

## A GREEN INNOVATION-DRIVEN TEACHING FACTORY MODEL FOR ECOPRENEURSHIP DEVELOPMENT IN VOCATIONAL EDUCATION

### UM MODELO DE “FÁBRICA DE ENSINO” ORIENTADO PARA A INOVAÇÃO VERDE PARA O DESENVOLVIMENTO DO ECOPRENEURISMO NA EDUCAÇÃO PROFISSIONAL

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**Andreas Suwandi\***

\*Universitas Pendidikan Indonesia, Bandung, Indonesia

Orcid: <https://orcid.org/0009-0002-1939-5922>

[andreassuwandi@upi.edu](mailto:andreassuwandi@upi.edu)

**Cica Yulia\***

\*Universitas Pendidikan Indonesia, Bandung, Indonesia

Orcid: <https://orcid.org/0000-0002-5414-5040>

[cicayulia@upi.edu](mailto:cicayulia@upi.edu)

**Ade Gafar Abdullah\***

\*Universitas Pendidikan Indonesia, Bandung, Indonesia

Orcid: <https://orcid.org/0000-0001-8917-2375>

[ade\\_gaffar@upi.edu](mailto:ade_gaffar@upi.edu)

**Rini Andari\***

\*Universitas Pendidikan Indonesia, Bandung, Indonesia

Orcid: <https://orcid.org/0009-0005-4170-7584>

[riniandari@upi.edu](mailto:riniandari@upi.edu)

**Nadhia Maesari\***

\*Universitas Pendidikan Indonesia, Bandung, Indonesia

Orcid: <https://orcid.org/0009-0003-7367-3855>

[nadhia.maesari@upi.edu](mailto:nadhia.maesari@upi.edu)

**Rattikah Fitrianti\***

\*Universitas Pendidikan Indonesia, Bandung, Indonesia

Orcid: <https://orcid.org/0009-0000-5158-1931>

[rattikah.f@upi.edu](mailto:rattikah.f@upi.edu)

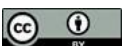
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#### Abstract

The growing urgency of sustainability challenges has encouraged vocational education to integrate sustainability-oriented entrepreneurship into its learning models. This study examines the effect of a green innovation-driven teaching factory model on students' ecopreneurship competencies. A quantitative survey was conducted involving 36 vocational students participating in a teaching factory programme at SMKS BPP Kota Bandung. Data were collected using a structured questionnaire based on a five-point Likert scale, covering green innovation practices, teaching factory learning processes, and ecopreneurship competencies. Descriptive and inferential statistical analyses were

#### Resumo

A crescente urgência dos desafios de sustentabilidade tem incentivado a educação profissional a integrar o empreendedorismo orientado para a sustentabilidade em seus modelos de aprendizagem. Este estudo examina o efeito de um modelo de “fábrica-escola” impulsionado pela inovação verde nas competências de ecopreneurismo dos alunos. Foi realizada uma pesquisa quantitativa envolvendo 36 alunos do ensino profissional que participavam de um programa de “fábrica-escola” na SMKS BPP Kota Bandung. Os dados foram coletados por meio de um questionário estruturado baseado em uma escala de Likert de cinco pontos, abrangendo práticas de inovação



employed to examine the relationships among variables. The results indicate that green innovation integrated into teaching factory learning has a positive and statistically significant effect on students' ecopreneurship competencies. Students engaged in green innovation-based activities demonstrate higher environmental awareness, improved recognition of sustainable opportunities, and greater entrepreneurial readiness. These findings highlight the importance of embedding green innovation within vocational learning to support sustainability and green economy agendas, while contributing to the development of ecopreneurship in vocational education.

**Keywords:** Teaching Factory. Green Innovation. Ecopreneurship. Vocational Education. Sustainability-Oriented Learning.

*verde, processos de aprendizagem da fábrica-escola e competências de ecopreneurismo. Análises estatísticas descritivas e inferenciais foram empregadas para examinar as relações entre as variáveis. Os resultados indicam que a inovação verde integrada à aprendizagem da fábrica-escola tem um efeito positivo e estatisticamente significativo nas competências de ecopreneurismo dos alunos. Os alunos envolvidos em atividades baseadas na inovação verde demonstram maior consciência ambiental, melhor reconhecimento de oportunidades sustentáveis e maior prontidão empreendedora. Essas descobertas destacam a importância de incorporar a inovação verde na aprendizagem profissional para apoiar as agendas de sustentabilidade e economia verde, ao mesmo tempo em que contribuem para o desenvolvimento do ecopreneurismo na educação profissional.*

**Palavras-chave:** Fábrica-Escola. Inovação Verde. Ecopreneurismo. Educação Profissional. Aprendizagem Orientada para a Sustentabilidade.

## 1 INTRODUCTION

Vocational education and training (VET) is increasingly acknowledged as a key mechanism for preparing a skilled workforce capable of adapting to labour market dynamics and broader socio-economic change. Alongside this role, rising global awareness of environmental degradation, climate change, and sustainable development has placed new demands on VET institutions to extend their focus beyond technical proficiency toward the cultivation of sustainability-oriented competencies (UNESCO, 2020; Ramsarup *et al.*, 2024). As a result, vocational education is now expected to integrate employability skills, entrepreneurship education, and environmental responsibility within learning environments that reflect real-world contexts (OECD, 2018; Li & Wong, 2022). Numerous studies have demonstrated that entrepreneurship education contributes positively to students' entrepreneurial intentions, self-efficacy, and ability to identify opportunities (Ajzen, 1991; Fayolle & Gailly, 2015; Soomro & Shah, 2021). Nevertheless, conventional approaches to entrepreneurship education have been criticised for their strong emphasis on economic value creation, often at the expense of

environmental sustainability considerations (Hall *et al.*, 2010; Schaltegger & Wagner, 2011). In response to this limitation, the concept of ecopreneurship has gained prominence, highlighting entrepreneurial initiatives that simultaneously pursue economic benefits and environmental improvement (Cohen & Winn, 2007; Hockerts & Wüstenhagen, 2010). Existing evidence suggests that ecopreneurship education can strengthen learners' pro-environmental orientations and commitment to sustainable business practices, particularly when delivered through experiential and practice-based learning models (Kuckertz & Wagner, 2010; Lans *et al.*, 2014). Despite its relevance, ecopreneurship education in vocational schools is often implemented in a fragmented and predominantly theoretical manner. Many VET programmes encounter difficulties in linking sustainability concepts with concrete production activities and market-oriented processes, which limits students' capacity to translate green knowledge into entrepreneurial action (Mahdavi *et al.*, 2021; Shamzzuzoha *et al.*, 2022). This situation underscores the need for instructional frameworks that coherently combine entrepreneurship, sustainability, and work-based learning in practice-oriented settings (Neck & Greene, 2011; Chinedu *et al.*, 2023). Within this context, the teaching factory model has attracted growing scholarly and practical interest due to its strong alignment with industry practices, emphasis on production-based learning, and experiential engagement of students (Sukardi *et al.*, 2019; Wibowo *et al.*, 2021). By recreating industrial working environments in schools, teaching factories enable learners to engage directly in authentic activities such as product development, manufacturing, quality assurance, and marketing, thereby enhancing both technical competence and entrepreneurial capability (Putra *et al.*, 2022; Kuat & Endang, 2023). Prior research indicates that participation in teaching factory learning contributes to improved problem-solving skills, collaborative abilities, and readiness for entrepreneurial careers (Yunanto, 2017; Aprilia *et al.*, 2021). However, many existing teaching factory practices continue to prioritise productivity, efficiency, and conformity with conventional industrial standards, while environmental sustainability and innovation remain marginal considerations (Handayani *et al.*, 2020; Jiang *et al.*, 2018). Consequently, the potential of teaching factories as platforms for fostering green innovation and ecopreneurship has not been fully explored. Integrating green innovation into teaching factory learning offers a promising pathway to reposition production activities as sustainability-oriented

entrepreneurial experiences, allowing students to internalise environmental values through direct engagement. Green innovation encompasses the development of products, processes, and practices that minimise environmental impact while sustaining or enhancing economic performance (Liu *et al.*, 2017; Habib *et al.*, 2020). In vocational education settings, green innovation provides a practical entry point for embedding sustainability into entrepreneurship education by directly connecting environmental responsibility with tangible production outcomes (Zhang & Chen, 2021; Akomea *et al.*, 2023). When operationalised within teaching factory models, green innovation supports the development of key ecopreneurship competencies, including the identification of sustainable business opportunities, eco-efficient production planning, and the design of green value propositions (Baquero, 2024; António Porfírio *et al.*, 2023). Vocational schools face the dual imperative of enhancing graduate employability while aligning educational practices with national sustainability and green economy agendas. At SMKS BPP Kota Bandung, the teaching factory programme has been positioned as a central strategy for strengthening work-based learning and entrepreneurship education. The incorporation of green innovation, particularly through the development of environmentally friendly products such as natural detergents, reflects a deliberate effort to embed ecopreneurship principles within authentic vocational learning experiences. This institutional context offers a valuable empirical setting to examine how green innovation can be systematically integrated into teaching factory learning to support the development of ecopreneurship competencies among vocational students (Fajarwati, 2024; Putra *et al.*, 2025). Although previous research has addressed teaching factories, green skills, and entrepreneurship education as separate domains, studies that integrate these elements into a comprehensive pedagogical model remain limited, especially within vocational education systems in developing countries (Ramsarup *et al.*, 2024; Stroud *et al.*, 2025). There is therefore a clear need for empirical research that conceptualises and validates a green innovation-driven teaching factory model capable of generating measurable ecopreneurship outcomes. Addressing this research gap is crucial for advancing vocational education theory and informing the design of sustainability-oriented pedagogical practices. Accordingly, this study seeks to develop and examine a green innovation-driven teaching factory model for ecopreneurship development in vocational education. Drawing on empirical evidence from SMKS BPP Kota Bandung,

the study aims to contribute to the literature on vocational pedagogy, sustainability-oriented entrepreneurship education, and work-based learning, while also offering practical insights for educators and policymakers committed to aligning vocational education with sustainable development goals.

## **2 MATERIALS AND METHODS**

### **2.1 Research design**

This research adopted a quantitative approach with a cross-sectional survey design to investigate the effect of a teaching factory model oriented toward green innovation on the formation of ecopreneurship competencies in vocational education. The quantitative method was selected because it facilitates objective measurement of students' perceptions and skill levels, as well as systematic analysis of the relationships among the studied variables. The study specifically examined the role of green innovation integration within teaching factory-based learning settings in fostering ecopreneurial competencies among vocational students.

### **2.2 Research context and participants**

The study was carried out at SMKS BPP Kota Bandung, a vocational high school that has incorporated a teaching factory model into its learning system. This model emphasizes production-oriented learning activities that replicate industrial working conditions while simultaneously encouraging the development of entrepreneurial abilities. The research participants comprised 36 students who were actively engaged in the teaching factory programme during the data collection period. Given the relatively small and accessible population, a total sampling technique was employed to include all eligible participants and ensure comprehensive representation.

### **2.3 Research instrument**

Data collection was conducted through a structured questionnaire designed to assess three core variables: the implementation of green innovation practices, the teaching factory learning process, and students' ecopreneurship competencies. The questionnaire items were developed based on relevant theoretical frameworks and previous studies related to green innovation, teaching factory models, and ecopreneurship education, thereby supporting content validity. A five-point Likert scale was used, ranging from 1 (strongly disagree) to 5 (strongly agree), to capture respondents' levels of agreement with each statement.

### **2.4 Data collection procedure**

Data were gathered during the ongoing implementation of the teaching factory programme. Before administering the questionnaire, participants were briefed on the objectives of the research and informed that their responses would remain confidential and anonymous. The questionnaires were distributed directly to students in a classroom environment to maximise response rates and ensure completeness of the data. All 36 questionnaires were returned and were considered suitable for further analysis.

### **2.5 Data analysis**

The obtained data were analysed using both descriptive and inferential statistical methods. Descriptive analysis was applied to provide an overview of students' perceptions regarding green innovation practices, teaching factory learning activities, and ecopreneurship competencies. Inferential statistical techniques were then utilised to assess the influence of the green innovation-based teaching factory model on the development of ecopreneurship competencies. Data processing and analysis were conducted using statistical software to maintain accuracy and analytical reliability.

## 2.6 Ethical considerations

Ethical principles were upheld throughout the research process. Participation was entirely voluntary, and informed consent was obtained from all respondents prior to data collection. The anonymity of participants was preserved, and all collected data were used exclusively for academic research purposes to ensure confidentiality and ethical integrity.

## 3 RESULTS

### 3.1 Results

**Table 1**

*Descriptive Statistics of Ecopreneurship Development Dimensions (n = 36)*

<b>Dimension</b>	<b>Mean</b>	<b>SD</b>
Knowledge of Ecopreneurship and Green Innovation	4.12	0.56
Attitude toward Natural Detergent Innovation	4.08	0.60
Behaviour and Engagement in Teaching Factory	4.18	0.52
Perceived Impact of Product Development	4.15	0.55

Table 1 presents the descriptive statistics for the four dimensions of ecopreneurship development measured in this study. Overall, the mean scores for all dimensions exceed 4.00, indicating a high level of agreement among students regarding the effectiveness of the green innovation-driven teaching factory model. The Behaviour and Engagement in Teaching Factory dimension recorded the highest mean score (M = 4.18, SD = 0.52), suggesting that students were highly engaged in production activities, experimentation, and the application of green economy principles. The relatively low standard deviation indicates consistent responses across participants, reflecting uniform behavioural involvement in sustainability-oriented learning activities. The Perceived Impact of Product Development dimension also demonstrated a high mean score (M = 4.15, SD = 0.55), indicating that students perceived the development of natural detergent products as environmentally beneficial and socially relevant. This suggests that teaching factory learning successfully connected entrepreneurial activities with tangible sustainability outcomes. Similarly, the Knowledge of Ecopreneurship and Green

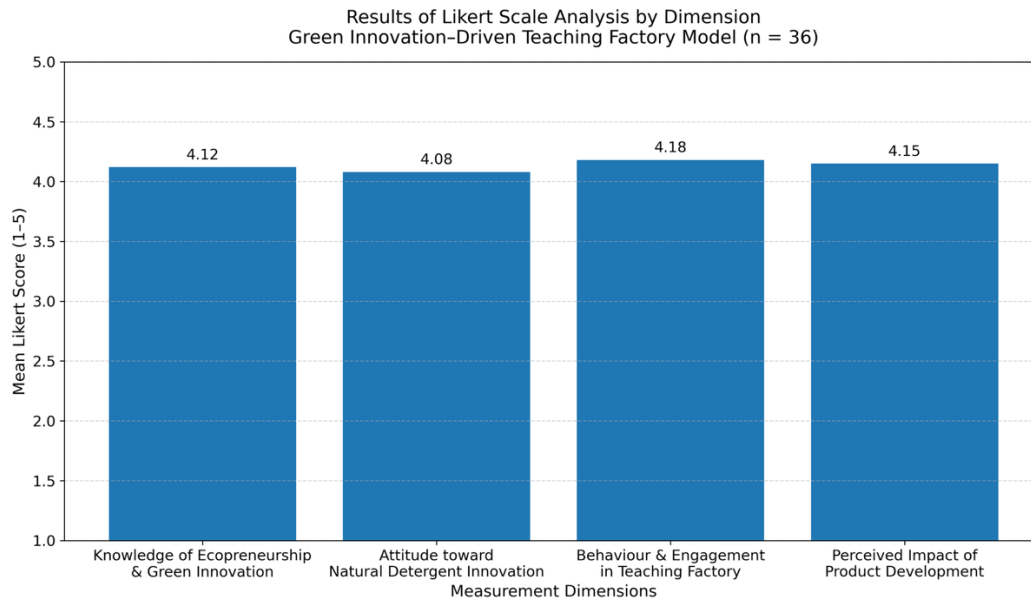
Innovation dimension showed a strong mean score ( $M = 4.12$ ,  $SD = 0.56$ ), reflecting students' solid conceptual understanding of ecopreneurship and green innovation principles. The moderate standard deviation indicates a relatively homogeneous level of knowledge acquisition among participants. The Attitude toward Natural Detergent Innovation dimension, while slightly lower than the other dimensions, still exhibited a high mean score ( $M = 4.08$ ,  $SD = 0.60$ ). This finding suggests that students held positive attitudes toward green product innovation, including its market potential and environmental benefits, though individual perceptions varied slightly more than in other dimensions. Overall, the descriptive statistics confirm that the green innovation-driven teaching factory model positively supports cognitive, affective, and behavioural aspects of ecopreneurship development among vocational students.

### **3.2 Reliability analysis**

The internal consistency of the research instrument was assessed using Cronbach's alpha to ensure the reliability of the Likert-scale questionnaire. Reliability analysis was conducted for each dimension of ecopreneurship development: knowledge of ecopreneurship and green innovation, attitude toward natural detergent innovation, behaviour and engagement in teaching factory activities, and perceived impact of product development. The results indicate that all dimensions achieved Cronbach's alpha coefficients exceeding the commonly accepted threshold of 0.70, demonstrating satisfactory internal consistency and reliability of the measurement instrument. This suggests that the questionnaire items within each dimension consistently measured the intended constructs and were appropriate for assessing students' perceptions of the green innovation-driven teaching factory model. Given the relatively small sample size ( $n = 36$ ), the reliability values are considered acceptable and consistent with quantitative studies in vocational education and entrepreneurship research. The reliability results confirm that the instrument provides a stable and dependable basis for subsequent descriptive and inferential analyses.

## 4 DISCUSSION

### 4.1 Discussion: linking figure 1 to green innovation and teaching factory theory



The results presented in Figure 1 demonstrate consistently high mean scores across all four dimensions, indicating that the green innovation-driven teaching factory model effectively supports ecopreneurship development among vocational students. From a theoretical perspective, these findings reinforce the role of teaching factory learning as a form of experiential and work-based learning that enables students to integrate knowledge, attitudes, and behaviours in authentic production contexts. The high mean score in the knowledge dimension confirms that embedding green innovation within teaching factory learning enhances students' conceptual understanding of sustainability-oriented entrepreneurship. This finding supports green innovation theory, which emphasises that environmental innovation becomes more meaningful when learners are actively involved in eco-friendly production processes rather than passively receiving theoretical instruction. Through direct engagement with green materials, eco-efficient processes, and sustainable product design, students are able to internalise the principles of ecopreneurship more effectively. The positive results observed in the attitude dimension suggest that exposure to green product innovation within teaching

factory environments fosters favourable perceptions toward environmentally friendly business opportunities. This aligns with entrepreneurship education theory, which posits that attitudes toward entrepreneurship are shaped by experiential learning and perceived feasibility. When students participate in green innovation activities that demonstrate both environmental benefits and market potential, their motivation to engage in ecopreneurial ventures is strengthened. The behaviour and engagement dimension, which recorded the highest mean score, highlights the effectiveness of teaching factory learning in translating sustainability awareness into concrete entrepreneurial actions. This finding strongly supports teaching factory theory, which views production-based learning as a mechanism for developing practical competencies through real-world problem-solving, experimentation, and collaboration. When teaching factories are explicitly driven by green innovation, they function not only as training environments but also as platforms for cultivating sustainability-oriented entrepreneurial behaviour. Similarly, the strong score in the perceived impact dimension indicates that students recognise the broader environmental and social value of green product development. This finding reinforces sustainability education theory, which emphasises the importance of connecting learning outcomes with real-world impacts. By perceiving their products as environmentally beneficial and socially relevant, students are more likely to develop a long-term commitment to ecopreneurship. Overall, the findings provide empirical support for positioning green innovation as a pedagogical driver within teaching factory models, extending existing vocational education theories by integrating sustainability-oriented entrepreneurship into work-based learning frameworks.

## **4.2 Implications**

### *4.2.1 Theoretical implications*

This study contributes to the literature on vocational education and entrepreneurship by extending teaching factory theory toward a sustainability-oriented perspective. The findings demonstrate that green innovation functions as a critical mechanism that strengthens the pedagogical effectiveness of teaching factory learning in fostering ecopreneurship development. By empirically linking green innovation practices

with cognitive, affective, and behavioural outcomes, this study bridges previously fragmented research on teaching factories, green innovation, and ecopreneurship education. Furthermore, the results support experiential learning and sustainability education theories by providing quantitative evidence that sustainability-oriented competencies are most effectively developed through authentic, production-based learning environments. This study therefore advances theoretical understanding of how vocational pedagogy can be aligned with green economy and sustainable development agendas.

#### *4.2.2 Practical implications*

From a practical standpoint, the findings suggest that vocational schools should intentionally integrate green innovation principles into teaching factory programmes to enhance students' ecopreneurship competencies. Educators are encouraged to design production activities that prioritise eco-friendly materials, sustainable processes, and environmentally responsible business models. Such practices not only improve students' technical and entrepreneurial skills but also cultivate environmental awareness and ethical responsibility. For vocational school management, the results highlight the importance of supporting teaching factory infrastructure and industry partnerships that enable green product innovation. By aligning teaching factory outputs with sustainability-oriented market demands, vocational institutions can improve graduate employability while contributing to environmental sustainability.

#### *4.2.3. Policy implications*

At the policy level, the findings provide evidence-based support for integrating green innovation and ecopreneurship into national vocational education and training (VET) frameworks. Policymakers are encouraged to promote teaching factory models that align vocational education with green economy strategies and sustainable development goals. Support in the form of curriculum guidelines, teacher training, and funding for green innovation infrastructure can enhance the role of vocational education as a driver of sustainable economic transformation.

#### *4.2.4 Implications of the study*

The findings of this study have important theoretical, practical, and policy implications for vocational education and sustainability-oriented entrepreneurship. Theoretically, this study extends teaching factory and ecopreneurship literature by demonstrating that green innovation functions as a key pedagogical driver that strengthens the effectiveness of teaching factory learning in developing sustainability-oriented entrepreneurial competencies. Practically, the results suggest that vocational schools should intentionally integrate green innovation principles into teaching factory programmes to enhance students' knowledge, attitudes, and entrepreneurial behaviours related to sustainable business practices. Embedding eco-friendly materials, environmentally responsible production processes, and sustainability-based value creation into production-oriented learning can transform teaching factories into effective platforms for ecopreneurship development. From a policy perspective, the findings provide empirical support for aligning vocational education and training frameworks with green economy agendas by promoting teaching factory models that incorporate green innovation and sustainability principles, thereby positioning vocational education as a strategic contributor to sustainable economic development.

#### *4.2.5 Limitations of the study*

Despite its contributions, this study has several limitations that should be acknowledged. First, the relatively small sample size ( $n = 36$ ) and the use of a single vocational school context limit the statistical generalisability of the findings. However, the study prioritises analytical generalisation by contributing to theory development rather than population-level inference. Second, the reliance on self-reported data measured through a Likert-scale questionnaire may introduce response bias, as students' perceptions may not fully capture actual entrepreneurial behaviour over time. Third, the cross-sectional research design restricts the ability to examine changes in ecopreneurship competencies longitudinally or to establish causal relationships. Future research is therefore encouraged to employ larger and more diverse samples, incorporate longitudinal or experimental designs, and triangulate survey data with observational or

performance-based measures to strengthen the robustness of findings related to green innovation–driven teaching factory models.

## 5 CONCLUSIONS

This study concludes that a green innovation–driven teaching factory model is an effective pedagogical approach for developing ecopreneurship competencies in vocational education. The quantitative findings indicate that integrating green innovation into production-based learning positively influences students' knowledge, attitudes, and entrepreneurial behaviours related to sustainability-oriented business practices. By embedding green product innovation within an authentic teaching factory environment, this study extends existing teaching factory and ecopreneurship literature beyond industry alignment toward a sustainability-focused educational paradigm. Although the study is limited by its sample size and contextual scope, it provides meaningful empirical insights into how vocational schools can operationalise green innovation to support sustainable entrepreneurship education. Overall, the findings highlight the potential of teaching factory models to function as strategic platforms for aligning vocational education with green economy and sustainable development agendas.

## PATENTS

This section is not mandatory but may be added if there are patents resulting from the work reported in this manuscript.

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