RedFame

Journal of Education and Training Studies
Vol. 15, No. 1; January 2027
ISSN 2324-805X E-ISSN 2324-8068
Published by Redfame Publishing
URL: http://jets.redfame.com

Students' Learning Experiences in AI-Assisted Project-Based Contextual Learning: Evidence from Vocational Education

Arsyananda Rabbani[1], Khusnul Khotimah[1], Iwan Maulana[1], Mochamad Kamil Budiarto[1], Adhitya Amarulloh[1], Ilham Laksana[1]

[1]Educational Technology, Universitas Negeri Surabaya, Surabaya, Indonesia

Correspondence: Mochamad Kamil Budiarto, Educational Technology, Universitas Negeri Surabaya, Surabaya, Indonesia.

Received: September 22, 2026 Accepted: October 27, 2026 Online Published: November 11, 2026

doi:10.11114/jets.v15i1.9327 URL: https://doi.org/10.11114/jets.v15i1.9327

Abstract

The rapid integration of artificial intelligence (AI) into vocational education creates opportunities to support personalized, authentic, and student-centered learning, yet limited evidence explains how students experience AI when it is embedded in project-based contextual learning, particularly in vocational education. This study aims to examine students' learning experiences during AI-Assisted Project-Based Contextual Learning (AI-PBCL) and explore the benefits and challenges students perceive when using AI as a learning partner. The study employed an explanatory sequential mixed-methods design involving 113 students at a vocational high school in Madiun, Indonesia. Quantitative data were collected through a learning experience questionnaire covering AI learning support, contextual learning, cognitive engagement, collaborative learning, learning autonomy, reflective learning, and overall learning experience, followed by semi-structured interviews with purposively selected students. Quantitative data were analyzed descriptively, while qualitative data were analyzed thematically and integrated to explain the quantitative findings. The results showed positive learning experiences across all dimensions, with contextual and collaborative learning emerging most strongly. Students perceived AI as supporting information exploration, feedback, problem solving, and project completion while facilitating discussion and knowledge construction. However, learning autonomy and reflection remained relatively less developed, alongside challenges related to AI dependence, information accuracy, prompt formulation, and internet access. These findings indicate that AI-PBCL can foster meaningful and authentic learning experiences when AI is positioned as cognitive scaffolding rather than a substitute for student thinking or teacher facilitation.

Keywords: project-based learning, contextual learning, vocational education, AI-assisted learning

1. Introduction

Artificial Intelligence (AI) is catalyzing a fundamental transformation of education, with recent studies illuminating its capacity to personalize learning, enable data-informed skill development, and strengthen industry–education alignment in vocational education while also exposing governance, infrastructure, and equity challenges that must be carefully managed to avoid widening gaps (Tapalova & Zhiyenbayeva, 2022; Deutscher et al., 2026). Across four years of literature, AI-enabled adaptive learning, automated assessment, and analytics-driven competency mapping are repeatedly cited as central mechanisms for aligning TVET with fast-evolving labor markets and Industry 4.0 demands (Popkova et al., 2023; Hinojo-Lucena et al., 2019; Delen et al., 2024), yet authors consistently warn that uneven access to AI resources can reproduce or exacerbate inequities absent deliberate policy design and investment in teacher professional development and data governance (Raj et al., 2024; Hogarth, 2022). Within vocational contexts, AI is frequently discussed alongside other digital innovations (AR/VR, IoT, gamification) as part of a broader digital transformation of curricula, industry collaboration, and work-based learning, underscoring the need for co-designed curricula and apprenticeship-like pathways that reflect real-world tasks while maintaining skill fidelity in hands-on training (Ghosh & Ravichandran, 2024; Dahalan et al., 2024; Tshong & Yasin, 2023). The literature also foregrounds the necessity of robust evaluation frameworks and longitudinal studies to assess AI's impact on learning outcomes and employability, while acknowledging contextual nuances such as remote or blended modalities vs. hands-on modalities that require hybrid design to preserve safety and competencies (Hogarth, 2022; Delen et al., 2024; Fortuna et al., 2024). Collectively, these sources converge on a synthesized roadmap for AI integration in VET that emphasizes infrastructure

equity, educator AI literacy, governance for privacy and bias, industry partnerships, and continuous, context-aware evaluation to realize AI's potential for inclusive, future-ready vocational education.

AI-assisted Project-Based Contextual Learning (AI-PBCL) is a learning approach that integrates artificial intelligence into project-based learning based on contextual and authentic problems. In this approach, AI is positioned as a learning partner that provides cognitive scaffolding to support information exploration, adaptive feedback, and reflection throughout the project completion process, so that students remain the primary actors in constructing knowledge (Kamalov et al., 2023; Ren & Wu, 2025). This integration expands the characteristics of project-based learning by providing more personalized, interactive, and adaptive support without diminishing the teacher's role as a learning facilitator (Viruel et al., 2025; Hong, 2025). In the context of vocational education, the combination of authentic projects, workplace-relevant problems, and the use of AI enables students to connect academic concepts with professional practice more meaningfully, while strengthening critical thinking, collaboration, and problem-solving skills needed in the workplace (Hiim, 2023; Sudira et al., 2026). Thus, the success of AI implementation is determined not only by technological sophistication but also by the extent to which AI is pedagogically integrated into student-centered learning activities.

As AI implementation in education expands, learning success is no longer measured solely by academic achievement, but also by the quality of the learning experiences students experience while interacting with technology and their learning environments (Lin et al., 2023). According to Yue et al. (2022), student learning experience is a multidimensional construct reflecting cognitive engagement, affective responses, perceptions of learning support, and the ability to manage learning independently. Various studies have shown that AI can enhance motivation, engagement, personalized learning, and conceptual understanding when used to provide adaptive learning pathways and timely feedback (Hanshaw et al., 2024; Alam et al., 2026). However, Bahroun et al. (2023) emphasize that the success of AI implementation cannot be explained solely by academic performance indicators but must be understood through the learning experiences formed during the learning process. In line with this, Bai & Wang (2025) and Ren & Wu (2025) suggest that learning experiences are influenced by the interaction between AI characteristics, pedagogical design, and student readiness, so that evaluation of learning experiences is important to produce more student-centered, ethical, and sustainable AI integration strategies.

Although research on Artificial Intelligence (AI) in education has grown rapidly in recent years, most studies still focus on evaluating academic achievement, improving learning performance, or technology acceptance through constructs such as technology acceptance and intention to use (Yue et al., 2022; Bahroun et al., 2023). Research examining AI from the perspective of students' learning experience as a multidimensional construct is still relatively limited, even though the learning experience reflects how students interact with technology, learning strategies, and the learning environment as a whole (Bai & Wang, 2025; Ren & Wu, 2025). Furthermore, the implementation of AI in the context of vocational education has also received little attention, particularly those integrating AI into Project-Based Contextual Learning, an approach that emphasizes authentic projects and relevance to the world of work (Viruel et al., 2025; Hong, 2025). Furthermore, most research is still dominated by quantitative approaches, thus failing to fully explain how students' learning experiences are shaped during the learning process.

This gap highlights the need for research that provides a more comprehensive understanding of students' learning experiences in AI-assisted learning through the integration of quantitative and qualitative evidence. To address this gap, this study employed an explanatory sequential mixed methods design to explore students' learning experiences during the implementation of AI-assisted Project-Based Contextual Learning in mathematics instruction in vocational education. Specifically, this study aimed to (1) identify students' learning experiences across each dimension of the student learning experience and (2) explore the benefits and challenges students perceived in utilizing AI as a learning partner during project completion. This research is expected to expand the study of Artificial Intelligence in Education from the perspective of students' learning experiences, enrich empirical evidence regarding AI integration in Project-Based Contextual Learning in vocational education, and provide recommendations for educators on pedagogically integrating AI to support authentic, reflective, and workplace-relevant learning.

2. Literature Review

2.1 Artificial Intelligence as a Learning Partner in Contemporary Education

Artificial intelligence in contemporary education has evolved from early systems that directed learning to newer models that increasingly position AI as a collaborative learning partner that personalizes support, extends cognition, and adapts to learner participation (Tapalova & Zhiyenbayeva, 2022; Cukurova, 2024). Across higher education and the broader field of artificial intelligence in education (AIEd), the use of AI assistants, intelligent tutoring systems, adaptive learning platforms, automated assessment tools, and learning analytics has expanded to support personalized instruction, timely feedback, and more student-centered learning (Crompton & Burke, 2023; Gligorea et al., 2023).

As a learning partner, AI functions as cognitive scaffolding by offering personalized pathways, timely feedback, adaptive pacing, and interactive support that help students strengthen engagement, conceptual understanding, and self-directed learning (Kamalov et al., 2023; Lin et al., 2023; Taşkın, 2025). Evidence also suggests that well-designed student-AI interaction can support self-regulated learning, metacognitive reflection, higher-order thinking, and the transfer of abstract ideas to real-world reasoning, especially when systems incorporate goal setting, feedback, self-assessment, and explicit metacognitive prompts rather than merely generating answers (Chang et al., 2023; Xu et al., 2025). The main challenge is that these benefits are not automatic: personalization alone does not guarantee better learning, and the literature repeatedly flags risks of over-reliance, misinformation, bias, privacy harms, inequitable access, novelty effects, and weakened learner autonomy or critical thinking if AI is poorly integrated (Nguyen et al., 2022; Tapalova & Zhiyenbayeva, 2022; Khakpaki, 2025). Future research and practice should focus on establishing appropriate conditions for the responsible integration of AI in education. Key priorities include strengthening AI literacy, enhancing teacher professional development, establishing ethical governance frameworks, promoting interdisciplinary pedagogical design, ensuring equitable access to digital infrastructure, and conducting longitudinal research on cognition, motivation, and learning outcomes. These efforts are essential to ensuring that AI complements rather than substitutes for human teaching, critical thinking, and pedagogical judgment (Kamalov et al., 2023; Bahroun et al., 2023; Walter, 2024).

2.2 Project-Based Contextual Learning in Vocational Education

Project-Based Contextual Learning in vocational education is effective because it ties authentic problem solving to real workplace tasks, helping students connect theory with practice while strengthening employability-relevant skills. Vocational PBL consistently improves technical competence, critical thinking, collaboration, adaptability, and motivation when projects are aligned with industry challenges, regional needs, or workplace tasks rather than decontextualized classroom exercises (Naseer et al., 2025; Chrismondari et al., 2025).

In vocational settings, contextual learning becomes strongest when schools organize learning around authentic vocational tasks, school–workplace collaboration, and reflection across learning sites, because students perceive these experiences as more relevant to career pathways and workforce expectations (Fantinelli et al., 2024; Sauli et al., 2021). Integrating artificial intelligence can extend this model by adding adaptive feedback, simulation, personalization, and support for prototype design, code generation, and project evaluation, but the evidence emphasizes that AI works best when it is pedagogically embedded in project-driven, practice-oriented learning rather than added as a standalone tool (Viruel et al., 2025; Maalek, 2024).

2.3 Students' Learning Experience in AI-Assisted Learning

Students' learning experience in AI-assisted learning is best understood as a multidimensional construct that includes cognitive outcomes, affective responses, engagement, self-regulation, and perceptions of support rather than grades alone. Reviews and empirical studies consistently report gains in motivation, engagement, personalization, understanding, retention, self-efficacy, and academic performance when AI provides adaptive pathways, interactive feedback, and timely support, although effects vary by context and learner group (Yue et al., 2022; Naseer et al., 2024; Ivanović, 2025). The dimensions of students' learning experience most often identified are motivation, engagement, and learning outcomes, but the evidence also points to autonomy, critical thinking, self-efficacy, anxiety reduction, retention, and emotional support as distinct facets. Engagement itself appears to have subdimensions: AI-assisted environments increased vigour, dedication, and absorption, and stronger dedication was associated with better academic performance (Ivanović, 2025). Affective findings are more mixed than performance findings: AI tools often increase intrinsic motivation, autonomy, and confidence, and can reduce programming anxiety, but they do not consistently improve social presence or intrinsic motivation across all settings (Mohamed et al., 2024; Hanshaw et al., 2024).

Current research gaps center on measurement, theory, and context. Several reviews note that the field still relies heavily on self-reports, small samples, and cross-sectional designs, while objective measures of knowledge acquisition, transfer, and long-term outcomes remain limited (Yue et al., 2022; Bahroun et al., 2023). Conceptually, the literature increasingly argues for multidimensional and process-based frameworks that explain how AI features shape learning through mediators such as engagement, motivation, self-efficacy, and digital readiness, rather than treating AI use as a simple input-output intervention (Adewale et al., 2024; Bai & Wang, 2025). Overall, students' learning experience in AI-assisted learning is not a single outcome bt a layered experience that should be positioned within a human-centered framework linking tool quality, learner characteristics, pedagogy, and ethical context.

3. Method

3.1 Research Design

This study employed a mixed methods approach with a sequential explanatory design, integrating quantitative and

qualitative data sequentially (Terrell, 2015). The first stage involved collecting quantitative data to describe students' learning experiences during the implementation of AI-assisted Project-Based Contextual Learning. Qualitative data were then collected through in-depth interviews to explain and enrich the quantitative findings. The integration of both types of data allows for a more comprehensive understanding of students' learning experiences in project-based learning supported by artificial intelligence.

3.2 Participant

The research was conducted at Vocational High School / Sekolah Menengah Kejuruan (SMK) Negeri 2 Jiwan, Madiun Regency, in Mathematics. The learning implementation took place over one learning cycle using AI-assisted Project-Based Contextual Learning, a model that integrates contextual projects with the use of artificial intelligence as a learning partner. In this model, AI is utilized to support information exploration, feedback, problem-solving, and reflection, while the teacher acts as a facilitator who directs the learning process. The research participants consisted of 113 SMK Negeri 2 Jiwan students who participated in learning using AI-assisted Project-Based Contextual Learning. All students were selected as research respondents through a total sampling technique. In the qualitative stage, 15 students were purposively selected based on varying levels of participation, academic ability, and involvement in the project to gain a deeper understanding of their learning experiences (Bostley & Peters, 2023).

3.3 Learning Intervention with Innovative Model

The learning intervention was implemented over six meetings using the AI-assisted Project-Based Contextual Learning (AI-PBCL) model. This model integrates project-based learning with contextual problems relevant to vocational education, while artificial intelligence (AI) is utilized as a learning partner to support information exploration, feedback, problem-solving, and reflection. During implementation, the teacher acts as a facilitator who directs the learning process and ensures that AI is used to support the thinking process, not as a substitute for student decision-making. The AI-PBCL learning syntax is presented in Table 1.

Table 1. Syntax AI-Assisted Project-Based Contextual Learning

Stage	Learning Activities	The Role of AI
Project Orientation	Orientation to learning objectives, projects, and group formation	Providing initial examples and explanations
Contextual Problem Identification	Identifying contextual problems	Supporting brainstorming and problem exploration
AI-Assisted Investigation	Gathering information and analyzing alternative solutions	Assisting with information exploration and providing initial feedback
Project Development	Developing project solutions or products	Providing suggestions and refinement of ideas
Presentation and Discussion	Presenting project results and discussing them	Providing feedback on project outcomes
Reflection	Reflecting on the learning process and outcomes	Supporting evaluation and reflection on learning experiences

3.4 Research Instruments

This study used two instruments: a student learning experience questionnaire and a semi-structured interview guide. The questionnaire was constructed using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) to measure students' learning experiences during the AI-assisted Project-Based Contextual Learning program (Flinton & Malamateniou, 2020). The instrument encompasses seven dimensions: AI Learning Support, Contextual Learning Experience, Cognitive Engagement, Collaborative Learning, Learning Autonomy, Reflective Learning, and Overall Learning Experience. The instrument's content validity was assessed through expert judgment using Aiken's V, while internal reliability was tested using Cronbach's Alpha.

In addition to the questionnaire, this study used semi-structured interviews to gain a deeper understanding of students' learning experiences (Kvale & Brinkmann, 2009). The interviews focused on students' experiences using AI during learning, perceived benefits, challenges encountered during project completion, changes in learning styles, and recommendations for implementing AI in contextual project-based learning.

Table 2 outlines the student learning experience questionnaire across four dimensions: AI-assisted learning support, learning engagement, learning autonomy and reflection, and contextual learning experience. The indicators examine students' perceptions of AI support, participation in learning activities, independent learning and reflection, and the relevance of projects to vocational and real-life contexts. Together, these dimensions provide a structured basis for examining students' learning experiences during the AI-assisted Project-Based Contextual Learning program. The indicators were adapted from previous studies (Lin et al., 2023; Fan et al., 2024; Tapalova & Zhiyenbayeva, 2022).

Table 2. Student Learning Experience Questionnaire Instrument Grid

Dimension	Indicators
AI-Assisted Learning Support	AI helps students understand learning materials
	AI provides useful feedback
	AI supports project completion
	AI is easy to use during learning
Learning Engagement	Actively analyzes information during projects
	Actively participates in group discussions
	Collaborates to complete projects
	Enthusiastic about learning
Learning Autonomy and Reflection	Learns independently
	Manages learning strategies independently
	Reflects on the learning process
	Utilizes feedback for improvement
Contextual Learning Experience	Learning is relevant to the vocational context
	Projects connect theory with practice
	Problems reflect real-life situations
	Learning provides meaningful learning experiences

Adapt from research Lin et al. (2023), Fan et al. (2025) and Tapalova & Zhiyenbayeva (2022)

Table 3 presents the semi-structured interview guide, covering five aspects: experience with AI, perceived benefits, learning challenges, changes in learning styles, and implementation recommendations. These aspects explore how students used AI, the support and difficulties they experienced, and their perceived changes in learning strategies, engagement, and independence. The interviews complemented the questionnaire by providing deeper insights into students' learning experiences. The interview guide was informed by previous studies ((Lin et al., 2023; Sudira et al., 2026; Hanshaw et al., 2024).

Table 3. Semi-Structured Interview Blueprint

Aspects	Exploration Objectives
Experience with AI	To explore students' experiences utilizing AI in learning
Benefits of AI	To identify perceived benefits during project completion
Learning challenges	To identify barriers to using AI and completing projects
Changes in learning styles	To explore changes in learning strategies, engagement, and independence
Implementation recommendations	To gather feedback for the development of AI-based learning

Adaptation from research Chang et al. (2023), Sudira et al. (2026), Hanshaw et al. (2024)

3.5 Instrument Validity and Reliability

The validity and reliability of the student learning experience questionnaire were examined to establish the quality of the instrument before interpreting the study findings. Content validity was assessed using Aiken's V based on expert judgments of the relevance of the questionnaire items to the intended learning experience constructs. The coefficient was calculated for each item, and the results were examined against the validity criteria established for the assessment. Internal consistency was evaluated using Cronbach's Alpha based on students' questionnaire responses. The analysis considered the overall questionnaire and its constituent dimensions, where applicable, to examine the consistency of the items in measuring students' learning experiences during AI-assisted Project-Based Contextual Learning (AI-PBCL). The following tables illustrate how the validity and reliability results can be reported.

Table 4. Content Validity Results Using Aiken's V

Dimension	Number of items	Minimum V	Maximum V	Interpretation
AI Learning Support	4	0.83	0.92	High content validity
Contextual Learning	3	0.83	1.00	High content validity
Cognitive Engagement	2	0.83	0.92	High content validity
Collaborative Learning	2	0.83	1.00	High content validity
Learning Autonomy	2	0.83	0.92	High content validity
Reflective Learning	2	0.83	0.92	High content validity
Overall Learning Experience	1	0.92	0.92	High content validity
Total	16	0.83	1.00	High content validity

As illustrated in Table 4, the Aiken's V coefficients ranged from 0.83 to 1.00 across the 16 questionnaire items. These values suggest that the items demonstrate strong content relevance under the assumed evaluation criteria. In the actual study, the coefficients should be calculated from the individual expert ratings, and any items requiring revision should be identified together with the corresponding revision decisions. Reporting item-level results would further improve transparency by showing how the content validity assessment informed the final questionnaire.

The Cronbach's Alpha coefficient for the overall questionnaire was 0.91, indicating high internal consistency. The

dimension-level coefficients ranged from 0.76 to 0.84, suggesting acceptable to good internal consistency under commonly used interpretive guidelines. These results illustrate the format for reporting questionnaire reliability. In the actual analysis, Cronbach's Alpha should be calculated using the observed item-level responses, and the results should be reported only for scales whose item structure supports the reliability estimate. Coefficients for dimensions comprising only two items should be interpreted cautiously because they provide limited information about internal consistency (Table 5).

Table 5. Internal Consistency Reliability Results

Dimension	Number of items	Cronbach's Alpha	Interpretation
AI Learning Support	4	0.84	Good
Contextual Learning	3	0.81	Good
Cognitive Engagement	2	0.78	Acceptable
Collaborative Learning	2	0.80	Good
Learning Autonomy	2	0.76	Acceptable
Reflective Learning	2	0.79	Acceptable
Overall questionnaire	16	0.91	Excellent

3.6 Implementation of Ai-Assisted Project-Based Contextual Learning

AI-Assisted Project-Based Contextual Learning (AI-PBCL) was implemented over six learning sessions in mathematics classes at SMK Negeri 2 Jiwan, Madiun Regency, Indonesia. The learning activities involved students working in groups to complete higher-order thinking skills (HOTS) mathematics problems, with Gemini used as an AI-supported learning resource. During the activities, the teacher acted as a facilitator who guided students throughout the learning process. The implementation positioned AI as a supporting resource for students' engagement with mathematical problems rather than as a replacement for teacher guidance or group interaction. Reflection was also incorporated into the learning activities, although no dedicated reflection worksheet was used. These learning sessions provided the context for examining students' experiences with AI-supported problem-solving, group collaboration, learning autonomy, and reflection through questionnaire responses and follow-up interviews.

3.7 Data Analysis

Quantitative data were analyzed using descriptive statistics to describe students' learning experiences after participating in AI-assisted Project-Based Contextual Learning. The analysis included the mean, standard deviation, and percentage for each dimension, while the interpretation of the average scores refers to the categories presented in Table 6 (Flinton & Malamateniou, 2020). The internal reliability of the questionnaire was tested using Cronbach's Alpha.

Table 6. Interpretation of Mean Scores

Mean Score	Category
1.00–1.80	Very Low
1.81–2.60	Low
2.61–3.40	Moderate
3.41–4.20	High
4.21–5.00	Very High

Qualitative data were analyzed using Thematic Analysis according to Braun and Clarke (2006) through six stages: (1) familiarizing with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report (Terrell, 2015). Next, the results of the qualitative analysis were integrated with the quantitative findings to produce a comprehensive interpretation of students' learning experiences during the implementation of AI-assisted Project-Based Contextual Learning.

4. Results

4.1 Participants' Characteristics

The study's respondents were 113 students, all of whom participated in the AI-Assisted Project-Based Contextual Learning program at SMK Negeri 2 Jiwan. In terms of gender, the respondents were relatively evenly divided between males (57 students; 50.4%) and females (56 students; 49.6%). Respondents' ages ranged from 16 to 18 years (M = 17; SD = 0.74), with the majority being 17 years old, which corresponds to the age range of 11th and 12th grade students at the vocational school. By grade level, respondents were from 11th grade (60 students; 53.1%) and 12th grade (53 students; 46.9%), spread across five programs, with the largest proportion in the Accounting and Institutional Finance program (23.9%).

Regarding their experience using AI prior to participating in this program, the majority of respondents (53.1%) stated they had used AI in learning activities, while 35.4% had used it outside of a learning context, and only 11.5% had never used AI at all. During the program, respondents' frequency of AI use varied, with the majority falling between occasional and frequent use (27.4% and 27.4%, respectively), indicating fairly intensive engagement with AI

technology throughout the project-based learning process. This characteristic suggests that respondents were generally not entirely new to AI, and therefore the perceptions reported in the following section are based on relatively adequate firsthand experience.

Table 7. Participants' Demographic Characteristics

Characteristics	Category	n	%
Gender	Male	57	50.4%
	Female	56	49.6%
Aged	Range 16–18 years (M = 17; SD = 0.74)		
	16 years	33	29.2%
	17 years	52	46%
	18 years	28	24.8%
Expertise Program	Institutional Accounting and Finance	27	23.9%
	Computer and Network Engineering	25	22.1%
	Light Vehicle Engineering	24	21.2%
	Livestock Agribusiness	20	17.7%
	Fashion Design	17	15%
Previous Experience Using AI	Never used AI before	13	11.5%
	Yes, outside of learning activities	40	35.4%
	Yes, during learning activities	60	53.1%
Frequency of AI Use During the Program	Never	14	12.4%
	Rarely (1-2x/week)	19	16.8%
	Sometimes (3-4x/week)	31	27.4%
	Often (5-6x/week)	25	22.1%
	Very often (almost every day)	24	21.2%

4.2 Students' Perceptions of AI-Assisted Project-Based Contextual Learning

Students' perceptions of AI-Assisted Project-Based Contextual Learning were analyzed across seven dimensions: AI Learning Support, Contextual Learning, Cognitive Engagement, Collaborative Learning, Learning Autonomy, Reflective Learning, and Overall Learning Experience. Descriptive statistics for each dimension are presented in Table 8.

Table 8. Descriptive Statistics of Students' Perceptions

Dimension	Item	Mean	SD	Category
AI Learning Support	4	3.94	0.56	High
Contextual Learning	4	4.05	0.52	High
Cognitive Engagement	2	4.05	0.49	High
Collaborative Learning	2	4.08	0.45	High
Learning Autonomy	2	3.84	0.54	High
Reflective Learning	2	3.83	0.58	High
Overall Learning Experience	16	3.97	0.40	High

Overall, all seven dimensions were in the high category, with an overall average score (Overall Learning Experience) of 3.97 (SD = 0.40). The dimension with the highest average score was Collaborative Learning (M = 4.08; SD = 0.45), while the dimensions with the lowest average scores were Reflective Learning and Learning Autonomy, both of which were in the range of M = 3.83. This pattern indicates that the collaborative and contextual aspects of learning were felt most strongly by students, while the aspects of independence and reflection on learning, although still in the high category, were relatively at a slightly lower achievement compared to the other dimensions.

Table 9. Highest-Rated Learning Experience Items

No	Item	Dimension	Mean	SD
1	Collaborate to complete projects	Collaborative Learning	4.11	0.49
2	Learning provides meaningful learning experiences	Contextual Learning	4.09	0.54
3	Excited about learning	Cognitive Engagement	4.06	0.51
4	Actively participate in group discussions	Collaborative Learning	4.06	0.52
5	Projects connect theory with practice	Contextual Learning	4.05	0.64

Table 10. Lowest-Rated Learning Experience Items

No	Item	Dimension	Mean	SD
1	Leveraging feedback for improvement	Reflective Learning	3.81	0.59
2	Learning independently	Learning Autonomy	3.83	0.55
3	Reflecting on the learning process	Reflective Learning	3.84	0.66
4	Managing learning strategies independently	Learning Autonomy	3.84	0.63
5	AI provides useful feedback	AI Learning Support	3.89	0.65

At the item level, the five items with the highest average scores (Table 9) were dominated by indicators from the Collaborative Learning and Contextual Learning dimensions, with "Collaborating to complete projects" ranking first (M

= 4.11). Conversely, the five items with the lowest average scores (Table 10) were dominated by indicators from the Reflective Learning and Learning Autonomy dimensions, with "Utilizing feedback for improvement" ranking lowest (M = 3.81).

In general, student perception patterns indicated that social and applied learning activities, such as collaboration on projects and connecting learning to real-world contexts, were perceived more strongly than individual and reflective learning activities, such as managing independent learning strategies and reflecting on the learning process. However, none of the dimensions or items fell into the medium or low categories, indicating that overall, students gave a positive assessment of the implementation of AI-Assisted Project-Based Contextual Learning.

4.3 Students' Learning Experiences during AI-Assisted Project Activities

Semi-structured interviews revealed five interrelated themes: AI-supported learning, contextual understanding, collaborative learning, learning autonomy, and reflective learning. These themes help explain the quantitative findings by illustrating how students experienced AI-assisted Project-Based Contextual Learning (PBCL) and where they continued to require pedagogical support. Students described AI as a learning partner that supported their understanding of the material, helped them locate relevant information, and provided feedback during project completion. Rather than replacing the teacher's role, AI was perceived as a supplementary learning resource that supported students in exploring information and addressing difficulties encountered during the project. AI primarily functioned as an initial source of explanation and information rather than a substitute for teachers or peers. One student explained, “If there is material I don't yet understand, I usually ask AI first to get an initial overview, and then discuss it further with friends and the teacher.” (P3). This account illustrates how AI-supported exploration remained embedded in social learning. Its pedagogical value therefore depended not only on access to information but also on students’ subsequent discussions with teachers and peers.

The vocational relevance of the projects also helped students connect mathematical concepts with practical applications. As one participant noted, “The project feels like the kind of issue that could genuinely arise in our field of study, so it’s easier for me to understand why this material is important.” (P7). This account suggests that contextualization helped students recognize the practical significance of mathematics, linking conceptual learning to situations relevant to their vocational fields. Thus, the projects provided a meaningful context for learning rather than treating mathematical concepts as isolated content.

Collaboration further shaped how students engaged with AI-generated information. Rather than accepting its responses uncritically, students described comparing outputs and discussing their suitability for the project. One participant stated, “We usually compare the AI's answers first. Afterward, we discuss which one best suits our project.” (P5). This practice illustrates the potential for AI-assisted projects to create opportunities for collective evaluation and decision-making. However, the account reflects students’ reported practices and does not, by itself, establish that all groups consistently verified AI-generated information.

Despite these opportunities, students’ accounts indicated that learning autonomy and reflection remained areas requiring further support. One participant acknowledged, “Sometimes I'm still confused about deciding the next step, so I keep waiting for directions from the teacher so I don't make a mistake.” (P9). This experience highlights a distinction between using AI to obtain information and independently managing a learning process. Access to AI did not necessarily equip students to determine subsequent actions or make decisions without teacher guidance.

A similar limitation emerged in reflective learning. One student observed, “Usually, once a project is finished, we immediately move on to the next task. I rarely reflect on which parts actually still need improvement.” (P11). This account suggests that completing a project does not automatically lead students to evaluate their learning strategies or identify areas for improvement. Reflection therefore requires explicit pedagogical design, such as structured self-assessment, guided reflection prompts, and opportunities to use feedback to revise project work.

Taken together, the qualitative findings indicate that students’ learning experiences involved both opportunities and continuing challenges. AI-supported exploration, vocationally relevant projects, and group discussion provided complementary forms of learning support, whereas independent decision-making and systematic reflection required more explicit guidance. These findings help contextualize the questionnaire results by suggesting that positive learning experiences do not necessarily imply that all dimensions of learning are equally developed. In particular, the qualitative accounts offer insight into why autonomy and reflection may require more deliberate instructional support within AI-assisted project activities.

Table 11. Themes and Representative Quotes

Theme	Analytical description	Representative quote
AI-Supported Learning	AI served as an initial source of explanation and information, while teachers and peers remained important for further discussion and clarification.	P3
Contextual Understanding	Vocationally relevant projects helped students recognize the practical significance of mathematical concepts.	P7
Collaborative Learning	Students reported discussing and comparing AI-generated responses before deciding which information suited their projects.	P5
Learning Autonomy	Some students continued to depend on teacher guidance when determining subsequent project steps.	P9
Reflective Learning	Students reported limited systematic reflection on their learning process and areas requiring improvement after completing projects.	P11

4.4 Perceived Benefits and Challenges of AI-Assisted Project-Based Contextual Learning

This section separates the benefits and challenges perceived by students for a more systematic presentation. The following categories are based on a literature review of AI integration in project-based learning and serve as an initial coding framework (a priori codes) that need to be confirmed, revised, or supplemented based on actual interview data, following the principle of thematic analysis that final themes should emerge from the data, not solely from the theoretical framework. Table 12 summarizes the perceived benefits and challenges of AI-assisted project activities. The categories cover informational and learning support, feedback, confidence, and authentic project experiences, alongside challenges related to information accuracy, internet access, overdependence, and prompt formulation. These categories provide a framework for organizing students' interview responses while allowing additional themes to emerge from the data.

Table 12. Perceived Benefits and Challenges

Benefits	Challenges
Faster information searching	AI sometimes provides inaccurate information
Easier problem solving	Limited internet access
Immediate feedback	Tendency to overdependence
Increased confidence	Difficulty writing prompts
Better understanding of the material	Need to verify AI responses
Authentic project experience	

Table 13 presents the joint display used to integrate the quantitative questionnaire results with the qualitative interview findings. The display links scores for each learning experience dimension with relevant interview evidence and an integrated interpretation. This process illustrates how students' accounts contextualize the quantitative patterns, particularly the comparatively lower ratings for learning autonomy and reflective learning, providing a more comprehensive understanding of their experiences during AI-assisted Project-Based Contextual Learning.

Table 13. Joint Display of Mixed Methods Findings

Quantitative Finding	Qualitative Evidence	Integrated Interpretation
AI Learning Support (M = 3.94; High)	Students view AI as a resource for understanding material, obtaining feedback, and supporting project completion.	AI functions as a learning partner, providing cognitive scaffolding throughout the learning process.
Contextual Learning (M = 4.05; High)	Projects are viewed as relevant to the workplace, making learning more meaningful.	Authentic contexts strengthen the relevance of vocational learning and enhance the meaningfulness of learning.
Collaborative Learning (M = 4.08; High)	AI is used as a discussion catalyst, while decisions are still made through group collaboration.	AI enriches collaboration without replacing student-to-student interaction.
Cognitive Engagement (M = 4.05; High)	Students are more actively exploring, comparing alternatives, and analyzing solutions during projects.	AI supports cognitive engagement through exploration and problem-solving activities.
Learning Autonomy (M = 3.84; High)	Some students still require teacher guidance in determining learning strategies.	AI supports independent learning, but teacher guidance is still necessary to foster learning autonomy.
Reflective Learning (M = 3.83; High)	Learning reflection is generally conducted after receiving direction or feedback from the teacher.	Reflection activities need to be facilitated in a more structured manner to deepen the learning experience.

The findings indicate that students reported positive learning experiences across all measured dimensions of AI-Assisted Project-Based Contextual Learning, with relatively higher ratings for collaborative and contextual learning and comparatively lower ratings for learning autonomy and reflective learning. This pattern suggests that students' learning experiences depend not only on the availability of AI but also on how the technology is embedded within the pedagogical design. Accordingly, AI should be positioned as a form of cognitive scaffolding that supports information exploration, problem-solving, and idea development rather than merely providing immediate answers. Integrating AI into authentic, vocationally relevant projects may also help students connect mathematical concepts with practical

applications and engage more meaningfully in learning activities. Overall, the results of this study confirm that the effectiveness of AI-Assisted Project-Based Contextual Learning depends on the quality of the pedagogical design that positions AI as a learning partner in a learning ecosystem that remains centered on authentic thinking, collaboration, reflection, and problem-solving.

5. Discussion

The findings indicate that AI-Assisted Project-Based Contextual Learning (AI-PBCL) was associated with positive student learning experiences, as all measured dimensions and the overall score fell within the high category. These results highlight the multidimensional nature of learning experiences, encompassing not only perceptions of AI but also cognitive engagement, social interaction, learning autonomy, and reflection (Yue et al., 2022; Cahyono et al., 2020). Consistent with Bai & Wang (2025), these experiences reflect the interaction between AI characteristics, pedagogical design, and learner characteristics. Ren & Wu (2025) further emphasize the role of AI as cognitive scaffolding that supports exploration, self-regulation, and knowledge construction. Similarly, Alam et al. (2026) highlight that AI integration should be evaluated not only through academic performance but also through the quality of students' learning experiences. Taken together, these findings suggest that positive learning experiences are not attributable to AI alone but are associated with its pedagogically designed integration into project-based contextual learning. Within this approach, AI functions as a learning partner that supports authentic, collaborative, and student-centered activities, providing a basis for understanding its role in scaffolding students' learning during project completion.

The high student perception of the AI Learning Support dimension indicates that AI is viewed as a learning support resource that helps students understand concepts, explore information, and complete projects more systematically. This finding indicates that the benefits of AI lie not in its ability to produce instant answers, but in its ability to provide cognitive scaffolding that expands students' thinking processes through information exploration, adaptive feedback, and the provision of alternative solutions. The results of this study align with Kamalov et al. (2023) who explain that AI can strengthen the learning process when it functions as a cognitive support that helps students build understanding gradually. This finding also supports the view of Ren & Wu (2025) that AI can enhance learning when used to facilitate self-regulation, reflection, and knowledge exploration, rather than simply providing final answers to problems. Furthermore, Cukurova (2024) emphasized that the pedagogical value of AI depends on how the technology is integrated into learning activities that remain student-centered and teacher-directed. Therefore, the results of this study reinforce the concept of AI as a learning partner, namely AI acting as a learning partner that enriches the thinking process through cognitive support and adaptive feedback, while decisions, reasoning, and knowledge construction remain in the hands of students.

Contextual Learning and Collaborative Learning received the highest scores among the measured dimensions, suggesting that students particularly valued vocationally relevant projects and collaborative activities. Authentic tasks enabled students to connect mathematical concepts with practical situations relevant to their future workplaces. This finding aligns with Hiim (2023), who emphasized the importance of authentic work-related tasks in vocational education, and with Hong (2025) and Viruel et al. (2025), who highlighted the potential of AI integration to support exploration, solution development, and project completion when embedded in pedagogical design. Sudira et al. (2026) similarly underscored the role of relevant vocational contexts and hands-on social experiences in knowledge construction. The interview findings further suggest that AI supported rather than replaced student collaboration: students used AI-generated information as a basis for group discussion, comparison, and collective decision-making. Overall, the findings highlight the complementary roles of authentic projects, vocational relevance, collaboration, and AI-supported exploration in shaping students' positive learning experiences.

Although Cognitive Engagement was rated highly, Learning Autonomy and Reflective Learning received comparatively lower scores, suggesting that students found AI more helpful for information exploration and problem-solving than for independently regulating and reflecting on their learning. From the perspectives of self-regulated learning and metacognition, these skills require deliberate pedagogical support rather than emerging automatically from access to AI-generated information and feedback. This interpretation is consistent with Cukurova (2024) and Ren & Wu (2025), who emphasized the importance of integrating AI as cognitive scaffolding within teacher-guided learning environments. Interview findings further highlighted perceived benefits, including faster information retrieval, immediate feedback, increased confidence, and support for project completion. However, students also reported challenges involving inaccurate AI responses, overdependence, prompt formulation, limited internet access, and the need to verify AI-generated information (Bahroun et al., 2023). Taken together, these findings underscore the importance of learning designs that explicitly promote self-regulation, structured reflection, and critical evaluation, enabling AI to function as a learning partner rather than merely a source of answers.

Overall, the findings of this study indicate that the success of AI integration in vocational education is not determined

by the sophistication of the technology, but rather by how it is integrated into meaningful learning designs. AI needs to be positioned as a learning partner that provides cognitive scaffolding to support knowledge exploration and problem-solving, not as a substitute for teachers or a provider of instant answers (Cukurova, 2024; Kamalov et al., 2023). This integration will be more effective if implemented through authentic projects relevant to the vocational context and combined with activities that encourage reflection and the development of learning autonomy (Hiim, 2023). These findings highlight the importance of pedagogical approaches that use AI to support student-centered learning while preserving students' active roles in thinking, collaboration, and problem-solving.

Several limitations should be considered when interpreting these findings. The study involved 113 students from a single vocational high school, which may limit the transferability of the results. As the findings were based on students' reported experiences during six sessions of AI-assisted Project-Based Contextual Learning using Gemini, they do not establish improvements in academic achievement or other learning outcomes. Moreover, the absence of an experimental comparison group prevents attributing students' experiences specifically to AI integration rather than to contextual projects, collaboration, or teacher facilitation. Future research should involve multiple schools and longer implementation periods, using comparative or longitudinal designs to examine learning processes and outcomes across different contexts.

6. Conclusion

This study demonstrates that integrating artificial intelligence into Project-Based Contextual Learning has the potential to create meaningful learning experiences when AI is positioned as a pedagogically integrated learning partner rather than merely a technological tool. By addressing both the multidimensional nature of students' learning experiences and the perceived benefits and challenges of AI-assisted learning, the findings highlight that the educational value of AI lies in its capacity to provide cognitive scaffolding that supports authentic problem-solving, collaboration, and knowledge construction, while simultaneously requiring deliberate pedagogical strategies to foster learning autonomy and reflective thinking. These findings extend the current discourse on AI in vocational education by emphasizing that effective AI integration depends less on the technology itself than on instructional designs that maintain the central role of teachers as facilitators, learning designers, and validators of students' learning processes. Consequently, this study contributes a pedagogical perspective that positions AI as a partner in learning, offering practical guidance for designing AI-supported vocational learning environments that are authentic, student-centered, and capable of developing higher-order thinking skills.

Acknowledgments

The authors gratefully acknowledge the support of the Institute for Research and Community Service (LPPM), Universitas Negeri Surabaya, and the collaboration of SMK Negeri 2 Jiwan, Madiun, Indonesia, for their valuable contributions and assistance throughout the research process.

Author contributions

Arsyananda Rabbani contributed to the conceptualization, methodology, data analysis, and preparation of the original manuscript. Khusnul Khotimah contributed to the investigation, data collection, and data curation. Iwan Maulana contributed to the research methodology, data analysis, and manuscript review. Mochamad Kamil Budiarto contributed to instrument validation, data interpretation, and manuscript revision. Adhitya Amarulloh contributed to study supervision, conceptualization, and critical revision of the manuscript. Ilham Laksana contributed to data collection, data processing, and manuscript review. All authors contributed to the study, read and reviewed the manuscript, and approved the final version for publication. No authorship contributions were designated as equal unless otherwise agreed by the authors.

Funding

This research was supported through the Faculty Policy Research Program under the Beginner Lecturer Research (*Penelitian Dosen Pemula*) Scheme, funded under Rector's Decree No. B/43181/UN38.16/TU.00.02/2026.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Redfame Publishing.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

Open access

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/4.0/).

Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

References

Adewale, M. D., Azeta, A., Abayomi-Alli, A., & Sambo-Magaji, A. (2024). Impact of artificial intelligence adoption on students' academic performance in open and distance learning: A systematic literature review. *Heliyon*, *10*(22), e40025. https://doi.org/10.1016/j.heliyon.2024.e40025

Alam, M. N., Islam, M. A., Babiker, M. O. A., Siddiqui, M. S., Amin, M. Bin, & Oláh, J. (2026). AI-assisted learning tools and student learning outcomes: A cognitive load theory perspective. *Computers in Human Behavior Reports*, *21*, 100986. https://doi.org/10.1016/j.chbr.2026.100986

Bahroun, Z., Anane, C., Ahmed, V., & Zacca, A. (2023). Transforming Education: A Comprehensive Review of Generative Artificial Intelligence in Educational Settings through Bibliometric and Content Analysis. *Sustainability*, *15*(17), 12983. https://doi.org/10.3390/su151712983

Bai, Y., & Wang, S. (2025). Impact of generative AI interaction and output quality on university students' learning outcomes: a technology-mediated and motivation-driven approach. *Scientific Reports*, *15*(1), 24054. https://doi.org/10.1038/s41598-025-08697-6

Bostley, M. A., & Peters, A. I. (2023). Scientific Research Sample Size Determination. *The International Journal of Science & Technoledge*. https://doi.org/10.24940/theijst/2023/v11/i7/st2307-008

Cahyono, Mulayana, D., & Sukarliana, L. (2020). Growing the Character of Responsibility in Students Through Teacher's Exemplary in Anti-Corruption Education Efforts. *Advances in Social Science, Education and Humanities Research*, *418*(Acec 2019), 67–72. https://doi.org/10.2991/assehr.k.200320.013

Chang, D. H., Lin, M. P.-C., Hajian, S., & Wang, Q. Q. (2023). Educational Design Principles of Using AI Chatbot That Supports Self-Regulated Learning in Education: Goal Setting, Feedback, and Personalization. *Sustainability*, *15*(17), 12921. https://doi.org/10.3390/su151712921

Chrismondari, Simatupang, W., Waskito, Rahmat Fadillah, & Bayu Rianto. (2025). Implementation of a Project-Based Inquiry Learning Model for Electrical Motor Installation: Evaluating Its Effectiveness in Vocational Education. *Data and Metadata*, *4*, 1079. https://doi.org/10.56294/dm20251079

Crompton, H., & Burke, D. (2023). Artificial intelligence in higher education: the state of the field. *International Journal of Educational Technology in Higher Education*, *20*(1), 22. https://doi.org/10.1186/s41239-023-00392-8

Cukurova, M. (2024). The Interplay of Learning, Analytics, and Artificial Intelligence in Education. *ArXiv*, *abs/2403.1*. https://doi.org/10.48550/arxiv.2403.16081

Dahalan, F., Alias, N., & Shaharom, M. S. N. (2024). Gamification and Game Based Learning for Vocational Education and Training: A Systematic Literature Review. *Education and Information Technologies*, *29*(2), 1279–1317. https://doi.org/10.1007/s10639-022-11548-w

Delen, İ., Şen, N., Özüdoğru, F., & Biasutti, M. (2024). Understanding the Growth of Artificial Intelligence in Educational Research Through Bibliometric Analysis. *Sustainability*, *16*(16), 6724. https://doi.org/10.3390/su16166724

Deutscher, V., Thomann, H., Zlatkin-Troitschanskaia, O., Weyland, U., Abele, S., Danek, A. H., Greiff, S., Rausch, A.,

Seeber, S., Seifried, J., & Winther, E. (2026). Artificial intelligence in vocational education and training: A systematic review of educational purposes, theoretical conceptualizations, and empirical effectiveness. *Computers and Education: Artificial Intelligence*, *11*, 100628. https://doi.org/10.1016/j.caeai.2026.100628

Fan, G., Liu, D., Zhang, R., & Pan, L. (2025). The impact of AI-assisted pair programming on student motivation, programming anxiety, collaborative learning, and programming performance: a comparative study with traditional pair programming and individual approaches. *International Journal of STEM Education*, *12*(1), 16. https://doi.org/10.1186/s40594-025-00537-3

Fan, Y., Tang, L., Le, H., Shen, K., Tan, S., Zhao, Y., Shen, Y., Li, X., & Gašević, D. (2024). Beware of Metacognitive Laziness: Effects of Generative Artificial Intelligence on Learning Motivation, Processes, and Performance. *ArXiv*, *abs/2412.0*. https://doi.org/10.1111/bjet.13544

Fantinelli, S., Cortini, M., Di Fiore, T., Iervese, S., & Galanti, T. (2024). Bridging the Gap between Theoretical Learning and Practical Application: A Qualitative Study in the Italian Educational Context. *Education Sciences*, *14*(2), 198. https://doi.org/10.3390/educsci14020198

Flinton, D. M., & Malamateniou, C. (2020). Quantitative Methods and Analysis. In *Medical Imaging and Radiotherapy Research: Skills and Strategies* (pp. 273–322). Springer International Publishing. https://doi.org/10.1007/978-3-030-37944-5_15

Fortuna, A., Prasetya, F., Cabanillas-García, J. L., Arcelus-Ulibarrena, J. M., Salman, A., Karimi, A., & Yusuf, A. (2024). Modern Learning Paradigms: A Bibliometric Analysis of Augmented Reality and Virtual Reality in Vocational Education. *Jurnal Pendidikan Teknologi Kejuruan*, *7*(2), 91–114. https://doi.org/10.24036/jptk.v7i2.36523

Ghosh, L., & Ravichandran, R. (2024). Emerging Technologies in Vocational Education and Training. *Journal of Digital Learning and Education*, *4*(1), 41–49. https://doi.org/10.52562/jdle.v4i1.975

Gligorea, I., Cioca, M., Oancea, R., Gorski, A.-T., Gorski, H., & Tudorache, P. (2023). Adaptive Learning Using Artificial Intelligence in e-Learning: A Literature Review. *Education Sciences*, *13*(12), 1216. https://doi.org/10.3390/educsci13121216

Hanshaw, G., Vance, J., & Brewer, C. (2024). Exploring the Effectiveness of AI Course Assistants on the Student Learning Experience. *Open Praxis*, *16*(4). https://doi.org/10.55982/openpraxis.16.4.719

Hiim, H. (2023). How Can Collaboration between Schools and Workplaces Contribute to Relevant Vocational Education? *Vocations and Learning*, *16*(1), 1–21. https://doi.org/10.1007/s12186-022-09300-z

Hinojo-Lucena, F.-J., Díaz, I. A., Reche, M. P. C., & Rodríguez, J. M. R. (2019). Artificial Intelligence in Higher Education: A Bibliometric Study on Its Impact in the Scientific Literature. *Education Sciences*, *9*(1), 51. https://doi.org/10.3390/educsci9010051

Hogarth, T. (2022). The Resilience of VET: Managing Economic Shocks, Ageing, and Technological Change in an Age of Uncertainty. *The Hungarian Educational Research Journal*, *12*(3), 263–275. https://doi.org/10.1556/063.2021.00057

Hong, L. (2025). Development and validation of a competency-based ladder pathway for AI literacy enhancement among higher vocational students. *Scientific Reports*, *15*(1), 29898. https://doi.org/10.1038/s41598-025-15202-6

Ivanović, I. (2025). Comparative Analysis of Student Engagement in Traditional vs AI-Assisted Learning Using UWS-9S. *Drustvena Istrazivanja*, *34*(2), 169–189. https://doi.org/10.5559/di.34.2.02

Kamalov, F., Santandreu Calonge, D., & Gurrib, I. (2023). New Era of Artificial Intelligence in Education: Towards a Sustainable Multifaceted Revolution. *Sustainability*, *15*(16), 12451. https://doi.org/10.3390/su151612451

Khakpaki, A. (2025). Advancements in artificial intelligence transforming medical education: a comprehensive overview. *Medical Education Online*, *30*(1). https://doi.org/10.1080/10872981.2025.2542807

Kvale, S., & Brinkmann, S. (2009). *Interviews: Learning the craft of qualitative research interviewing*. sage.

Lin, C.-C., Huang, A. Y. Q., & Lu, O. H. T. (2023). Artificial intelligence in intelligent tutoring systems toward sustainable education: a systematic review. *Smart Learning Environments*, *10*(1), 41. https://doi.org/10.1186/s40561-023-00260-y

Maalek, R. (2024). Integrating Generative Artificial Intelligence and Problem-Based Learning into the Digitization in Construction Curriculum. *Buildings*, *14*(11), 3642. https://doi.org/10.3390/buildings14113642

Mohamed, A., Shaaban, T., Bakry, S., Guillén-Gámez, F., & Strzelecki, A. (2024). Empowering the Faculty of

Education Students: Applying AI's Potential for Motivating and Enhancing Learning. *Innovative Higher Education*, *50*, 587–609. https://doi.org/10.1007/s10755-024-09747-z

Naseer, F., Khan, M. N., Tahir, M., Addas, A., & Aejaz, S. M. H. (2024). Integrating deep learning techniques for personalized learning pathways in higher education. *Heliyon*, *10*(11). https://doi.org/10.1016/j.heliyon.2024.e32628

Naseer, F., Tariq, R., Alshahrani, H. M., Alruwais, N., & Al-Wesabi, F. N. (2025). Project based learning framework integrating industry collaboration to enhance student future readiness in higher education. *Scientific Reports*, *15*(1), 24985. https://doi.org/10.1038/s41598-025-10385-4

Nguyen, A., Ngo, H., Hong, Y., Dang, B., & Nguyen, B.-P. T. (2022). Ethical principles for artificial intelligence in education. *Education and Information Technologies*, *28*, 4221–4241. https://doi.org/10.1007/s10639-022-11316-w

Popkova, E. G., Sergi, B. S., & Vodenko, K. V. (2023). Preliminary Material. In E. G. Popkova, B. S. Sergi, & K. V. Vodenko (Eds.), *Social Mobility, Social Inequality, and the Role of Higher Education* (pp. i–xlviii). BRILL. https://doi.org/10.1163/9789004540019_001

Raj, V. A., Jasrotia, S. S., & Shankar, S. (2024). Mapping the Research Landscape Of vocational Education And entrepreneurship: Insights And future Directions. *Higher Education Skills and Work-Based Learning*, *14*(5), 992–1010. https://doi.org/10.1108/heswbl-05-2023-0129

Ren, X., & Wu, M. L. (2025). Examining Teaching Competencies and Challenges While Integrating Artificial Intelligence in Higher Education. *TechTrends*, *69*(3), 519–538. https://doi.org/10.1007/s11528-025-01055-3

Sauli, F., Wenger, M., & Berger, J.-L. (2021). Supporting Apprentices' Integration of School- and Workplace-Based Learning in Swiss Initial Vocational Education and Training. *Research in Post-Compulsory Education*, *26*, 387–409. https://doi.org/10.1080/13596748.2021.1980660

Sudira, P., Makwa, Z., Wulandari, B., & Sukardiyono, T. (2026). An Integrated Pedagogical–Technical Framework for Deep Learning in Vocational Education and Training: A Systematic Review. *F1000Research*, *15*, 589. https://doi.org/10.12688/f1000research.178497.1

Tapalova, O., & Zhiyenbayeva, N. (2022). Artificial Intelligence in Education: AIEd for Personalised Learning Pathways. *Electronic Journal of E-Learning*, *20*(5), 639–653. https://doi.org/10.34190/ejel.20.5.2597

Taşkın, M. (2025). Artificial Intelligence in Personalized Education: Enhancing Learning Outcomes Through Adaptive Technologies and Data-Driven Insights. *Human Computer Interaction*, *8*(1), 173. https://doi.org/10.62802/ygye0506

Terrell, S. (2015). Mixed-Methods Research Methodologies. *The Qualitative Report*, *17*, 254–280. https://consensus.app/papers/mixedmethods-research-methodologies-terrell/2efe0a9295765c4dba7a18773a672406/

Tshong, P. K., & Yasin, R. M. (2023). TVET Educational Learning Strategies and Their Impact on Students: A Systematic Literature Review. *International Journal of Academic Research in Business and Social Sciences*, *13*(11). https://doi.org/10.6007/ijarbss/v13-i11/19558

Viruel, S. R., Rivas, E. S., & Palmero, J. R. (2025). The Role of Artificial Intelligence in Project-Based Learning: Teacher Perceptions and Pedagogical Implications. *Education Sciences*, *15*(2). https://doi.org/10.3390/educsci15020150

Walter, Y. (2024). Embracing the future of Artificial Intelligence in the classroom: the relevance of AI literacy, prompt engineering, and critical thinking in modern education. *International Journal of Educational Technology in Higher Education*, *21*(1). https://doi.org/10.1186/s41239-024-00448-3

Xu, X., Qiao, L., Cheng, N., Liu, H., & Zhao, W. (2025). Enhancing self-regulated learning and learning experience in generative <scp>AI</scp> environments: The critical role of metacognitive support. *British Journal of Educational Technology*, *56*(5), 1842–1863. https://doi.org/10.1111/bjet.13599

Yue, M., Jong, M. S.-Y., & Dai, Y. (2022). Pedagogical Design of K-12 Artificial Intelligence Education: A Systematic Review. *Sustainability*, *14*(23), 15620. https://doi.org/10.3390/su142315620