "Good" and "Very Good" categories. In addition, the TEFA model based on scientific creativity also significantly enhanced students' sustainable entrepreneurship abilities, including their capacity for identifying ideas and opportunities, resource utilization, and entrepreneurial actions, which were previously underdeveloped. The effectiveness of the TEFA model based on scientific creativity in enhancing soft skills and sustainable entrepreneurship aligns with the literature that emphasizes the importance of practice-based and creativity-driven learning approaches in preparing students for the demands of the modern workforce and industry. This model allows students to learn through realistic, hands-on experiences, creating an environment that supports the development of critical thinking, problem-solving, and innovation skills.

In summary, the development and testing of the TEFA model based on scientific creativity demonstrate that this model can be an effective solution for addressing the challenges of implementing university entrepreneurship programs. This pedagogy not only serves as a bridge between theory and practice but also has the potential to become a strong foundation for developing graduates who are both technically competent and possess a creative and sustainable entrepreneurial spirit. Thus, the implementation of the TEFA model based on scientific creativity in higher education is expected to produce graduates who are better equipped to compete in the era of Industry 4.0 and the dynamic global economy.

CONCLUSION

This study successfully developed and validated a TEFA model based on scientific creativity to enhance students' soft skills and foster sustainable entrepreneurship. The

integration of scientific creativity within this pedagogy proved highly effective in improving students' communication, teamwork, creativity, leadership, and time management, as well as their ability to identify entrepreneurial opportunities, utilize resources, and take entrepreneurial action. The structured learning cycle, which includes phases of need identification, curriculum development, implementation, evaluation, and reflection, offers a comprehensive pathway for bridging the gap between theoretical knowledge and practical application in entrepreneurship education.

The results demonstrate that the TEFA model based on scientific creativity significantly enhances both soft skills and sustainable entrepreneurship, meeting the evolving needs of modern industry and entrepreneurship. This highlights the importance of creativity-driven, hands-on learning in university entrepreneurship programs, contributing to the development of graduates who are not only technically proficient but also equipped with innovative thinking, which are essential for addressing the challenges of today's dynamic and competitive global marketplace.

LIMITATION

One limitation of this study is the relatively small sample size of 15 students, which may restrict the generalizability of the findings to a wider range of university settings. While the results are promising, further research involving larger and more diverse student populations across different universities would be beneficial to validate the effectiveness of the TEFA model based on scientific creativity in various educational contexts. Additionally, the study primarily focused on short-term outcomes related to soft skills and entrepreneurship; it would be valuable to conduct longitudinal studies to assess the long-term impact on students' entrepreneurial success and career development.

RECOMMENDATION

Based on the findings, it is recommended that universities adopt the TEFA model based on scientific creativity in their entrepreneurship curricula. This approach can better prepare students for the demands of the global economy by fostering critical skills such as creativity, innovation, and sustainable entrepreneurship. Future research should aim to expand this pedagogy to larger, more diverse educational contexts, and investigate its long-term impact on students' entrepreneurial success.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

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Declaration of Interest

The authors declare no conflict of interest..

REFERENCES

Allahar, H., & Sookram, R. (2019). Emergence of university-centred entrepreneurial ecosystems in the Caribbean. *Industry and Higher Education*, *33*(4), 246–259. https://doi.org/10.1177/0950422219838220

An, W., Zhang, J., You, C., & Guo, Z. (2018). Entrepreneur's creativity and firm-level innovation performance: Bricolage as a mediator. *Technology Analysis & Strategic Management*, *30*(7), 838–851. https://doi.org/10.1080/09537325.2017.1383979

Bacigalupo, M., Kampylis, P., Punie, Y., & Van den Brande, G. (2016). *EntreComp: The entrepreneurship competence framework.* Publications Office of the European Union. https://data.europa.eu/doi/10.2791/593884

Barnard, B., & Herbst, D. (2019). Entrepreneurship, Innovation and Creativity: The Creative Process of Entrepreneurs and Innovators. *Expert Journal of Business and Management*, *7*(1). https://business.expertjournals.com/23446781-709/

Bhakti, Y. B., Simorangkir, M. R. R., Tjalla, A., & Sutisna, A. (2022). Kendala Implementasi Kebijakan Merdeka Belajar Kampus Merdeka (MBKM) di Perguruan Tinggi. *Research and Development Journal of Education*, *8*(2), 783. https://doi.org/10.30998/rdje.v8i2.12865

Chryssolouris, G., Mavrikios, D., & Rentzos, L. (2016). The Teaching Factory: A Manufacturing Education Paradigm. *Procedia CIRP*, *57*, 44–48. https://doi.org/10.1016/j.procir.2016.11.009

Fitriani, H., Samsuri, T., Karmana, I. wayan, Sulastri, N., Zaenuddin, M., Haerazi, H., Aminullah, A., Soemardiawan, S., Hariyanto, F. A., & Ikhsan, M. (2023). Marketing Management Training for UMKM Assisted by Baznas Microfinance Village (BMD) Gunungsari. *Sasambo: Jurnal Abdimas (Journal of Community Service)*, *5*(4), Article 4. https://doi.org/10.36312/sasambo.v5i4.1682

Fortunato, M. W.-P., & Alter, T. (2017). Community entrepreneurship development: An introduction. In M. W.-P. Fortunato & T. R. Alter (Eds.), *Entrepreneurship, Community, and Community Development* (1st ed., pp. 1–12). Routledge. https://doi.org/10.4324/9781315112893-1

Hasanah, H., & Malik, Muh. (2018). Teaching Factory-Based for Entrepreneurship Learning Model in Vocational High Schools. *Proceedings of the International Conference on Indonesian Technical Vocational Education and Association (APTEKINDO 2018)*. International Conference on Indonesian Technical Vocational Education and Association (APTEKINDO 2018), Surabaya, Indonesia. https://doi.org/10.2991/aptekindo-18.2018.46

Haugsevje, Å. D. (2024). Justifying creative work: Norwegian business support and the conflicting narratives of creative industries. *Cultural Trends*, *33*(1), 37–51. https://doi.org/10.1080/09548963.2022.2126747

Hulyadi, H., Muhali, M., Hendrawani, H., Samsuri, T., Mirawati, B., Fuaddunazmi, M., & Rahmawati, H. (2022). Biointerprenership Skill Modal Sukses Pasca Pandemi Covid-19. *Lumbung Inovasi: Jurnal Pengabdian Kepada Masyarakat*, *7*(2), 195–204. https://doi.org/10.36312/linov.v7i2.724

Jing, Z., Turi, J. A., Lu, S., & Rosak-Szyrocka, J. (2023). Sustainability through Factory-Based Learning in Higher Education. *Sustainability*, *15*(6), 5376. https://doi.org/10.3390/su15065376

Kakouris, A. (2021). Teaching creativity in entrepreneurship: Embolden or discourage? *Industry and Higher Education*, *35*(4), 465–470. https://doi.org/10.1177/0950422221996640

Kharkhurin, A. V. (2014). Creativity.4in1: Four-Criterion Construct of Creativity. *Creativity Research Journal*, *26*(3), 338–352. https://doi.org/10.1080/10400419.2014.929424

Kumar, R., & Shukla, S. (2022). Creativity, Proactive Personality and Entrepreneurial Intentions: Examining the Mediating Role of Entrepreneurial Self-efficacy. *Global Business Review*, *23*(1), 101–118. https://doi.org/10.1177/0972150919844395

Kusmintarti, A., Ismanu, S., & Anshori, Moh. A. (2021). *Design of Entrepreneurship Learning Model with Teaching Factory Method to Improve Student's Competencies:* 2nd Annual Management, Business and Economic Conference (AMBEC 2020), Batu, East Java, Indonesia. https://doi.org/10.2991/aebmr.k.210717.041

Liu, F., Qu, S., Fan, Y., Chen, F., & He, B. (2023). Scientific creativity and innovation ability and its determinants among medical postgraduate students in Fujian province of China: A cross sectional study. *BMC Medical Education*, *23*(1), 444. https://doi.org/10.1186/s12909-023-04408-9

Liu, M. (2023). How entrepreneurship programs foster students' study engagement and entrepreneurship competence: Insights from job demands-resources theory. *The International Journal of Management Education*, *21*(3), 100890. https://doi.org/10.1016/j.ijme.2023.100890

Machali, I., Wibowo, A., Murfi, A., & Narmaditya, B. S. (2021). From teachers to students creativity? The mediating role of entrepreneurial education. *Cogent Education*, *8*(1), 1943151. https://doi.org/10.1080/2331186X.2021.1943151

Mashur, M., Hunaepi, H., & Samsuri, T. (2022). The sustainability status and the development strategy of collective cage-based beef cattle smallholder farming on Lombok Island. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *11*(1), 1. https://doi.org/10.33394/j-ps.v11i1.5241

Monetti, F. M., Boffa, E., De Giorgio, A., & Maffei, A. (2023). The Impact of Learning Factories on Teaching Lean Principles in an Assembly Environment. In K.-Y. Kim, L. Monplaisir, & J. Rickli (Eds.), *Flexible Automation and Intelligent Manufacturing: The Human-Data-Technology Nexus* (pp. 271–283). Springer International Publishing. https://doi.org/10.1007/978-3-031-18326-3_27

Mourtzis, D., Panopoulos, N., & Angelopoulos, J. (2023). A hybrid teaching factory model towards personalized education 4.0. *International Journal of Computer Integrated Manufacturing*, *36*(12), 1739–1759. https://doi.org/10.1080/0951192X.2022.2145025

Müller, B. C., Menn, J. P., & Seliger, G. (2017). Procedure for Experiential Learning to Conduct Material Flow Simulation Projects, Enabled by Learning Factories. *Procedia Manufacturing*, *9*, 283–290. https://doi.org/10.1016/j.promfg.2017.04.047

Prayogi, S., Yuanita, L., & Wasis. (2018). Critical Inquiry Based Learning: A Model of Learning to Promote Critical Thinking Among Prospective Teachers of Physic. *Journal of Turkish Science Education*, *15*(1), Article 1.

Rentzos, L., Mavrikios, D., & Chryssolouris, G. (2015). A Two-way Knowledge Interaction in Manufacturing Education: The Teaching Factory. *Procedia CIRP*, *32*, 31–35. https://doi.org/10.1016/j.procir.2015.02.082

Rua, O. L., & Maia, A. R. (2023). Do creativity techniques enhances employees soft skills? *Revista de Gestão e Secretariado (Management and Administrative Professional Review)*, *14*(7), 11674–11699. https://doi.org/10.7769/gesec.v14i7.2499

Samsuri, T., Prayogi, S., & Verawati, N. N. S. P. (2023). The Impact of Entrepreneurship Education Programs (EEPs) on Students' Entrepreneurial Interests. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *11*(4), 1145–1152. https://doi.org/10.33394/j-ps.v11i4.11183

Sanda, M.-A. (2024). Human factors in creative entrepreneurship: Significance of entrepreneurs' personal characteristics, perceived status, and emotions. *Journal of the*

International Council for Small Business, *5*(1), 25–36. https://doi.org/10.1080/26437015.2023.2275605

Sarooghi, H., Libaers, D., & Burkemper, A. (2015). Examining the relationship between creativity and innovation: A meta-analysis of organizational, cultural, and environmental factors. *Journal of Business Venturing*, *30*(5), 714–731. https://doi.org/10.1016/j.jbusvent.2014.12.003

Setyawati, Y., Sugiharto, F. B., Rosyanafi, R. J., Cahyanto, B., Rini, T. A., & Yusuf, A. (2021). Pengaruh MBKM Kewirausahaan Terhadap Minat Berwirausaha Mahasiswa. *MOTORIC*, *5*(2), Article 2.

Škare, M., Blanco-Gonzalez-Tejero, C., Crecente, F., & Del Val, M. T. (2022). Scientometric analysis on entrepreneurial skills - creativity, communication, leadership: How strong is the association? *Technological Forecasting and Social Change*, *182*, 121851. https://doi.org/10.1016/j.techfore.2022.121851

Sternberg, R. J., & Karami, S. (2022). An 8P Theoretical Framework for Understanding Creativity and Theories of Creativity. *The Journal of Creative Behavior*, *56*(1), 55–78. https://doi.org/10.1002/jocb.516

Subari, I., Muliadi, A., & Samsuri, T. (2022). Pengaruh Lingkungan Keluarga Dan Norma Subyektif Terhadap Adversity Question Dan Motivasi Entrepreneur Mahasiswa. *Multi Discere Journal*, *1*(1), Article 1. https://doi.org/10.36312/mj.v1i1.850

Tisch, M., Abele, E., & Metternich, J. (2019). The Life Cycle of Learning Factories for Competency Development. In E. Abele, J. Metternich, & M. Tisch, *Learning Factories* (pp. 127–198). Springer International Publishing. https://doi.org/10.1007/978-3-319-92261-4_6

Wagner, U., AlGeddawy, T., ElMaraghy, H., & MŸller, E. (2012). The State-of-the-Art and Prospects of Learning Factories. *Procedia CIRP*, *3*, 109–114. https://doi.org/10.1016/j.procir.2012.07.020

Wahyudi, W., Verawati, N. N. S. P., Ayub, S., & Prayogi, S. (2019). The Effect of Scientific Creativity in Inquiry Learning to Promote Critical Thinking Ability of Prospective Teachers. *International Journal of Emerging Technologies in Learning (iJET)*, *14*(14), Article 14. https://doi.org/10.3991/ijet.v14i14.9532

Wang, Y., & Ma, Y. (2022). Innovation and Entrepreneurship Education in Chinese Universities: Developments and Challenges. *Chinese Education & Society*, *55*(4–5), 225–232. https://doi.org/10.1080/10611932.2022.2136446

Weyand, A., Lehnert, S., Alish, V., & Weigold, M. (2023). Approach for the implementation of resource analysis methods in learning factories. *Production & Manufacturing Research*, *11*(1), 2209152. https://doi.org/10.1080/21693277.2023.2209152

Xu, X. (2022). The Structural VPR Model for the Evaluation of Innovation and Entrepreneurship Education. *Chinese Education & Society*, *55*(4–5), 307–321. https://doi.org/10.1080/10611932.2022.2136464

Zhou, Z., & Verburg, R. (2020). Open for business: The impact of creative team environment and innovative behaviour in technology-based start-ups. *International Small Business Journal: Researching Entrepreneurship*, *38*(4), 318–336. https://doi.org/10.1177/0266242619892793