The impact of project-based learning on 21st century skill development of vocational engineering students: A systematic literature review

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Abstract: This study conducts a systematic literature review to evaluate the impact of Project-based Learning (PjBL) to vocational education and its effects on developing 21st-century skills. Utilizing the PRISMA framework, the study analyzes 21 articles from an initial pool of 1,036 papers from Scopus and Google Scholar databases. The included literature consists of articles published within the last five years (2019-2024) and systematically examines the findings from relevant studies. The analysis results demonstrate that PjBL is crucial in preparing students for a dynamic, technology-driven workforce by enhancing skills such as learning and innovation, information, media, technology, and life and career skills. Despite challenges in implementing PjBL, such as insufficient technological proficiency, inadequate resources, and misaligned curricula, PjBL offers opportunities to develop more effective pedagogical approaches aligned with industry needs. The study emphasizes the importance of collaboration between educators, policymakers, and industry stakeholders to address these challenges and improve vocational education quality. Additionally, the study identifies the need for further research to bridge existing gaps, particularly in developing information, media, and technology skills. Therefore, PjBL is a potential method for equipping students with essential skills for the ever-evolving job market.

Keywords: Quality education; Secondary education; Vocational education; Project assignment

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1. Introduction

Vocational education plays a vital role in preparing a competent, adaptable, and competitive workforce for the industrial sector (Fortuna, Prasetya, Luis, et al., 2024; Prasetya, Fortuna, Jalinus, et al., 2024; Wulansari et al., 2024). In the era of Industry 4.0, 21st-century skills such as critical thinking, collaboration, creativity, and digital literacy are crucial for graduates to swiftly adapt and compete globally (Varas et al., 2023). However, vocational education in Indonesia still faces challenges in designing effective learning systems to foster these skills, particularly in preparing competent

secondary and higher vocational education graduates. Project-Based Learning (PjBL) is a practical approach to developing 21st-century skills (Baran et al., 2021; Hujjatusnaini et al., 2022). This method encourages students to engage in real-world projects relevant to their fields of expertise, allowing them to develop theoretical knowledge, practical skills, critical thinking, and teamwork (Jalinus et al., 2023; Le et al., 2022). Numerous studies have shown PjBL's impact on cultivating critical thinking and collaboration skills through hands-on project involvement, fostering independent and creative learning.

Nevertheless, prior literature has not thoroughly explored the specific impact of PjBL on 21st-century skills within Indonesia's technical vocational education. Previous studies, such as those by (Guo et al., 2020), which examine PjBL implementation in higher education, and by (Ahmad et al., 2023) and (Syahril et al., 2022), which focus on the cognitive impacts of PjBL in vocational education, indicate positive outcomes. However, no comprehensive review exists on the distribution of PjBL's effects on 21st-century skills in vocational education.

This research focuses on how implementing Project-Based Learning (PjBL) in vocational education can support the development of 21st-century skills. The study aims to address gaps in the literature by conducting a systematic review of previous studies on PjBL within the context of vocational education. Additionally, it seeks to synthesize findings from prior research to provide in-depth insights into the effectiveness of PjBL in enhancing 21st-century skills among vocational students.

This research is expected to serve as a foundational resource for educators and curriculum designers, providing an understanding of best practices and challenges in implementing PjBL, particularly about developing critical thinking, creativity, collaboration, and digital literacy skills. The focus on 21st-century skills, as outlined by the (The Partnership for 21st Century, 2019), encompasses key aspects illustrated in Figure 1.

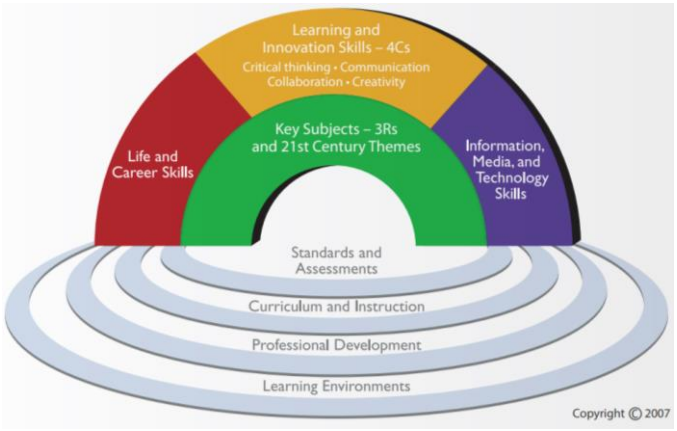

Figure 1. 21st Century Learning

Figure 1 presents the framework developed by the The Partnership for 21st Century, 2019), highlighting core skills and support systems essential for preparing students for success in an ever-evolving world. The framework comprises several layers, each representing different aspects of 21st-century learning. Key elements within the core skills framework for 21st-century education include Learning and Innovation Skills,

often called the "4Cs": critical thinking, communication, collaboration, and creativity. These skills are foundational for supporting innovation and problem-solving in the era of Industry 4.0 (Thornhill-Miller et al., 2023). Information, Media, and Technology Skills also emphasize digital literacy, including competencies in accessing information, media, and technology—critical skills for navigating the rapidly evolving technological landscape (Diseiye et al., 2024). Finally, Life and Career Skills encompass flexibility, adaptability, initiative, social skills, productivity, and leadership, all essential for success in careers and daily life (Eryandi & Nuryanto, 2020).

This study aims to address the challenges of developing 21st-century skills in technical vocational education by exploring the implementation of Project-Based Learning (PjBL). Recognized as an effective method, PjBL equips students with skills relevant to current industrial demands. Using a Systematic Literature Review (SLR) approach based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Page et al., 2021), this research will identify, analyze, and synthesize literature on PjBL's impact on 21st-century skill development in vocational education. The literature reviewed includes articles from leading journals that have undergone rigorous peer review, providing a comprehensive understanding of best practices and opportunities for direct PjBL application in vocational education. Research questions guiding this study are presented in Table 1.

Table 1. Research question (RQ)

No	Research Question
1	What is the distribution of research data on Project-Based Learning in vocational education over the past 5 years (2019-2024)?
2	What skills are involved in 21st-century learning, and how is Project-Based Learning applied in vocational education?
3	What are the challenges and opportunities of project-based learning in vocational education, especially regarding 21st-century skills?

This research presents an innovative perspective, as there are currently limited review articles examining the application of project-based learning (PjBL) in developing 21st-century skills, especially within vocational education. To date, there has not been a comprehensive review synthesizing studies on the impact of PjBL on enhancing Life and Career Skills, Learning and Innovation Skills, and Information, Media, and Technology Skills in vocational education. Therefore, by highlighting best practices, challenges, and opportunities in implementing PjBL in vocational settings, this study offers a fresh perspective on understanding the effectiveness of the PjBL approach in preparing students with skills essential for addressing global challenges and meeting the needs of modern industries.

Additionally, this research addresses the challenges of developing 21st-century skills in vocational education by providing guidelines that educators, curriculum designers, and policymakers can use to design more effective and industry-relevant learning programs. The findings are expected to serve as a critical reference for supporting the broader implementation of Project-Based Learning (PjBL) so that vocational graduates acquire technical competencies and critical thinking, innovation, collaboration, communication skills, and the ability to keep pace with technological advancements in the workforce.

2. Material and methods

2.1 Research design

This study employs a Systematic Literature Review (SLR) using the PRISMA approach (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) to identify, select, analyze, and synthesize relevant literature (Page et al., 2021). The SLR method allows researchers to comprehensively understand the effectiveness of PjBL by considering existing empirical evidence, particularly findings related to vocational education and 21st-century skills.

2.2 Study identification

This study applies inclusion criteria to literature selection, including only articles from reputable international peer-reviewed journals published within the past five years (2019–2024). Selected articles must discuss the application of Project-Based Learning (PjBL) in vocational education and 21st-century skills, such as Learning and Innovation Skills, Information, Media, and Technology Skills, and Life and Career Skills. In contrast, exclusion criteria included studies published before 2019, conference papers, book reviews, and other non-peer-reviewed publications (non-English records), which are excluded from this review. This approach ensures that only relevant, up-to-date, and substantial literature forms the basis for analyzing PjBL's impact on skill development in 21st-century education. Table 2 provides an overview of the keywords used to obtain these results.

Table 2. Criteria for determining relevant research results

Data source	Keywords
The databases used include reputable databases such as Scopus and Google Scholar to obtain relevant research results.	Keywords used include “Project-Based Learning”, “21st-century skills”, and “vocational education”.

Table 2 shows the data sources and keywords applied in the literature search. Primary sources come from leading databases like Scopus and Google Scholar, which were selected to ensure the relevance of the research for this study. The keywords focus on project-based learning (PBL) implementation, 21st-century skills, and vocational education, which are central themes of this research. After establishing keywords and inclusion/exclusion criteria, 1,036 articles were identified and processed using the PRISMA flow diagram, as illustrated in Figure 2.

Figure 2 illustrates the PRISMA flow diagram for the study selection process in this systematic literature review. The process begins with the identification stage, where 1,036 articles are retrieved from two databases, Scopus (536 articles) and Google Scholar (500 articles). Of these, 288 articles are excluded for not meeting the initial criteria. Subsequently, 746 articles were further screened, and an additional 195 were eliminated due to irrelevance. From the remaining 551 articles, 165 were inaccessible, leaving 435 articles for eligibility evaluation. At this stage, 414 articles were excluded for being outside the study's focus. Ultimately, 21 relevant studies that met the criteria were included in the systematic review.

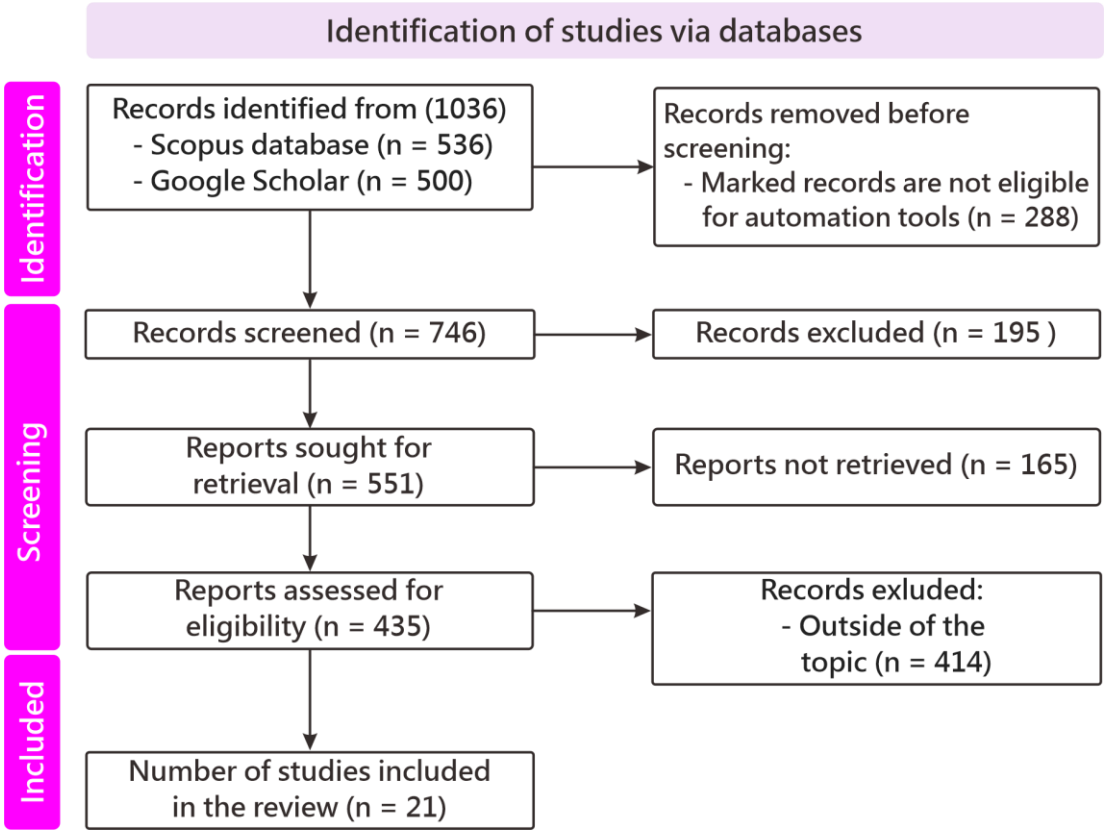

Figure 2. PRISMA framework for the identification and selection of studies via databases

2.3 Data analysis

Data analysis in this study was conducted through the systematic evaluation and synthesis of findings from relevant studies, focusing on the effectiveness of Project-Based Learning (PjBL) in vocational education and the development of 21st-century skills. The collected publications were then analyzed using Microsoft Excel to report the necessary findings for addressing the research questions (Prasetya, Fortuna, Samala, et al., 2024). The analysis results are presented in tables and distribution diagrams, illustrating the distribution of PjBL's impact on skills like Learning and Innovation Skills, Information, Media, and Technology Skills, and Life and Career Skills.

Additionally, VOSviewer software was utilized to visualize the development of this research domain over the past five years (Orduña-Malea & Costas, 2021). VOSviewer facilitates the identification of patterns, trends, and keyword networks related to PjBL and 21st-century skills in vocational education, providing a deeper understanding of research focus and its contributions to the existing literature (Fortuna, Prasetya, García, et al., 2024). Thus, the PRISMA approach ensures transparency and replicability in the analysis process, from identification to selection of relevant literature (Page et al., 2021). Each stage of this analysis aims to generate a comprehensive, evidence-based understanding of PjBL's impact on vocational education, providing a solid foundation for future policy development and more effective teaching practices.

3. Results

The literature analysis, which reviewed 1,036 records, indicates that Project-Based Learning (PjBL) holds significant potential for developing 21st-century skills in vocational education. Following a comprehensive screening process, 21 studies met the eligibility criteria for inclusion in the systematic literature review. The findings from these studies align with the research questions aimed at guiding future research directions.

Studies over the past five years highlight the impact of PjBL on preparing students to face increasingly dynamic and technology-driven workforce challenges, providing a solid foundation for designing relevant and adaptive learning methods in vocational education. Based on these findings, the first research question in this review is as follows:

RQ1. What is the distribution of research data on Project-Based Learning in vocational education over the past 5 years (2019-2024)?

Figure 3 illustrates a network visualization of keyword relationships generated by VOSviewer, a bibliometric analysis tool. Each colour represents a different cluster comprising closely related keywords; for example, the blue cluster includes keywords related to "education" and "networking," the green cluster focuses on "training" and "workshops," and the red cluster includes topics like "creativity" and "engineering." The yellow cluster, meanwhile, groups topics such as "21st-century learning," "innovation skills," and "project-based learning."

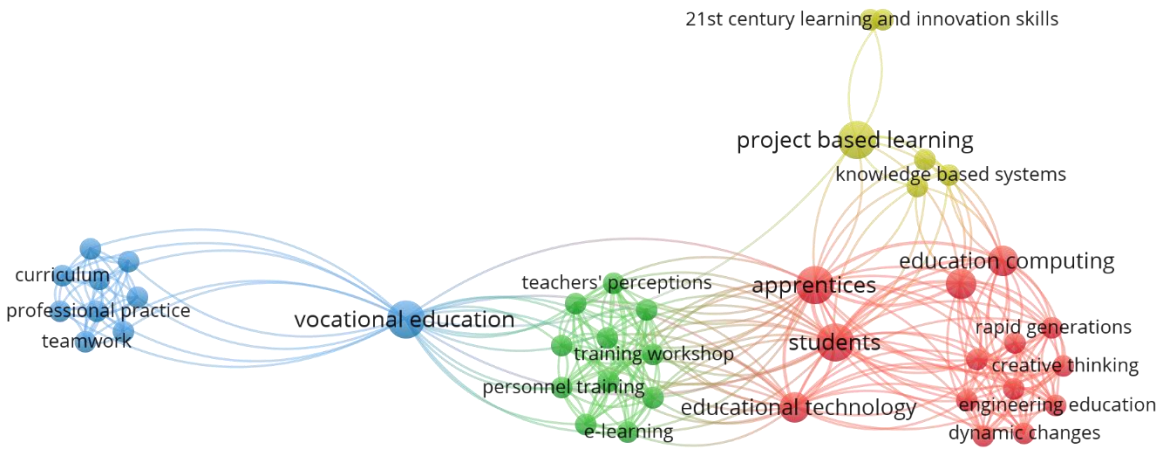

Figure 3. Keyword cluster analysis using VOSviewer

The connecting lines in the network denote relationships between keywords, with "vocational education" as a central link among various keywords, indicating its interdisciplinary relevance. The size of each node reflects the frequency or importance of the keyword; the more significant the node, the more frequently the keyword appears or the stronger its relevance. Overall, this network of keyword interactions facilitates the identification of conceptual links across research areas, enhancing the understanding of the evolving 21st-century skills within vocational education.

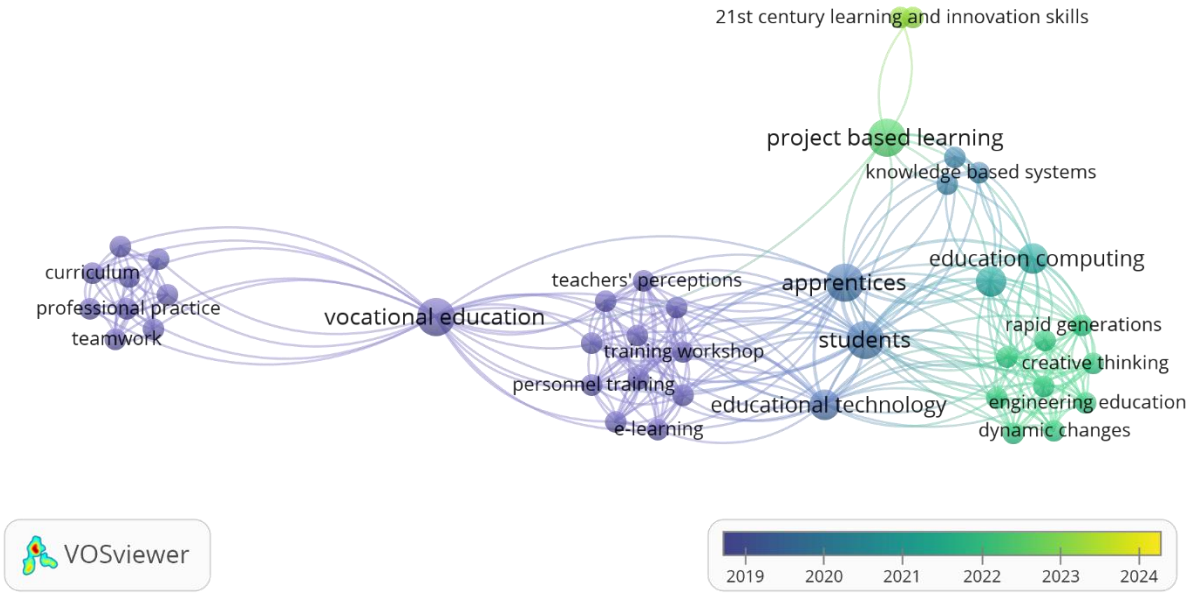

Figure 4. Keyword relationship network visualization from 2019-2024

Figure 4 presents a visualization of keyword networks by year, with a colour gradient ranging from dark blue (2019) to yellow (2024). Each colour group reflects the focus of research topics within specific periods. For instance, keywords emerging in the earlier years (2019–2021) are shown in blue and purple, whereas more recent topics from 2022 to 2024 are highlighted in green to yellow. This gradient illustrates the evolution of research focus, where themes related to "training" and "education" were more prominent at the beginning, while newer areas, such as "creativity" and "engineering," appear in green, indicating recent developments. The connecting network reveals relationships between topics, showing how research has progressed from one theme to another over time.

Following this analysis of research trends over the past five years, the review proceeds with a summary of studies on Project-Based Learning (PjBL) in vocational education, presented in Table 3. This table includes information on authors, study objectives, research limitations or gaps, and the applications or benefits of each prior study. Table 3 provides a comprehensive overview of the contributions and challenges associated with PjBL implementation, helping to identify areas where further research is needed to optimize PjBL methods in vocational education.

Table 3. Summary of studies on project-based learning in vocational education

No	Author	Aims	Gap/Limitation	Application/Benefit
1	(Rahim et al., 2024)	Assess the effectiveness of project-based learning using the STEAM framework to enhance affective, cognitive, and psychomotor	Although the number of vocational institutions in Indonesia is increasing, the quality of vocational graduates has yet to meet industry expectations.	Allows students to apply theoretical knowledge and skills to prepare them as competent graduates in SMAW metal welding.

No	Author	Aims	Gap/Limitation	Application/Benefit
		skills in metal welding.		
2	(Sari et al., 2024)	Create and evaluate a project-based learning module for electrical circuit courses.	Foreign-language materials reduce student interest and engagement; more accessible, practical materials like modules are needed.	Motivates students to solve problems in electrical circuit courses, fostering active and more profound learning than conventional methods.
3	(Hao et al., 2024)	Test the impact of project-based learning on critical thinking and creativity among business English learners in vocational college.	Existing studies on flipped PjBL classrooms emphasize motivation and academic achievement, with a limited focus on creativity and critical thinking.	PjBL is proven effective for enhancing student engagement, academic performance, communication, and other soft skills.
4	(Wanglang & Chatwattana, 2023)	Develop a project-based learning model incorporating gamification to enhance Thai students' 21st-century skills.	Limited participant numbers may affect generalizability, as the study lacks a representative sample of students or teachers using this model in the field.	Gamification activities should motivate and encourage learning, equipping students with creative thinking skills relevant to the modern era.
5	(Lesmana et al., 2023)	Project-based learning (PjBL) in vocational education aims to enhance students' creativity and critical thinking skills, with a strong focus on preparing them for the workforce.	A learning model is needed to increase students' creativity and interaction in the classroom.	It helps students develop skills such as creativity, entrepreneurship, teamwork, and presentation, essential for real-world success.
6	(Chistyakov et al., 2023)	Identify the characteristics, effectiveness, and elements of implementation of project-based learning (PjBL) in science and STEAM education.	Limited database collection	Enables students to apply the skills they learn in academic and future professional settings.
7	(Le et al., 2022)	Evaluate the skills required for success in the 21st century and the effectiveness of suitable learning methods for this era.	Current technical and vocational education curricula do not prepare students with the skills required in the 21st-century job market, including	Using project-based learning as a vocational and technical learning model) to instil the skills needed for the 21st-century workforce.

No	Author	Aims	Gap/Limitation	Application/Benefit
			learning, literacy, and life skills.	
8	(Syahril et al., 2022)	This study examines the effectiveness of project-based learning (PjBL), focusing on regional potential in improving 4C skills in vocational students in higher education.	This study is limited to developing the 4C skills, but future research could explore how this model impacts higher-order thinking skills (HOTS).	The PjBL model benefits vocational education by motivating students with relevant, practical projects that enhance their expertise and make learning more engaging and meaningful.
9	(Surti et al., 2022)	Assess the effectiveness of project-based learning with a STEM approach to enhance 21st-century skills like critical thinking, creativity, and digital literacy.	Vocational students, especially in automotive fields, lack modern problem-solving, communication, and collaboration skills.	A hands-on method for developing 21st-century skills in vocational students, especially those in automotive programs.
10	(Nilsook et al., 2021)	Determine the most suitable project-based learning management method for vocational and technical students in Thailand.	Improve vocational and technical education in Thailand to prepare students for Industry 4.0 and support economic growth.	Develops students' innovation, creativity, scientific thinking, and problem-solving skills, enabling technology use for collaboration and learning practical techniques.
11	(Haniah et al., 2021)	Examine how online project-based learning (PBL) can teach the 4C skills (creativity, critical thinking, communication, and collaboration) and explore students' perceptions of these skills.	While PBL is well-studied in offline or blended settings, little research exists on fully online PBL, especially regarding 21st-century skills like the 4Cs.	Supports students in developing 4C skills, solving real-world problems, making judgments, and linking new knowledge to prior learning.
12	(Rahmawati et al., 2021)	Determine how project-based learning impacts students' learning outcomes and creative thinking skills in the computer numerical control course.	The small sample size relies on self-reported learning outcomes and creative thinking, which can introduce bias.	It enables students to explore, evaluate, interpret, organize, and produce various learning outcomes.
13	(Agus Sudjima et al., 2021)	Assess the effectiveness of the WBL-SL model versus the PjBL	The WBL-SL model is rarely applied or studied in Indonesian vocational education,	Bridges the gap between school-based and work-based learning,

No	Author	Aims	Gap/Limitation	Application/Benefit
		model in enhancing technical skills and boosting student motivation.	with most prior studies comparing PjBL to traditional learning models.	enhancing students' learning motivation.
14	(Sudjimat et al., 2021)	This study explores how project-based learning (PjBL) models and the development of modern workforce character are connected.	The main limitation of this research is the difficulty in consistently tracking vocational learning processes, which can take up to six hours each day.	It enhances 21st-century skills such as collaboration, communication, critical thinking, technology proficiency, and project management.
15	(Hamdani & Suherman, 2021)	Develop a self-designed project-based learning model as an alternative to enhance vocational students' job skills to meet industry demands.	There is a mismatch between skills taught in vocational schools and those required by the industry.	Enhances industry-relevant skills by allowing students to learn product planning, manufacturing, and quality control skills.
16	(Sugiyanto et al., 2020)	Develop a model combining project-based and mobile learning to enhance vocational students' skills in computer assembly and basic networking.	Fundamental limitations include technical issues with software, extended learning time, and the need for better preparation.	Due to mobile app use, there are significant improvements in students' cognitive, psychomotor, and affective skills, with a strong boost in psychomotor skills.
17	(Dogara et al., 2020)	Develop a conceptual project-based learning framework to improve soft skill integration among engineering college students in Nigeria.	Technical colleges in Nigeria overly focus on technical knowledge rather than soft skills development.	PjBL can facilitate soft skill integration in technical colleges.
18	(Mitchell & Rogers, 2020)	Explore perceptions and experiences of new and experienced staff in implementing project-based learning (PjBL) in vocational education.	Limited understanding of how staff, especially new to PjBL, adapt and gradually develop facilitation skills.	Enables students to apply technical knowledge while developing professional skills and understanding the social context of engineering.
19	(Sarwandi et al., 2019)	Design and implement the development of mobile-based e-modules and assess learning outcomes.	The current project management modules are incomplete, unengaging, and lack clear instructions, explanations, and competency details,	Provide guidance and recommendations to policymakers, curriculum developers, and educators in technical and vocational education on the skills needed in

No	Author	Aims	Gap/Limitation	Application/Benefit
			making independent learning challenging for students.	the 21st-century workforce.
20	(Dogara et al., 2019)	Evaluate how project-based learning, or PjBL, impacts students' soft skills development in vocational institutions.	Most technical and vocational institutions focus only on technical skills without considering the soft skills required in the workplace.	May encourage curriculum revisions in technical schools to focus more on activity-based learning, such as PjBL.
21	(Samsudi et al., 2019)	Design a project-based learning model and assess its use in productive programs to develop 21st-century skills.	PjBL models are ineffective in developing all five essential 21st-century skills (multimedia communication, workplace flexibility, analytical thinking, problem-solving, and openness to new perspectives).	The main benefit is developing 21st-century skills in vocational students.

The findings presented in Table 3 demonstrate implementing various project-based learning (PjBL) models to enhance 21st-century skills among vocational students. Several studies show significant results; for instance, research by (Sarwandi et al., 2019) revealed that the combination of project-based learning and mobile learning substantially improved students' cognitive, psychomotor, and affective skills, with a notable impact on psychomotor skills. Similarly, (Surti et al., 2022) found that a STEM-based approach effectively enhanced critical thinking, creativity, and digital literacy skills among vocational students, particularly in automotive programs. Meanwhile, (Rahim et al., 2024) reported that applying PjBL within a STEAM framework for metal welding improved students' affective, cognitive, and psychomotor skills.

On the other hand, some studies highlighted limitations or less significant outcomes. For example, (Rahmawati et al., 2021) reported limitations due to a small sample size and reliance on self-reported student data, which could affect data objectivity. Similarly, the study by (Wanglang & Chatwattana, 2023) noted that a limited number of participants might have restricted the generalizability of the findings according to (Nilsook et al., 2021) also emphasized the need to strengthen vocational and technical education in Thailand to align better with the Industry 4.0 era, even though the benefits of fostering innovation and scientific thinking were evident. Thus, while applying PjBL in vocational education is crucial for developing 21st-century skills, further research is needed to address existing limitations and validate the effectiveness of this learning model on a broader scale.

The preliminary assessment in this study aims to review the extent to which articles address Project-Based Learning across three main skill categories: life and career skills, learning and innovation skills, and information, media, and technology skills. The systematic review findings are presented in Table 3 and further visualized in Figure 3,

offering additional insights into how PjBL supports the development of 21st-century skills.

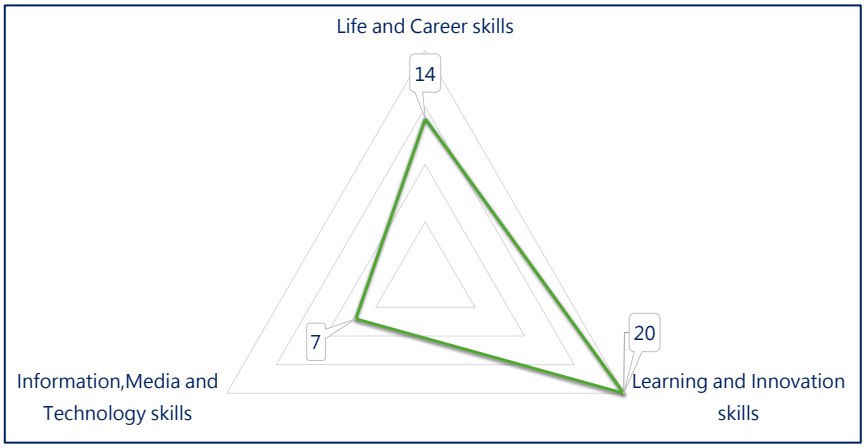

Figure 3. Distribution of 21st century skills in project-based learning in vocational education

Figure 3 illustrates the overall distribution of 21st-century skills in project-based learning, showing that 14 studies cover life and career skills, including subcategories such as flexibility and adaptability, initiative and self-direction, social and cultural skills, productivity, and leadership and responsibility. In the second category, 20 studies focus on learning and innovation skills, emphasizing creativity, innovation, critical thinking, communication, and collaboration. Meanwhile, seven articles in the third category specifically address information, media, and technology skills, encompassing information, media, and ICT literacy.

This study underscores the importance of structured learning, emphasizing life and career skills, learning and innovation skills, and information, media, and technology skills for developing 21st-century competencies. Students need skills such as technology literacy, creativity, initiative, collaboration, critical thinking, and adaptability to navigate the challenges of an evolving global workforce. The findings support that project-based learning can effectively drive the development of these skills in a way that is both relevant and engaging for students. If these skills are integrated into the curriculum, students will be better prepared for the workforce and possess the capabilities for lifelong learning and innovation. Based on these findings, future research should focus more on information, media, and technology skills, which are still underexplored. Future studies could delve deeper into how information literacy, media literacy, and technology skills can be developed through project-based learning. In today's digital era, critically understanding, managing, and utilizing information is increasingly essential.

RQ2. What types of skills are involved in 21st-century learning, and how is Project-Based Learning applied in vocational education?

3.1 Life and career skills

The first evaluation focuses on distributing articles addressing life and career skills, encompassing five main sub-skills: flexibility and adaptability, initiative and self-

management, social and cultural skills, productivity, and leadership and responsibility. This assessment provides insights into the extent to which life and career skills are integrated within Project-Based Learning (PBL) programs and the degree to which these topics are explored in a systematic literature review. A radar visualization detailing various life and career skills is presented in Figure 4.

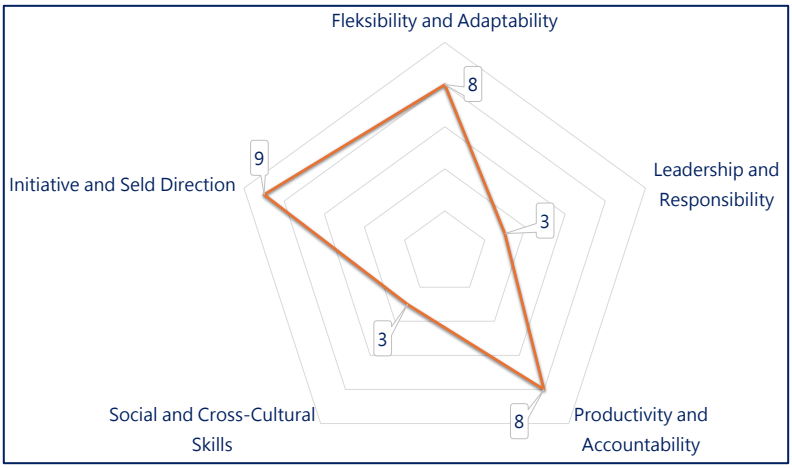

Figure 4. Frequency distribution of life and career skills

Figure 4 demonstrates a significant effort to integrate Life and Career Skills into PBL. The insights suggest that aspects like adaptability and initiative are frequently prioritized to prepare students for the dynamic challenges of the workforce. However, certain aspects, such as developing social and cultural skills, are less frequently discussed, which could further enrich cross-cultural understanding and teamwork. Furthermore, this evaluation highlights the extent to which these five sub-skills have been explored in the literature, thus allowing us to understand research trends, identify underexplored areas, and recognize existing knowledge gaps. Table 4 presents the distribution of articles covering life and career skills.

Table 4. Distribution of 21st century competencies in life and career skills

No	Author	FA	ISD	SC	P	LR
1	(Rahim et al., 2024)	√	√			
2	(Le et al., 2022)	√	√	√	√	√
3	(Syahril et al., 2022)	√	√		√	
4	(Rahmawati et al., 2021)	√	√		√	
5	(Sudjimat et al., 2021)	√			√	
6	(Sudjimat et al., 2021)		√		√	
7	(Hamdani & Suherman, 2021)				√	√
8	(Haniah et al., 2021)	√				
9	(Nilsook et al., 2021)	√				
10	(Dogara et al., 2020)		√	√		
11	(Mitchell & Rogers, 2020)		√		√	
12	(Samsudi et al., 2019)	√	√	√	√	√
13	(Sarwandi et al., 2019)		√			
	Total	**8**	**9**	**3**	**8**	**3**

FA = Flexibility and Adaptability; **ISD** = Initiative and Self-Direction; **SC** = Social and Cross-Cultural Skills; **P** = Productivity and Accountability; **LR** = Leadership and Responsibility

The study assessment in Table 4 shows variation in the number of articles highlighting each sub-skill. Flexibility and adaptability are discussed in eight articles, indicating a strong interest in understanding students' adaptability to diverse workplace scenarios and new situations. Additionally, nine articles address initiative and self-management, emphasizing the importance of developing students' abilities to manage their learning and take proactive measures independently.

On the other hand, social and cultural skills receive less attention, and these are discussed in only three articles, suggesting that this area might require further exploration. Conversely, productivity and accountability are highlighted in eight articles, underlining how PBL can enhance students' efficiency and performance. Leadership and responsibility appear in three articles, reflecting moderate interest in developing leadership roles within vocational education.

3.2 Learning and innovation skills

The second evaluation reveals the number of articles covering learning and innovation skills, which include creativity and innovation, critical thinking, and communication and collaboration. Emphasis on these skills is crucial to understanding how PBL supports students in thinking creatively, designing innovative solutions, and working effectively in teams. Figure 5 visualizes the frequency distribution of these skills.

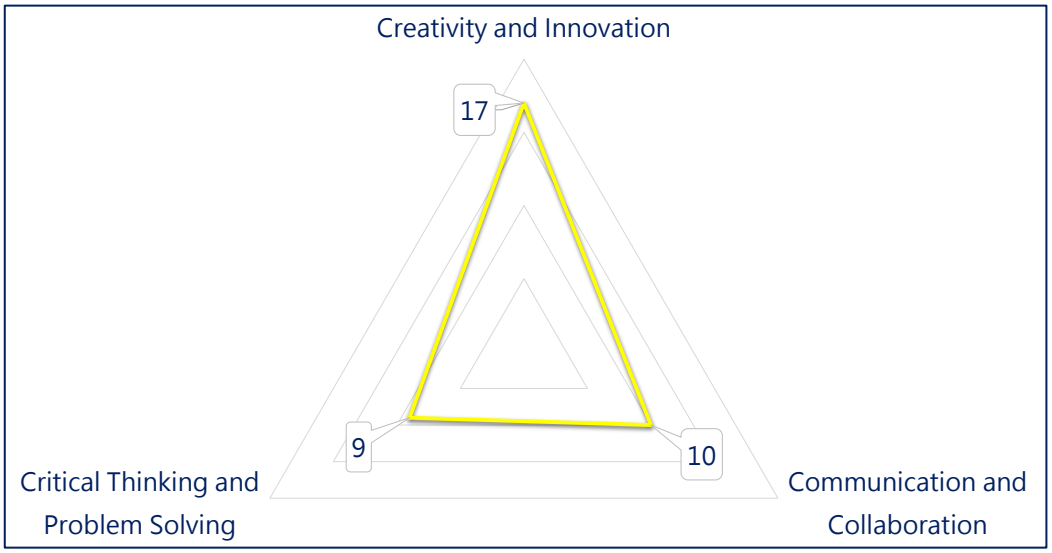

Figure 5. Frequency distribution of learning and innovation skills

The distribution in Figure 5 shows that most articles highlight the importance of creative and innovative thinking for tackling complex challenges and designing new solutions. Communication and collaboration are crucial elements that strengthen team dynamics and coordination and are essential for project-based work. These findings indicate that implementing PBL develops technical skills and enhances critical thinking and problem-solving abilities.

Additionally, this analysis underscores that students engaged in PBL are better prepared to face workplace demands that require adaptability and innovation. Project-centered learning allows them to apply theory to real-world situations, boosting their

confidence and readiness to work collaboratively and communicate effectively. Table 5 presents the distribution of studies addressing learning and innovation skills.

Table 5. Distribution of 21st century competencies in learning and innovation skills

No	Author	CI	CTPS	CC
1	(Rahim et al., 2024)	√	√	
2	(Sari et al., 2024)	√		
3	(Hao et al., 2024)	√	√	
4	(Chistyakov et al., 2023)		√	
5	(Lesmana et al., 2023)	√	√	
6	(Wanglang & Chatwattana, 2023)	√		√
7	(Le et al., 2022)	√	√	√
8	(Syahril et al., 2022)		√	√
9	(Surti et al., 2022)	√		
10	(Rahmawati et al., 2021)	√		√
11	(Sudjimat et al., 2021)	√		√
12	(Sudjimat et al., 2021)	√		
13	(Hamdani & Suherman, 2021)	√	√	
14	(Haniah et al., 2021)	√		
15	(Nilsook et al., 2021)	√		
16	(Dogara et al., 2020)	√		√
17	(Mitchell & Rogers, 2020)	√		√
18	(Sarwandi et al., 2019)	√		√
19	(Dogara et al., 2019)		√	√
20	(Samsudi et al., 2019)	√	√	√
	Total	**17**	**9**	**10**

CI = Creativity and Innovation; **CTPS** = Critical Thinking and Problem Solving; **CC** = Communication and Collaboration

The assessment of learning and innovation skills in Table 5 demonstrates a strong focus on creativity and innovation, with 17 studies covering this topic. This highlights creativity and innovation as core components in PBL for vocational education, encouraging students to develop new ideas and devise innovative solutions to real problems. In contrast, critical thinking appears in only nine studies, indicating that while it is essential, it may not receive equal emphasis as creativity. Communication and collaboration are discussed in 10 articles, signifying that interpersonal skill development through PBL remains an essential aspect of 21st-century learning.

3.3 Information, media and technology skills

In the third evaluation, this research assesses the distribution of articles discussing information, media, and technology skills, including information literacy, media literacy, and information and communication technology (ICT) literacy. This evaluation aims to understand the degree to which digital skills and technology utilization are integrated into PBL in vocational education. Figure 6 depicts the radar visualization covering various life and career skills.

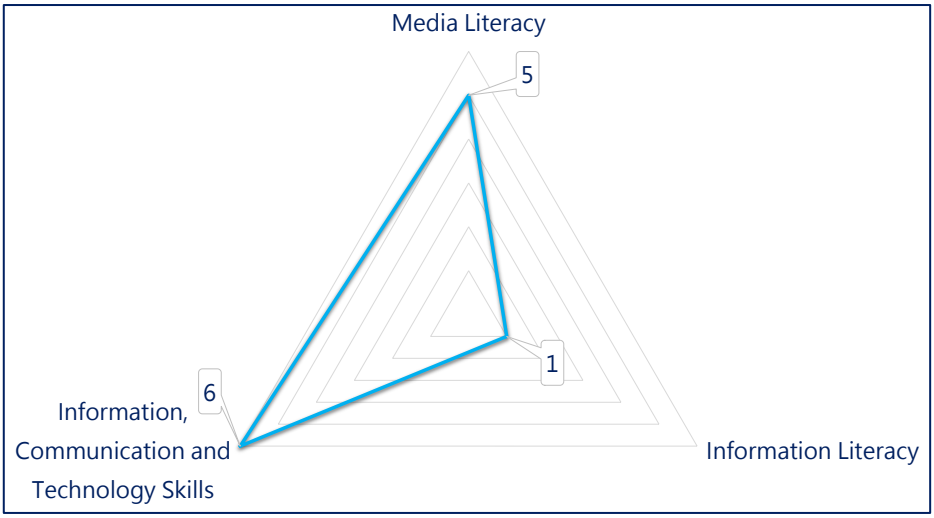

Figure 6. Frequency distribution of information, media and technology skills

Figure 6 shows that information, media, and technology skills receive substantial attention, with most articles emphasizing the importance of these skills to prepare students for an increasingly digital workforce. Although information literacy does not dominate discussions, it remains recognized as a crucial skill, enabling students to seek, evaluate, and apply information prudently within the vocational education context. Media literacy is also vital in equipping students to analyze, evaluate, and understand various media content. This skill helps them identify credible information and develop a critical understanding of media messages, a highly relevant ability in the digital age where information can rapidly spread and impact a broad audience.

Table 6. Distribution of 21st Century Competencies on Information, Media and Technology Skills

No	Author	ML	IL	ICT
1	(Le et al., 2022)			√
2	(Haniah et al., 2021)	√		
3	(Nilsook et al., 2021)	√		√
4	(Mitchell & Rogers, 2020)			√
5	(Sugiyanto et al., 2020)	√		√
6	(Sarwandi et al., 2019)	√		√
7	(Samsudi et al., 2019)	√	√	√
	Total	**5**	**1**	**6**

ML = Media Literacy; **IL** = Information Literacy; **ICT** = Information, Communication, and Technology Skills

Additionally, ICT literacy occupies a significant portion of the discussion, emphasizing the importance of mastering technology for students to manage digital tools and platforms required in the workplace. Therefore, integrating information, media, and technology skills through PBL is expected to enhance students' technical competencies and foster critical, adaptive, and responsible mindsets in utilizing technology across various work domains.

Table 6 of the information literacy evaluation shows that this topic receives less attention than the other categories. Media literacy is discussed in five studies, highlighting the importance of understanding and evaluating information from various media sources. Additionally, six studies discuss ICT skills, reflecting interest in enhancing students' ability to use technology effectively as a learning tool. Research on ICT highlights the importance of technological skills in supporting interactive and project-based learning, enabling students to access information flexibly and collaboratively.

Several studies in this category also explore the development of mobile-based e-modules and their implementation in learning (Sarwandi et al., 2019). This approach aims to facilitate material access and support students' independent learning flexibly and interactively, allowing for more effective evaluation and understanding of materials. Moreover, some studies discuss the integration of PBL and mobile learning as a strategy to enhance 21st-century skills (Haniah et al., 2021; Sugiyanto et al., 2020). This combined approach seeks to create a more dynamic learning environment, enabling students to learn contextually through real projects while using mobile technology to access information anytime, anywhere. Media literacy and information and communication technology (ICT) skills are central themes in the literature, highlighting that mobile technology and ICT have become significant concerns in vocational education development. This aligns with the demand for graduates who are technically proficient and adaptable to technological advancements in a dynamic work environment.

These studies emphasize the importance of equipping learners with digital skills that support lifelong learning. Through integrating mobile technology and Project-Based Learning (PjBL), learners can practice critical thinking, foster creativity, and develop collaborative skills in real-world projects, better preparing them to face challenges in the digital era. This approach also reinforces the role of technology in supporting learning beyond the classroom, enabling students to access and apply knowledge anytime and anywhere.

RQ3. What are the challenges and opportunities of project-based learning in vocational education, especially regarding 21st-century skills?

Project-based learning (PjBL) in vocational education offers an approach highly relevant to 21st-century skills, such as problem-solving, collaboration, creativity, and critical thinking. Amid rapid advancements in technology and globalization, these skills are increasingly essential in the workforce. Implementing PjBL in vocational education encounters various challenges and opportunities, as noted by several researchers and outlined in Table 7.

Table 7. Challenges and opportunities in vocational education

No	Author	Challenge	Opportunity
1	(Sari et al., 2024)	A significant issue in the electrical circuits course is that students do not achieve optimal learning outcomes.	It is developing a project-based learning module for the electrical circuits course.

No	Author	Challenge	Opportunity
2	(Rahim et al., 2024)	The low quality of vocational education graduates in Indonesia is due to misaligned curricula, inadequate facilities, and lack of collaboration with industry.	It is developing more efficient pedagogical approaches for metal welding technology courses.
3	(Hao et al., 2024)	Current education methods do not meet the essential demand for fostering students' critical and creative thinking skills.	It is improving English business education in vocational colleges in China to promote critical thinking and creativity.
4	(Chistyakov et al., 2023)	Identify the characteristics, effectiveness, and elements of implementation of project-based learning (PjBL) in science and STEAM education.	It is developing new methods for data collection and content analysis that educators can use.
5	(Lesmana et al., 2023)	Some students may be reluctant to collaborate with peers during project-based learning activities.	Enhancing creativity and critical thinking skills in vocational students' creative products.
6	(Wanglang & Chatwattana, 2023)	Through project-based learning and gamification, it is developing 21st-century learning skills in students, such as critical thinking, problem-solving, creativity, communication, and collaboration.	It enhances 21st-century learning skills among students, such as critical thinking, problem-solving, creativity, communication, and collaboration.
7	(Le et al., 2022)	Preparing students with the skills needed for the 21st-century workforce requires curricula and learning methods to be aligned with technological advancements across economic, social, cultural, and educational fields.	Opportunities for technical and vocational education include the demand for skills needed by the 21st-century workforce, such as learning, literacy, and life skills.
8	(Syahril et al., 2022)	Research is limited to developing 4C skills, with suggestions for further studies to explore higher-order thinking Skills (HOTS).	Implementing this model can enhance student engagement, positively influence their perceptions of learning, and develop soft skills through potential regional projects, which can become viable businesses after graduation.
9	(Surti et al., 2022)	Lack of 21st-century skills in vocational education students.	It is developing 21st-century skills such as problem-solving, critical thinking, creativity, communication, collaboration, and digital literacy.
10	(Rahmawati et al., 2021)	Creating competitive, high-quality human resources by enhancing students' learning skills, innovation, and creative thinking.	Project-based learning models can improve students' learning outcomes and creative thinking skills in computer numerical control courses.
11	(Sudjimat et al., 2021)	Development of modern workforce character.	Testing the effectiveness of a work-based learning (WBL-SL) model to improve engineering learning outcomes.

No	Author	Challenge	Opportunity
12	(Hamdani & Suherman, 2021)	Preparing students with the knowledge, skills, and attitudes needed by industry and designing education programs aligned with real-world job requirements to ensure the relevance of students' skills.	Developing a vocational education model better prepares students for industry needs and the workforce.
13	(Haniah et al., 2021)	Technical issues such as poor internet connections may cause students to be disconnected from video conferences and miss sessions. Low technology levels may limit teachers' ability to track students' progress.	Implementing online project-based learning (PBL) to teach 4C skills to students during the COVID-19 pandemic: creativity, critical thinking, communication, and collaboration.
14	(Nilsook et al., 2021)	Innovation and learning skills have not developed, making it challenging to keep up with changes in the Industry 4.0 era.	Project-based learning can help students enhance the skills needed by the 21st-century workforce, such as creativity, critical thinking, teamwork, and communication.
15	(Sudjimat et al., 2021)	Lack of motivation and problem-solving skills contribute to high unemployment among vocational school graduates.	Improving learning outcomes and motivation in vocational high school students.
16	(Sugiyanto et al., 2020)	Learning media and facilities must be better prepared to avoid disruptions in the learning process.	Using digital tools and mobile learning can make learning more flexible, collaborative, and productive.
17	(Dogara et al., 2020)	A key issue identified in this paper is the lack of soft skills among engineering students in Nigeria.	Developing a conceptual framework for project-based learning (PjBL) to integrate soft skills among engineering college students.
18	(Mitchell & Rogers, 2020)	During the first two years, they are introducing project-based learning (PjBL) activities in several engineering degree programs.	Project-based learning (PjBL) can help engineering students acquire broader skills beyond technical knowledge, such as social context understanding, teamwork, creativity, problem-solving, and better communication.
19	(Samsudi et al., 2019)	There is a need to develop five specific indicators of 21st-century skills further.	It is refining the project-based learning model to address the five 21st-century skill indicators that are still lacking.
20	(Dogara et al., 2019)	Shortage of resources, lack of teacher training to support soft skills development in project design, and curricula focused too heavily on technical skills.	Project-based learning (PjBL) can create real-world learning environments where students develop communication, problem-solving, and teamwork skills.
21	(Sarwandi et al., 2019)	Lack of soft skills and specialized skills among vocational education graduates.	Industry 4.0 opportunities in Indonesia include setting success benchmarks beyond school, addressing workforce needs, and providing adequate facilities.

Based on Table 7, the assessment findings highlight several challenges encountered in implementing Project-Based Learning (PjBL) within vocational education, particularly concerning developing 21st-century skills. These challenges, identified by multiple researchers, include a notable deficiency in 21st-century skills among vocational students (Surti et al., 2022), limitations in innovative and learning skills, which hinder students' adaptability to changes within the Industry 4.0 era (Wanglang & Chatwattana, 2023), as well as technical constraints such as poor internet connectivity (Haniah et al., 2021). Moreover, current instructional methods are perceived as insufficiently effective in meeting the need to foster students' skills holistically (Hao et al., 2024). These challenges underscore the imperative to enhance vocational education quality, enabling students to cultivate essential skills and graduate as competent professionals.

Conversely, adopting PjBL also presents significant opportunities for students to advance essential 21st-century workforce skills, such as creativity, critical thinking, teamwork, and communication (Syahril et al., 2022). These capabilities are crucial for navigating an ever-evolving professional landscape. By integrating PjBL, vocational education can deliver more relevant and contextualized learning experiences, allowing students to directly apply their knowledge in real-world projects, refining practical skills while nurturing the professional attributes essential for the workplace.

Overall, the successful implementation of PjBL in vocational education necessitates close collaboration among educators, policymakers, and industry stakeholders to address existing challenges and maximize potential benefits. Efforts such as improved technology access, skill-oriented curriculum development, and educator training in PjBL methodologies could be vital to advancing vocational education. Consequently, vocational graduates would acquire technical competence, interpersonal skills, and adaptability, equipping them to excel within the dynamic demands of modern industry.

4. Conclusion and future work

This study conducted a systematic literature review on the effectiveness of Project-Based Learning (PjBL) in vocational education and its impact on developing 21st-century skills. Employing a Systematic Literature Review approach and the PRISMA protocol, an initial pool of 1,036 studies was reviewed, ultimately narrowing down to 21 articles relevant to the research objectives within the 2019–2024 timeframe after stringent selection criteria ensured the quality of evaluated research. Findings indicate that PjBL is instrumental in preparing students for a dynamic and technology-driven workforce by enhancing creativity, innovation, critical thinking, and collaboration skills. Despite challenges in PjBL implementation, such as insufficient technological proficiency and a misaligned curriculum, PjBL in vocational education offers opportunities to advance pedagogical approaches better aligned with industry needs. Thus, collaboration among educators, policymakers, and industry stakeholders is essential to overcome these challenges and improve vocational education quality.

Future research should focus on developing information, media, and technology skills, which remain underrepresented in the current literature. Further studies are needed to explore optimal strategies for integrating PjBL with existing curricula to ensure this approach is widely and effectively applied across diverse vocational education contexts. Future investigations could also explore utilizing emerging technologies and

digital tools to support PjBL implementation and comprehensively assess its impact on student learning outcomes.

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Declarations

Author contribution

Alief Depa Rozan: Conceptualization, formal analysis, funding acquisition, research, validation, visualization, project management, resources, supervision, writing - original draft, writing - review & editing. Budi Syahri and Febri Prasetya: Conceptualization, data curation, formal analysis, investigation, methodology, writing - review & editing. Aprila Fortuna, Agariadne Dwinggo Samala and Soha Rawas: Investigation, validation, visualization.

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Competing interest

There are no conflicts of interest in this research.

Ethical Clearance

This study only reviewed published articles, there were no human or animal subjects in this study.

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