

A THEMATIC SYNTHESIS OF STEM-PjBL LEARNING TRANSFORMATION: A STRATEGY FOR STRENGTHENING GREEN SKILLS OF THE VOCATIONAL HIGH SCHOOL IN INDONESIA

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ABSTRACT

The current challenges of the green economy require vocational high school graduates to have strong environmental competencies. The purpose of this study is to formulate an innovative STEM PjBL learning framework integrated with Green Skills to strengthen students' green skills. This study is a qualitative descriptive study through a literature review using an integrative review approach on 18 reputable articles (2022-2026) that were rigorously obtained through the PRISMA flow to ensure contextual relevance to vocational education innovative learning. The data were analyzed using thematic synthesis techniques to integrate multidisciplinary findings. The results of the literature analysis showed that STEM learning, or project-based learning (PjBL) integrated with STEM, is successful and effective in enhancing 21st-century skills but has not explicitly explained its correlation with strengthening Green skills as a competency foundation for students in entering the green industry workforce. The study provides recommendations for an operational framework of STEM-PjBL learning by integrating Green skill indicators as aspects to be measured and developed. The implications for educational policy direction to be implemented in a green curriculum, as well as the synergy between teachers and educational staff in preparing vocational school students, emphasize the need to synergize local wisdom with STEM-PjBL-based green technology to achieve work readiness that is adaptive to absorption in the green industry.

Keywords: STEM-PjBL; Green skill; Vocational High School

INTRODUCTION

The current transformation of the global industry is moving towards a sustainability paradigm in line with the challenges of climate change and environmental degradation, so vocational high schools (SMKs), as one of the formal educational institutions that function to provide the workforce, must be able to integrate environmental awareness into the learning process. Through contextual learning, students are able to build ecological awareness by connecting the learning materials or concepts they receive with their relevant applications in the working world (Islami & Armianti, 2020). Environmental strengthening vocational high school graduates not only focuses on

technical competencies but also includes green skills, which are a combination of knowledge, skills, and values necessary for a sustainable society. (UNESCO-UNEVOC International Centre, 2020). Vocational schools play a role in the growth of job opportunities and the green industry by equipping their students with green skills (Wahyuni & Mutohhari, 2024)

The integration of sustainability into the education system is an effort to achieve the Sustainable Development Goals (SDGs), especially regarding climate policy and sustainable development (Kwauk & Casey, 2022). Vocational education or Technical and Vocational Education and Training (TVET), including vocational high schools (SMK), faces the

challenge of requiring a Greening Action Plan that can align the curriculum with global environmental policies, as outlined in the UNESCO-UNEVOC ESD-2030 Framework, which prioritizes sustainability in vocational education.(Vasilev & Petkova, 2025).

Transformation is not only focused on technical skills but also on the formation of environmental stewardship character that equips students with moral responsibility toward the ecosystem (Welchman, 2023). Several recent literatures have explored the use of interdisciplinary approaches such as STEM (Science, Technology, Engineering, and Mathematics) to support sustainability, including the implementation of STEM-PjBL-based learning modules for 10th-grade students at SMAN 7 Banjarmasin to preserve exotic fruit plants. (Nurtamara et al., 2023).

In line with this, the implementation of Project-Based Learning (PjBL) based on the STEM approach has proven to empower critical thinking skills in biodiversity learning (Fatimah et al., 2023). Strengthening that learning becomes one of the strategies in realizing the competencies needed in the future workforce, especially in vocational education, which has the obligation to support sustainable development thru green skills. (Haloho et al., 2023).

Although the literature on the effectiveness of STEM-PjBL and vocational education framework policies has developed rapidly (Pagkratis, 2024) there are still significant research gaps in synthesizing that approach comprehensively toward strengthening green skills for vocational high school students. This gap becomes even more apparent in the Biodiversity material as one of the crucial sub-material developments in

the Merdeka Curriculum, where the integration of sustainability values often remains theoretical without addressing the practical aspects of green job readiness (Mukhitdinova, 2026).

This article aims to examine the development of vocational learning based on STEM-PjBL and green skills over the last five years through an integrative review, with the main focus on synthesizing research findings to build an operational framework that integrates aspects of innovative learning strategies to strengthen green skills. The results of this review are expected to provide policy direction for curriculum developers and educators in designing teaching materials that are adaptive to the needs of the green industry in the future, where STEM-PjBL can enhance green skills for vocational high school students.curriculum developers .

Research questions are formulated as a guide in systematically analyzing the literature review, namely:

RQ 1: How is STEM-PJBL learning implemented in vocational high schools in Indonesia?

RQ 2: What efforts are being made to improve green skills for vocational high school students in Indonesia?

RQ 3: How can STEM-PJBL strengthen green skills in vocational high school students in Indonesia?

METHOD

This research is a type of descriptive qualitative research thru literature study using an integrative review approach. This approach was chosen to synthesize various literature with a multidisciplinary perspective to produce a new theoretical model. (Snyder, 2019). The data collection process uses the Purposive Sampling technique thru the selection of scientific

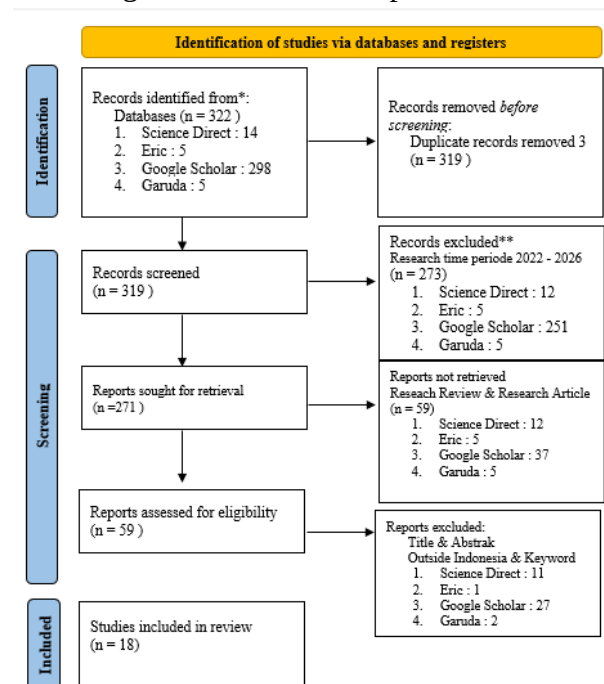
articles relevant to the established inclusion criteria, thereby maximizing the contribution to reconstructing the concept related to strengthening greenskills in vocational high school, particularly in Indonesia. (Suri, 2011).

The process of literature identification was conducted through a systematic search in the databases Science Direct, Eric, Google Scholar, and Garuda. The researchers used 5 search keywords, namely 1) STEM PjBL AND vocational high school 2) "STEM PjBL" AND "vocational high school" 3) vocational high school AND green skills, 4) "vocational high school" AND "green skills." 5) Indonesia AND "STEM" AND "green skill" AND "vocational high school." These five keywords are used to obtain articles that focus on research content, namely STEM PjBL, Green Skills, and Indonesia for articles published nationally and internationally. The search for national and international articles uses Science Direct and ERIC with keyword 1, and Google Scholar uses keyword 2. Keywords 3 and 4 are focused in Indonesian to search for articles that focus on research in Indonesia. Keyword 3 is used in the Garuda search database, and keyword 4 is used in the Google Scholar database. The fifth keyword is used to strengthen the overall component search through Science Direct, ERIC, and Google Scholar searches.. (Whittemore & Knafl, 2005).

The analysis is specifically focused on three main aspects, namely the development of vocational education curricula, innovative instructional strategies, and the development of learning media oriented toward environmental sustainability and green skills. Thru a rigorous screening The articles that were collected were then strictly selected through

PRISMA, resulting in 18 articles based on the database, including 1 articles from Science Direct, 4 articles from Eric, 10 articles from Google Scholar, and 3 articles from Garuda. The detailed stages of the article selection process are presented in the PRISMA flow diagram in Figure 1..

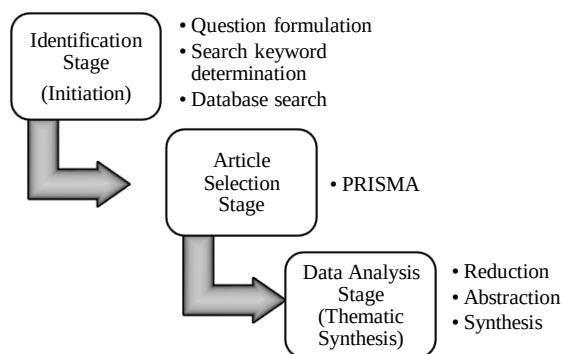
Fig.1 Article selection process



Data analysis was conducted using thematic synthesis techniques aimed at integrating various literature findings into a cohesive theoretical construct. (Thomas & Harden, 2008). In the diagram above, the number of articles obtained from the selection process was 25 articles, and then a data categorization process was carried out to group the literature into main themes according to the principles of thematic analysis coding. (Braun & Clarke, 2008) which includes the integration of STEM-PjBL in learning at vocational high schools as well as research on efforts to enhance green skills at the vocational high school level. The next stage is abstraction and cross-literature comparison (cross-literature analysis) to identify the relationship between the components of

STEM-PjBL integration and the strengthening of students' green skills at the vocational high school level. This process allows researchers to map research gaps and contextualize them with the needs of an independent curriculum at the vocational high school level. The final stage is conceptual synthesis by synergizing all the themes found to formulate new theoretical propositions as an innovative learning framework that integrates STEM-PjBL to strengthen green skills among vocational high school students. (Braun & Clarke, 2008). The overall research procedure is illustrated in Figure 2.

Fig.2 Research Procedure



RESULT AND DISCUSSION

RESULT

In the search for journals on the main category regarding the connection between STEM PjBL and the strengthening of Green Skills in vocational high schools in Indonesia, data were obtained as shown in Table 1.

Table 1. Mapping of keyword search results 5

Basic Code	Au	Jo	Thn	Met	Focus
SD1	Isbah, M. Falikul	Asian Education and Development	2025	Case Study	The readiness of vocational high school students towards

		Studies			the green economy industry.
GS1	Hafis Muaddab	Journal of Education Development And Review	2024	Literature Review	The criteria for vocational students' green skills are the technical skills, knowledge, and attitudes required.
GS2	Lukman Affandi, Mintasih Indriayu, Salma Nur Alfariy Totalia	International Journal of Research and Community Empowerment	2025	SLR	21st-century skills as work readiness, both soft skills and hard skills

Although the search using the keywords Indonesia AND "STEM" AND "green skill" AND "vocational high school" was conducted, the search results showed that all three require collaboration between the education curriculum and industry needs. Case study research indicated the uneven readiness of vocational high school students to face the green economy. The integration of green skills becomes crucial but is not yet aligned with industry needs, which do not yet require workers with green skills.(Isbah et al., 2025). Meanwhile, in another study using a literature review, there is already a connection between green skills and industry demand, but the vocational education curriculum has not fully introduced green skills as the technical skills needed in the green economy transition (Muaddab, 2024). Work readiness requires 21st-century skills as well as other skills, including soft skills and hard skills for vocational high school

students, which can be improved through various learning models, although the term green skills is not explicitly mentioned, this article discusses the role of vocational high schools in supporting sustainable development(Affandi et al., 2025)

The entire article above, both explicitly and implicitly, describes green skills as one of the skills required for vocational high school graduates. However, the criteria for integrating the PjBL learning model with the STEM approach have not been found, so they are analyzed separately to determine whether there is any overlap in research connecting the two. Furthermore, mapping of the articles based on the keywords STEM, PjBL, and Vocational High School was obtained through Table 2.

Table 2. Mapping of keyword search results 1 and 2

Basic Cod	Au	Jo	Thn	Met	Focus
Er1	Suyono Suyono , Tukiran Tukiran , Eka Yuliatu rosida	Educa tional Proce ss: Intern ationa l Journ al	2025	SLR	The use of STEM-integrated PjBL to improve creative thinking skills
Er2	Muhtar Muhtar, Suryant i, Bachtia r Sjaiful Bachri, Khusnu l Mila, Ayil Qoimat ul Laili, Eka Yuliatu rosida, Isnaini Nur Siyam	Educa tional Proce ss: Intern ationa l Journ al	2025	SLR	There is still a lack of integration between subjects in PjBL-based learning in vocational high schools
Er3	Muham mad Sadam Rizkyilil	Intern ationa l Journ	2025	Studi Kas us	PjBL to improve 21st

	lah, Soeprij anto, Muksin	al of Resea rch in Educa tion and Scien ce		Kol ektif	century skills
Er4	Muhtar, Suryant i, Bachtia r Sjaiful Bachri, Erika Kurnia wati, Ilma Indana Sari, Sulton n Huda, Wahyu Sulaim an	Educa tional Proce ss: Intern ationa l Journ al	2025	R & D	Developm ent of the PjBL model (Dick & Carey) to align the work readiness of vocational high school students
GS3	Syaifud din; Sarwi; Harton o; Murban gun Nuswo wati	Journ al of Educa tion and Learni ng (EduL earn)	2025	SLR & Bibl ome trik	STEM PjBL research trends in promoting physics at the vocational high school education level
GS4	Pinky Kusum a Ningtya s; Hayuni Retno Widarti ; Parlan Parlan; Sri Rahayu ; I Wayan Dasna	Intern ationa l Journ al of Educa tion in Mathe matics , Scien ce and Techn ology	2024	SLR	Integrated STEM PjBL, PBL, jigsaw, 5E-EDP and 6E- Circle have been proven to improve 21st- century skills

Based on Table 2, it can be seen that research on STEM integrated with Project Based Learning (PjBL) at the vocational high school level (SMK) is still limited. STEM-PjBL learning can enhance creative thinking skills (Suyono et al., 2025) and can be used to promote physics learning as a research trend(Syaifuddin et al., 2025), as well as fully support 21st-century skills

(Ningtyas et al., 2024). Other articles are still limited to the implementation of Project Based Learning (PjBL) in specific subject concepts or integrated across subjects but do not use a STEM approach, focusing on results in improving student skills, particularly 21st-century skills, as an effort to prepare SMK students for entering the workforce (Ratih & Arsih, 2024) (Rizkylillah et al., 2025)(Muhtar et al., 2025).

The measurement of 21st-century skills is used as an effort to shape the character of vocational high school students sustainably through the integration of green skills into the learning curriculum at schools or as an insertion in school curriculum development. Green skills, as one of the 21st-century skills, are needed to adapt products, services, and processes to be environmentally friendly. (Diplan et al., 2020) are required in preparing vocational high school students towards a sustainable workforce

Separate mapping is carried out to see the extent of the application of green skills through learning at the vocational secondary education level in Indonesia based on Indonesian-language keywords to capture SMK-specific research in Indonesia as outlined in Table .3.

Table 3. Mapping of keyword search results 3 and 4

Basic Cod	Au	Jo	Thn	Met	Focus
GS5	Nur Wah yuni, Farid Muto hhari	Jurnal Inovasi Pendi dikan dan Tekno logi Infor masi (JIPTI)	2024	Peneliti an Kuantita tif melalui Survey	Improvem ent of Green Skills in Vocationa l High School Students through Efforts in Learning Developm ent and Collaborat ion with the

GS6	Hafis Muad dab, Ika Zunit asari, Jefry Aulia Mart ha	RESE ARC H AND DEVE LOP MEN T JOUR NAL OF EDUC ATIO N	2024	Pendeka tan Kualitat if	Communit y The need for adjustmen t of green skills through the integratio n of vocational school curricula
GS7	Muha mma d Noor Fitriy anto, Dipla n, Agun g Priba di	Journa l of Vocati onal of Tehcn ical Educa tion	2022	Peneliti an Tindaka n Kelas	Integratio n of green skill aspects in waste managem ent projects enhances the green skills of vocational high school students
GS8	Tatan g Suhe ndra, Lamb ang Suba giyo, Abd Basir	Edune sia : Jurnal Ilmiah Pendi dikan	2025	R &D	Developm ent of green skills guidelines in vocational schools as an effort to bridge the green economic transform ation
GS9	Lilis Roha yati, Nika Nura stuti, Wita Sari, Musti ka Nura malia Handayani , Muk hidin	Edufo rtech	2022	Kualitat if Deskript if	Research on the developm ent of aspects of Environm ental awareness , Communi cation skills, Adaptabili ty in green jobs, Innovatio n skills to identify opportunit ies and create new

					strategies to respond to green challenges						no, Rifan Andi ka Mana lu,Wi lliam Joshua Sinag a			ent of renewable energy technology.		
GS 10	Nahl ah Must afa Kam al, Surya Dhar ma,	Jurnal Inovasi & Riset Pembe lajaran	2025	Kuantita tif metode cross survey	significant contributi on of environme ntal responsibi lity in mediating the influence of eco literacy and school policy on the green skill developm ent of Generatio n Z.						Ga3	Surya di*, M. Iqbal Adhy a Putra, Murs alin, Muha mma d Ali, Zahar	Journa l of Engin eering Scienc e and Techn ology Mana gemen t Social and Comm unity Servic e	2023	Pengabd ian kepada Masyara kat (PkM)	Improvem ent of environme nt-based skills in developin g feed techniques .
Ga1	Iswa ndi, Supri atno , Susil awati *, Tino Herm anto , Sams ul Abdu l Rah man Sidik Hasib uan, Rizki Muli ono , Ida Roya ni , Yopa n Rah mad Aldor i	Jurnal Anuge rah	2025	Pengabd ian kepada Masyara kat (PkM)	Training in fostering sustainabl e entreprene urial awareness equips students with sustainabl e skills and attitudes											
Ga2	Eria waty, Dewi Rakh maw ati, Eli Karli ani, Ali Sunar	Jurnal Solusi Masya rakat Dikara	2025	Pengabd ian kepada Masyara kat (PkM)	The developm ent of education in fostering environme ntal awareness , in the developm											

Based on Table 4, it was found that all articles emphasize strengthening green skill competence or green competence in Indonesia. Analysis of green skills in vocational school teachers and students through collaboration with the community (Wahyuni & Mutohhari, 2024) is conducted through an integrated curriculum so that it can bridge the workforce readiness needs in the industrial world (Muaddab, 2024). Project-based learning is carried out to improve green skills for vocational school students and the development of green skill guidelines is made as an effort to align vocational school students' green skills with the needs of the green economy (Suhendra et al., 2025). The enhancement of green skills through food product-making practices in vocational schools is carried out as one of the waste management strategies (Rohayati et al., 2022). Strengthening green skills in vocational school students as Generation Z is conducted through the modeling of Ecoliteracy and School Policy (Kamal & Dharma, 2025).

Other articles that discuss the development of green skill competencies

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Other articles that discuss the development of green skill competencies

include through community service methods that contribute to local communities of students in several areas, namely Tanjung Morawa with the use of fuel technology (Iswandi et al., 2025), Lhoksumawe for the utilization of green energy as renewable energy (Suryadi et al., 2025), and Kampar through feed preservation (Novita et al., 2023).

The majority of the analyzed literature comes from Indonesia and has contextual relevance to the uniqueness of the vocational education system at the secondary level, commonly known as SMK. This is important because Indonesia is currently undergoing a transition phase toward the implementation of the independent curriculum, which emphasizes the flexibility of teaching materials and projects through sustainable themes (Islamiati et al., 2024).

Discussion

The government's policy direction towards green skills

The direction of strategic policies regarding the realization of green employment has been written down in Indonesia's green workforce development roadmap. The limitations of technical training or the lack of access to vocational education programs relevant to the technical needs of the green sector, and the lack of access to vocational programs including vocational high schools (SMK) relevant to the needs of the green sector, make it difficult for the workforce to meet the demands of continuously developing green technology. (Nur Hygiawati Rahayu, 2025).

Meanwhile, Indonesia's education roadmap for 2025 - 2045 contains policy directions that do not explicitly discuss the provision of sustainable human resources

that are adaptive to Indonesia's role in realizing education that supports the SDGs. Specifically, in the field of vocational education (Vocational High Schools and Vocational Higher Education), it is explicitly stated that both are still not optimal in producing graduates who can be easily absorbed into the labor market and entrepreneurship, especially in fields that require high-level skills. (PPN/Bapenas, 2025).

The Ministry of Primary and Secondary Education has begun to change the vocational education strategy to align with the direction of the future economy through the reorientation of vocational education in the era of economic transformation, which is carried out not only as a curriculum renewal but also as a paradigm shift in human resource development as a productive asset capable of driving Indonesia's transformation towards a skills-based, innovation-oriented, and high value-added economy. (Khurniawan, 2025)

In line with the curriculum development on priority issues regarding reference learning guidelines, one of which includes guidance on STEM learning through the curriculum access page of Kemdikdasmen intended for all education levels including vocational high schools (SMK) (Kemendikdasmen, 2025) as a concrete step by the government to respond to the results of situation analysis and strategic issues regarding the gap between STEM and non-STEM graduates in Indonesia, which is still significant, with the contribution of STEM graduates in priority industries being much lower compared to developed countries. (PPN/Bapenas, 2025).

The two roadmaps created by the government through the Ministry of

Industry and the Ministry of Education and Culture are oriented towards strengthening human resources to meet the demands of the global labor market. Although it has not been explicitly stated in the education roadmap, references in the Ministry of Education and Culture curriculum actually include guidelines on, among others, priority issues concerning climate and STEM education specifically, which can refer to efforts to strengthen green skills for students, particularly in vocational high schools.

The green school guide was actually launched by the Ministry of Education in 2020, although it is for the design of school facility management, it contains explanations regarding green attitudes and skills to develop students' awareness of concern for the surrounding environmental conditions. (Suharto. Arie Wibowo Khurniawan, 2020) However, its implementation was hindered by the Covid-19 pandemic, which caused this guide not to be realized optimally.

STEM Learning and Green Skill

Analysis of the latest literature shows that vocational human resources are produced not only with reference to technical skills but also require a behavioral orientation and ecological awareness (Haloho et al., 2023).). The development of green competencies at the vocational education level requires a conceptual model that includes natural resource management, energy, and environmental ethics relevant to the graduate profile (Latif, 2025). Other research findings show that the global industrial sector today is beginning to prioritize green human resource management with higher priority and competitive advantage compared to other human resources (Siti Sabina, 2025)

Therefore, vocational education requires a curriculum transformation to align with strategies that adapt green policies globally (Vasilev & Petkova, 2025)

The Independent Curriculum provides educators with the flexibility to develop teaching materials that are more contextual and adaptive according to industry needs. (Islamiati et al., 2024). The STEM approach has been proven to drive the sustainable innovation needed in the transition towards a green economy (Pagkratis, 2024). The development of STEM-PjBL syntax not only strengthens cognitive aspects but also empowers students' critical thinking skills through solving real-world problems in the school environment (Fatimah et al., 2023).

The success level of implementing green skills in vocational education depends not only on technical materials but also on behavior habituation processes and students' emotional maturity. From the perspective of behaviorist learning theory, the development of green skills can occur through the mechanism of "operant conditioning" by positioning the STEM-PjBL instructional environment to function as a planned stimulus so that it produces consistent ecological behavior responses over time (Soares, 2023). Positive reinforcement provided at each stage of environmental projects allows students to gradually internalize sustainable industry performance standards into automated work behavior (Lestari et al., 2024).. This becomes important in vocational education by ensuring that green job readiness is manifested in concrete actions, not just theoretical understanding.

Another research fact shows that the global industrial sector is currently starting to prioritize green human resource management with higher priority and has

greater competitiveness among other human resources (Siti Sabina, 2025). Therefore, vocational education requires a curriculum transformation to align with strategies that adapt global green policies (Vasilev & Petkova, 2025) but also how the skills in managing natural resources, such as the environment, affect the global climate (Kwauk & Casey, 2022). Ecological literacy (ecoliteracy) as an initial step in building green skills thru green behavior can be strengthened thru an ethnoscience approach that highlights local wisdom as the basis of learning (Wisman & Santoso, 2024).

Research development is needed to bridge STEM-PjBL with the strengthening of green skills as a new framework for realizing green technology innovation grounded in global citizenship values as part of the skills required in the 21st century and supporting environmental conservation (Goodale et al., 2025). This aligns with the expectations for achieving the 8 graduate profiles in the independent curriculum (BBPMP, 2025). Through the integration of climate understanding and community empowerment into the curriculum, it is capable of producing vocational school graduates with strong ecological integrity (Kwauk & Casey, 2022).

The ecoliteracy curriculum plays an important role in school-level implementation to encourage students' sensitivity toward awareness, feeling, and the desire to protect the earth as one of the efforts to maintain the balance of nature (Fajariningtyas et al., 2024). The effectiveness of using the Project Based Learning (PjBL) syntax thru the STEM approach can enhance students' critical thinking and creativity (Fatimah et al., 2023) (Nurtamara et al., 2023)

Positive reinforcement given at each stage of the environmental project allows students to gradually internalize sustainable industry performance standards into automated work behavior. (Lestari et al., 2024). This becomes important in the world of vocational education by ensuring green job readiness is manifested in real actions, not just theoretical understanding. The effectiveness of green skills is also influenced by the affective dimension, particularly emotional intelligence. Daniel Goleman defines emotional intelligence as the ability to understand one's own feelings as well as those of others, and the ability to motivate oneself and manage emotions both for oneself and in relationships with others. (Sahrandi & Saparwadi, 2021).

In the context of sustainability, this concept is expanded into ecological intelligence, which is the ability to understand the impact of human activities on ecosystems (Doherty, 2009). Students with high emotional and ecological intelligence will be able to have a stronger intrinsic motivation in preserving nature, so an environment-based learning model can serve as an emotional bond that connects students' personal closeness to their surrounding environment.

Another urgency of STEM PjBL is in strengthening 21st-century environmental-based skills, allowing students not only to master science and technology separately but also to become multidisciplinary problem solvers for complex environmental issues. (Bybee, 1997). Environment-based projects can be an innovative solution to the challenges of climate change. (Hakim et al., 2023). Thus, the synergy between behavioral disciplines, emotional maturity, and mastery of 21st-century competencies thru STEM PjBL can produce vocational graduates who are not only technically

competent but also possess commendable ecological integrity.

STEM-PjBL strengthening Green Skills.

The articles captured in the search process indicate that research is still partial for certain variables and has not yet appeared to combine the three variables, namely STEM, PjBL, and Green Skill, in research at the vocational high school level in Indonesia, thereby creating a gap that can serve as a recommendation for the operational framework in PjBL learning through the STEM approach integrated with green skill indicators for students.. STEM-PjBL involves students through authentic tasks that are specifically important for addressing learning needs towards future workforce readiness (Capraro & Slough, 2013).

Green skill indicators include aspects of knowledge (4 items), attitudes (6 items), and skills (23 items), with all aspects used with the application of adapted items.(Fitriyanto et al., 2023). As for the development of the conceptual framework for STEM-integrated project-based learning (PjBL-STEM), it is compiled based on a four-phase design: (1) searching for and analyzing information, (2) designing collaborative learning and brainstorming, (3) presenting the project, and (4) reflection and follow-up.(Retno et al., 2025). Both variables can be compiled so that an operational framework can be obtained through the integration of green skill indicators as one of the aspects used in assessment or measurement within a STEM-based PjBL learning framework.

CONCLUSION

The study provides recommendations for the operational framework of STEM-PjBL that integrates green skill indicators as aspects measured in the learning assessment process so that if this process is carried out continuously, it is expected to form green habit patterns and strengthen

green skills in vocational high school students through STEM PjBL learning and become an environmentally-based learning alternative.

A review of 18 pieces of literature has generally informed about vocational high school learning regarding the implementation of STEM and the improvement of green skills that have been applied in Indonesia.

Policy recommendations are needed regarding the implementation of strengthening green skills in learning, especially STEM PjBL, so that it can be carried out sustainably, both through strengthening training for teachers on STEM PjBL and Green Skills and through partnership collaborations with stakeholders to develop students as prospective green workforce who are able to adapt to global green economic growth.

This research has limitations in the number of literature synthesized as well as its nature, which is still in the form of theoretical propositions. Therefore, it is recommended for future research to conduct empirical validation through Research and Development (R&D) methods to test the proposed operational framework model by including long-term sustainability indicators, among them the absorption of vocational high school graduates in the green industry or the adoption of sustainable practices through teacher practitioner communities via institutional policies so that the green curriculum aligns with the specific needs of the surrounding industry ical.

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