

Original Article

Integrating Generative AI Tools for Personalized Science Instruction: A Mixed-Method Study in Vocational School

Farrah L. Aminulla, Jocelyn J. Muñez , Al-fahad E. Jadjuli 

Author Information:

Mindanao State University-Sulu HBSAT,
Jolo, Sulu, Philippines

Corresponding Author:

Al-fahad E. Jadjuli
fahadliafourteentwentytwo1422@gmail.com

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Abstract. Limited empirical evidence explains how generative artificial intelligence (AI) supports personalized science instruction in Philippine vocational education, particularly within competency-based learning environments characterized by diverse student readiness, digital inequities, and constrained instructional resources. This study examined the integration of generative AI tools for personalized science instruction among vocational students through a convergent parallel mixed-methods design grounded in Constructivist Learning Theory and the Technology Acceptance Model, contributing to Sustainable Development Goal 4 (Quality Education). Quantitative data were collected from 200 Senior High School students using a validated five-point Likert-scale questionnaire (Cronbach's $\alpha = 0.91$), while qualitative data were obtained from 15 purposively selected students through focus group discussions and semi-structured interviews following an eight-week AI-supported intervention. Findings indicated positive exposure to AI-assisted instruction, with content delivery receiving the highest mean score ($M = 3.81$). Perceived effectiveness was strongest for conceptual understanding and motivation ($M = 3.78$); however, exposure was not significantly associated with perceived instructional effectiveness ($p = .055$, $p = .443$). Qualitative findings showed that generative AI simplified complex concepts, enhanced learning efficiency, and promoted independent learning, while raising concerns regarding information reliability, learner overdependence, and unequal digital access. The study recommends strengthening pre-service and in-service teacher training on AI-enhanced pedagogy, ethical AI use, and instructional design to support effective integration of generative AI in vocational science education.

Keywords: *Generative artificial intelligence; Mixed-method research; Personalized science instruction; Technology Acceptance Model; Vocational education.*

Scientific literacy and problem-solving skills have become indispensable competencies in the twenty-first century, enabling learners to navigate increasingly complex scientific, technological, and societal challenges (Annam et al., 2024). Science education plays a central role in cultivating these competencies by promoting critical thinking, inquiry, evidence-based reasoning, and informed decision making (Rafflesia et al., 2026). In Technical and Vocational Education and Training (TVET), science instruction extends beyond theoretical knowledge by supporting the development of practical competencies required in modern workplaces.

Competency-based vocational education requires learners to understand the scientific principles underpinning technical processes, making effective science instruction fundamental to workforce preparation (Ye et al., 2024). However, vocational classrooms frequently comprise students with diverse academic abilities, technical interests, prior knowledge, and learning needs, making it difficult for teachers to deliver instruction that effectively accommodates individual differences (Compen et al., 2024).

Globally, artificial intelligence (AI) has emerged as one of the most transformative innovations in education, reshaping instructional delivery across the science, technology, engineering, and mathematics (STEM) disciplines (Kamer, 2024). Educational AI has evolved from intelligent tutoring systems and adaptive learning platforms to sophisticated generative AI technologies capable of producing human-like explanations, answering complex scientific questions, generating instructional materials, providing personalized feedback, and facilitating inquiry-based learning (Al-Cheikh et al., 2025). Recent advances in large language models, including ChatGPT, Google Gemini, and Microsoft Copilot, have expanded the opportunities for science education by enabling interactive dialogue, adaptive explanations, virtual experimentation, and personalized learning pathways (Ahmad et al., 2023). These technologies support differentiated instruction by responding dynamically to learners' individual needs, allowing students to revisit difficult concepts, receive immediate feedback, and construct scientific understanding at their own pace (Linn et al., 2023). Consequently, AI has become a central component of global educational digital transformation initiatives aimed at improving the quality, accessibility, and efficiency of instruction.

The integration of AI into science education further supports the achievement of United Nations Sustainable Development Goal 4 (SDG 4): Quality Education, which promotes inclusive, equitable, and high-quality education while encouraging lifelong learning opportunities for all (Bhatta, 2026). SDG 4 emphasizes the responsible use of digital technologies to improve teaching quality, expand access to educational opportunities, and reduce learning inequality (Prajuhana et al., 2023). Within vocational education, AI-assisted personalized instruction offers considerable potential to provide adaptive learning experiences, strengthen scientific literacy, and equip learners with the digital competencies necessary for participation in an increasingly technology-driven workforce (Leong, 2025).

In the Philippines, Technical-Vocational Education and Training (TVET) has become a major pillar of national workforce development through competency-based curricula implemented by the Department of Education and the Technical Education and Skills Development Authority (TESDA) (Calles, 2025). Recent educational reforms have emphasized digital transformation, Education 4.0, and technology-enhanced learning to improve instructional quality across senior high schools and vocational education (Singh et al., 2023). Nevertheless, the adoption of artificial intelligence in Philippine vocational education is still in its early stages. Many vocational institutions continue to experience limited technological infrastructure, unstable Internet connectivity, insufficient instructional resources, unequal student access to digital technologies, and limited professional development opportunities for teachers in AI-enhanced pedagogy (Luo et al., 2024). These challenges are particularly evident in science education, where abstract scientific concepts often require individualized explanations, visualization, continuous formative feedback, and differentiated instructional support. Consequently, identifying innovative instructional approaches that are both pedagogically effective and contextually feasible has become increasingly important in Philippine vocational schools (De La Cruz, 2022).

Consequently, personalized instruction has emerged as an effective pedagogical approach for addressing learner diversity. Personalized learning adapts instructional content, learning activities, pacing, and assessment according to students' individual needs, prior knowledge, learning preferences, and academic readiness (Idowu, 2024). Rather than employing a one-size-fits-all approach, personalized learning promotes learner autonomy, self-regulated learning, differentiated instruction, and active engagement (Short & Shemshack, 2023). Numerous empirical studies have demonstrated that personalized instruction improves academic achievement, conceptual understanding, learner motivation, engagement, and higher-order thinking skills across diverse educational settings (Idowu, 2024). However, implementing personalized instruction remains particularly challenging within vocational education because teachers often manage large class sizes, limited instructional time, diverse learner abilities, and constrained educational resources (Idowu, 2024).

Recent developments in Generative Artificial Intelligence (GenAI) present promising opportunities to overcome these instructional challenges. Advanced AI systems such as ChatGPT, Google Gemini, and Microsoft Copilot

generate human-like responses, create instructional resources, explain complex scientific concepts, answer learners' questions, produce assessments, and provide immediate formative feedback (Bonde, 2024). Unlike conventional educational technologies, generative AI supports adaptive learning by dynamically responding to individual learner needs and assisting teachers in lesson preparation, classroom management, instructional differentiation, and assessment design (Bai, 2024). These capabilities position GenAI as a promising instructional partner for implementing personalized science instruction in competency-based vocational education.

Evidence from recent systematic reviews and meta-analyses further supports the educational potential of AI-assisted learning methods. Synthesized findings consistently indicate that AI-enhanced instruction significantly improves academic achievement, conceptual understanding, learner engagement, self-regulated learning, scientific reasoning, and learning motivation when implemented with sound pedagogical practices (Wang & Zhao, 2024). Nevertheless, these reviews also identified persistent challenges, including algorithmic bias, inaccurate or fabricated information, ethical concerns, excessive learner dependence on AI, academic integrity issues, and unequal access to digital technologies (Wu, 2025). Importantly, most of the synthesized evidence originates from higher education and general K-12 settings, while vocational science education, particularly in developing countries, remains substantially underrepresented. This imbalance highlights the need for context-specific investigations that examine how AI can effectively support personalized science instruction in competency-based vocational learning environments (Juan & Nagappan, 2025).

Within science education, the instructional potential of GenAI appears particularly significant because science learning often involves abstract concepts, scientific reasoning, inquiry processes, and persistent misconceptions that require differentiated explanations. Recent empirical studies indicate that AI-supported learning environments enhance conceptual understanding, facilitate inquiry-based learning, improve scientific reasoning, and encourage students to explore scientific phenomena through interactive dialogue (Ching Cheung et al., 2026). AI-generated explanations and immediate feedback allow learners to revisit difficult concepts at their own pace while supporting a deeper conceptual understanding. However, researchers have cautioned that AI-generated scientific information may occasionally contain inaccuracies or fabricated content, requiring careful teacher supervision and the development of students' critical AI literacy (Li et al., 2025).

The successful implementation of GenAI in vocational education depends not only on technological capabilities but also on institutional readiness, teacher competence, equitable digital access, and learner acceptance. Existing research demonstrates that vocational institutions continue to experience infrastructure limitations, inadequate digital resources, and insufficient professional development opportunities for teachers (Zhou & Zhou, 2024). Students and teachers generally recognize AI's potential to enhance learning experiences while simultaneously expressing concerns regarding information reliability, ethical use, academic integrity, and learner overdependence. These findings suggest that successful AI integration requires balancing technological innovation with responsible pedagogical implementation (Ali & Ekeng, 2024).

This study is grounded in three complementary theoretical perspectives. Constructivist Learning Theory explains that learners actively construct knowledge through meaningful experiences, interaction, reflection, and inquiry, making AI-generated dialogue and personalized explanations valuable tools for conceptual development. Self-Determination Theory (Kukreja et al., 2025). It further explains how AI-supported personalized learning enhances students' intrinsic motivation by satisfying their needs for autonomy, competence, and relatedness through individualized feedback, learner-controlled pacing, and adaptive instructional support. Finally, the Technology Acceptance Model (TAM) explains how perceived usefulness and perceived ease of use influence students' and teachers' willingness to adopt AI technologies in educational settings. Collectively, these theories provide a comprehensive framework for understanding how generative AI influences personalized science instruction, learner engagement, instructional effectiveness, and technology adoption in vocational education (Pierce & Jiang, 2025).

Despite the growing international evidence regarding AI-supported learning, important research gaps remain. Most previous investigations have been conducted in higher education or general K-12 settings, with comparatively limited attention paid to vocational science education. Furthermore, relatively few studies have employed mixed-methods approaches capable of integrating measurable instructional outcomes with learners' lived experiences during AI-supported instruction. Within the Philippine context, empirical evidence examining the integration of generative AI into personalized science instruction remains scarce, despite continuing national

efforts toward educational digitalization and competency-based vocational education.

Consequently, limited evidence explains how generative AI supports personalized science instruction within Philippine vocational schools characterized by diverse learner readiness, constrained instructional resources, and unequal digital access.

Accordingly, this study employed a convergent parallel mixed-methods design to investigate the integration of generative AI tools for personalized science instruction among Senior High School students in Philippine vocational education. Specifically, the study examined students' exposure to AI-assisted instruction, evaluated its perceived instructional effectiveness, and explored learners' experiences, opportunities, and challenges during AI-supported science learning. The findings are expected to contribute to the growing body of literature on artificial intelligence in vocational education while providing practical implications for science teachers, school administrators, curriculum developers, and policymakers seeking to promote ethical, equitable, and pedagogically effective AI integration in support of quality vocational science education.

Methodology

Research Design

This study employed a Convergent Parallel Mixed-Methods Design, which involves the concurrent collection, independent analysis, and subsequent integration of quantitative and qualitative data to obtain a comprehensive understanding of a research problem (Creswell & Plano Clark, 2018). This design was considered appropriate because it enabled the researchers to examine both the measurable outcomes and the contextual experiences associated with the integration of Generative Artificial Intelligence (GenAI) tools in personalized science instruction within vocational education.

The quantitative component assessed students' exposure to Generative AI tools and their perceived effectiveness in science learning using structured survey instruments. Simultaneously, the qualitative component explored students' lived experiences, perceptions, and challenges through focus group discussions and semi-structured interviews. The convergence of both datasets allowed for triangulation, corroboration, and comparison of quantitative trends with qualitative narratives, thereby enhancing the credibility, completeness, and interpretability of the findings. The mixed-methods approach was particularly suitable because the educational impact of Generative AI extends beyond measurable outcomes and encompasses students' learning experiences, perceptions, and contextual realities.

Participants were intentionally selected from students who had prior exposure to Generative AI tools during an eight-week AI-supported science intervention. This criterion ensured that participants possessed sufficient experience to meaningfully evaluate the instructional use of GenAI. However, the researchers acknowledge that selecting participants with prior AI exposure may introduce selection bias and limit the generalizability of the findings to vocational students without similar experiences. Consequently, the results should be interpreted within the context of AI-exposed learners and should not be generalized to all vocational education settings. Future studies are encouraged to include students with varying levels of AI experience across multiple institutions to enhance external validity and broader applicability.

Participants and Sampling

The participants in the study were 200 Senior High School students from the Hadji Butu School of Arts and Trades who were enrolled in science-related subjects during the conduct of the study. The study employed purposive sampling to identify respondents with prior exposure to Generative AI tools such as OpenAI ChatGPT, Google Gemini, and other AI-assisted educational technologies used in science learning. The inclusion criteria required participants to be currently enrolled in Senior High School, actively engaged in science instruction during the study period, and willing to participate voluntarily. The quantitative phase involved 200 students to ensure adequate representation and statistical reliability. For the qualitative phase, criterion-based purposive sampling was utilized to recruit 15 students with varying levels of AI usage, including frequent, moderate, and limited users of Generative AI technologies. These selected participants participated in Focus Group Discussions (FGDs) and semi-structured interviews to provide in-depth insights into their experiences, perceptions, and challenges regarding AI-supported personalized Science instruction.

Instructional Intervention

The instructional intervention involved integrating Generative AI tools into personalized Science instruction over an eight-week implementation period in the subjects Earth and Life Science and Physical Science. During the intervention, students utilized AI-powered platforms such as OpenAI ChatGPT and Google Gemini to support individualized learning experiences in selected Science topics, including Matter and Its Properties, Energy Transformation, Ecosystems and Environmental Science, Human Body Systems, and Scientific Inquiry and Problem-Solving. The AI tools were utilized to provide simplified explanations of complex scientific concepts, generate customized examples and practice activities, offer immediate feedback on exercises, and facilitate interactive question-and-answer sessions. The intervention emphasized adaptive, learner-centered instruction by enabling students to access personalized support tailored to their individual learning pace, needs, and preferences. Throughout the implementation, the teacher served as a facilitator, guiding students in the ethical and responsible use of AI technologies, monitoring the accuracy of AI-generated content, and encouraging critical evaluation of information obtained from AI platforms.

Research Instruments

The quantitative data were collected using a structured questionnaire developed based on the constructs of the Technology Acceptance Model (TAM) and related literature on AI-assisted learning and personalized instruction. The questionnaire consisted of items measuring students' exposure to Generative AI tools in terms of instructional support, content delivery, assessment and feedback, and learner engagement, as well as students' perceived effectiveness of AI tools in terms of understanding of concepts, motivation, participation, and academic support. A five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) was utilized to measure respondents' perceptions and experiences. Prior to administration, the instrument underwent expert validation by specialists in educational technology, Science education, and research methodology to ensure content validity and relevance. A pilot test was also conducted to establish reliability using Cronbach's Alpha. For the qualitative component, a semi-structured interview guide and Focus Group Discussion protocol were utilized to explore participants' experiences, benefits, challenges, and recommendations regarding the use of Generative AI tools in Science learning. The semi-structured format enabled flexibility in probing responses while ensuring alignment with the study objectives.

Data Collection Procedure

The data collection process was conducted in several stages. Initially, the researcher secured approval from the Vocational School Superintendent and the relevant ethics review authorities before conducting the study. Informed consent forms were distributed to all participants to explain the research's objectives, procedures, and ethical considerations. Following approval, participants completed an initial survey assessing their exposure to Generative AI tools and baseline perceptions regarding personalized Science instruction. The instructional intervention was then implemented over an eight-week period, during which students actively utilized AI-assisted technologies in Science learning activities under teacher supervision. After the intervention phase, participants completed a final survey to assess their perceived effectiveness and learning experiences with AI tools. Subsequently, selected participants participated in Focus Group Discussions and semi-structured interviews to provide deeper insights into their experiences and perceptions. All interviews and discussions were conducted with participants' consent and were audio-recorded and transcribed verbatim for analysis.

Data Analysis Plan

Quantitative data were analyzed using descriptive and inferential statistical techniques in SPSS. Descriptive statistics, including mean and standard deviation, were used to describe students' exposure to Generative AI tools and their perceived effectiveness in personalized Science learning. Spearman's Correlation was employed to determine significant relationships among variables where appropriate. Meanwhile, qualitative data obtained from interviews and Focus Group Discussions were analyzed using Thematic Analysis following the framework proposed by Braun and Clarke. A bottom-up inductive coding approach was employed to allow themes and patterns to emerge directly from participants' narratives. The analysis process included data familiarization, coding, theme generation, theme review, theme definition, and narrative interpretation. This analytical approach enabled the identification of recurring patterns regarding students' experiences, perceptions, benefits, and challenges related to AI-assisted personalized Science instruction.

Integration Protocol

The quantitative and qualitative findings were integrated during the interpretation stage using a joint display

analysis and side-by-side comparison approach. Quantitative results were compared and linked to qualitative themes to identify areas of convergence, divergence, and complementarity between the two datasets. For instance, quantitative findings indicating high levels of learner engagement and motivation were interpreted alongside qualitative narratives explaining how AI tools enhanced participation, personalized learning experiences, and conceptual understanding. The integration process enabled the researcher to develop a holistic and comprehensive interpretation of the effectiveness and implications of Generative AI integration in vocational Science education.

Ethical Considerations

The study adhered to established ethical principles in educational research. Participants were informed about the study's purpose, procedures, risks, and benefits before participation, and written informed consent was obtained from all respondents. Participation in the study was entirely voluntary, and participants were informed of their right to withdraw from the research at any stage without penalty or negative consequences. Confidentiality and anonymity were maintained through coded identifiers and pseudonyms, and all collected data were handled with strict confidentiality and used solely for research purposes. In addition, ethical considerations regarding the use of Artificial Intelligence were emphasized throughout the study. Students were informed that they would not be penalized for inaccuracies or limitations in AI-generated content and were encouraged to evaluate AI responses using credible academic sources critically. The researcher also promoted responsible and ethical practices in the use of AI during the intervention period.

Trustworthiness and Validity

To ensure methodological rigor, the study employed several strategies to establish validity, reliability, and trustworthiness. The quantitative instrument underwent expert validation to ensure content validity and appropriateness of the questionnaire items. Reliability testing was conducted through Cronbach's Alpha, with a coefficient of 0.70 or higher considered acceptable for internal consistency. For the qualitative component, trustworthiness was established through triangulation, member checking, audit trails, and rich, thick description. Triangulation involved comparing findings from surveys, interviews, and Focus Group Discussions to validate recurring themes and interpretations. Member checking was conducted by allowing participants to review and verify interview transcripts and thematic interpretations to ensure accuracy and credibility. An audit trail documenting the research procedures, coding processes, and analytical decisions was maintained to strengthen dependability and transparency. Furthermore, detailed contextual descriptions of participants' experiences were provided to improve transferability and deepen the understanding of AI-assisted personalized Science instruction in vocational education settings.

Results and Discussion

Extent of Students' Exposure to Generative AI Tools in Personalized Science Instruction Within Vocational Schools

Table 1 indicates that students reported a generally high level of exposure to Generative Artificial Intelligence (GenAI) tools in personalized Science instruction, as reflected in the overall grand mean of 3.77 (SD = 1.14), interpreted as "Agree." This finding suggests that GenAI technologies have become increasingly integrated into vocational science classrooms and are being used as instructional resources to support differentiated, learner-centered instruction. The positive ratings across all four dimensions indicate that students recognize the educational value of AI in facilitating personalized learning experiences that accommodate diverse learning needs, varying academic readiness, and competency-based instructional requirements.

Among the four dimensions, Content Delivery obtained the highest grand mean ($M = 3.81$, $SD = 1.13$), closely followed by Instructional Support ($M = 3.80$, $SD = 1.12$). These findings suggest that students perceive GenAI primarily as an instructional facilitator that organizes scientific information, simplifies complex concepts, and presents content in ways that are easier to comprehend. The ability of AI systems to generate adaptive explanations, provide examples, and respond to learners' questions appears to enhance the accessibility of science instruction, particularly within vocational education, where students possess diverse academic backgrounds and learning abilities.

Table 1. *Level of Students' Exposure to Generative AI Tools in Personalized Science Instruction in Vocational Schools in Terms of Instructional Support, Content Delivery, Assessment and Feedback, and Learner Engagement*

Dimensions and Indicators	M	SD	Interpretation
Instructional Support			
Generative AI tools help me understand Science lessons more clearly.	3.72	1.05	Agree
AI tools provide explanations suited to my learning needs.	3.81	1.11	Agree
AI tools assist me in completing Science-related activities.	3.77	1.19	Agree
AI tools help simplify difficult Science concepts.	3.87	1.13	Agree
AI tools provide additional learning resources for Science subjects.	3.84	1.10	Agree
Grand Mean	3.80	1.12	Agree
Content Delivery			
AI-generated explanations make Science lessons more understandable.	3.73	1.17	Agree
AI tools present scientific information in an organized manner.	3.78	1.13	Agree
AI tools provide interactive learning experiences in Science.	3.84	1.07	Agree
AI tools make Science lessons more engaging.	3.81	1.18	Agree
AI tools help deliver lessons according to my learning pace.	3.91	1.10	Agree
Grand Mean	3.81	1.13	Agree
Assessment and Feedback			
AI tools provide immediate feedback on my Science activities.	3.63	1.17	Agree
AI tools help me identify mistakes in my answers.	3.79	1.15	Agree
AI tools help me improve my performance in Science tasks.	3.66	1.24	Agree
AI tools provide useful practice questions and exercises.	3.73	1.15	Agree
AI feedback helps me better understand Science topics.	3.78	1.13	Agree
Grand Mean	3.72	1.17	Agree
Learner Engagement			
AI tools increase my interest in Science subjects.	3.77	1.14	Agree
I actively participate in Science learning when using AI tools.	3.68	1.14	Agree
AI tools encourage me to explore Science topics independently.	3.78	1.12	Agree
AI-assisted learning makes Science classes more enjoyable.	3.82	1.12	Agree
AI tools motivate me to study Science more frequently.	3.71	1.10	Agree
Grand Mean	3.75	1.12	Agree
<i>Likert Scale Interpretation: 4.21–5.00 = Strongly Agree; 3.41–4.20 = Agree; 2.61–3.40 = Neutral; 1.81–2.60 = Disagree; 1.00–1.80 = Strongly Disagree</i>			

This finding supports the Constructivist Learning Theory, which posits that knowledge is actively constructed through meaningful interaction, reflection, and engagement with learning resources rather than passively received from teachers. Generative AI provides immediate explanations, multiple representations of scientific concepts, and opportunities for iterative questioning, allowing learners to build understanding according to their individual needs. Consequently, AI serves as a cognitive scaffold that supports conceptual development while promoting active knowledge construction, rather than simple information retrieval. The findings also reinforce Self-Determination Theory, which argues that personalized instructional environments foster learners' autonomy and competence by allowing them to regulate their own learning pace and seek individualized academic support.

These findings are consistent with those of previous studies demonstrating that Generative AI has become an effective educational partner capable of supporting adaptive tutoring and personalized instruction. AI-driven educational platforms have been shown to greatly enhance students' grasp of concepts by providing explanations specifically designed to meet their cognitive requirements (Ogata et al., 2023). A systematic review by Gunsaldi et al. (2025) found that generative AI improves science education by offering conversational explanations, supporting inquiry-based learning, and allowing students to repeatedly review challenging scientific concepts until they grasp them fully. A meta-analysis similarly revealed that incorporating AI-supported instruction into STEM education, especially when combined with effective teaching methods, consistently enhances academic performance, student engagement, and understanding of concepts (Wang & Zhao, 2024).

At the indicator level, the highest-rated statement was "AI tools help deliver lessons according to my learning pace" (M = 3.91, SD = 1.10), indicating that students highly valued AI's capacity to facilitate self-paced and personalized learning. This finding reflects the instructional realities of vocational education, where students often differ considerably in their prior knowledge, technical competence, and academic preparedness. Personalized pacing allows learners to revisit challenging concepts without the pressure of keeping pace with the entire class, thereby reducing cognitive overload and enhancing their conceptual mastery. These results correspond with the findings of Short and Shemshack (2023) and Idowu (2024), who argued that personalized learning environments

increase learner autonomy, improve self-regulated learning, and accommodate individual differences more effectively than traditional teacher-centered instruction. Likewise, Almerino and Mangansat (2025), Ellikkal and Rajamohan (2024), and Ratniyom et al. (2025) found that AI-driven adaptive learning systems encourage independent learning and allow students to engage with scientific concepts at a pace consistent with their cognitive readiness.

Conversely, Assessment and Feedback obtained the lowest grand mean ($M = 3.72$, $SD = 1.17$), while the lowest-rated indicator was "AI tools provide immediate feedback on my Science activities" ($M = 3.63$, $SD = 1.17$). Although these scores remain within the "Agree" category, they suggest that students perceive AI-generated feedback as less effective than its instructional and explanatory functions. One possible explanation is that vocational science education frequently requires authentic assessment, laboratory performance, procedural demonstrations, and context-specific evaluation that extend beyond the current capabilities of most generative AI systems. While AI can rapidly generate responses, students may perceive such feedback as insufficiently personalized or lacking the pedagogical judgment necessary to evaluate practical competencies accurately and effectively.

This finding corroborates the previous literature highlighting the limitations of Generative AI in educational assessment. Cooper (2023) argued that AI-generated feedback often lacks contextual awareness and may not adequately diagnose learners' misconceptions or provide discipline-specific formative assessments. Similarly, Mimoudi (2025) observed that although students appreciate the speed and accessibility of AI-generated responses, they continue to rely on teachers for nuanced explanations, evaluative judgments, and authentic feedback on complex scientific reasoning. These findings reinforce the notion that AI functions most effectively as a supplementary instructional resource rather than as a replacement for teacher expertise in competency-based vocational education.

Furthermore, the relatively large standard deviations across all dimensions ($SD > 1.00$) indicate moderate variability in students' experiences with GenAI-assisted learning. Although the overall results demonstrated positive perceptions, the dispersion suggests that the educational benefits of AI were not experienced equally by all learners. Such variability may be attributed to differences in digital literacy, access to technological resources, familiarity with AI applications, teaching strategies, and institutional support for AI integration.

The variability observed in the present study aligns with research on the second digital divide, which argues that educational inequalities increasingly arise from differences in digital competence and the ability to use technology effectively, rather than from technology access alone. Gabriel (2024) emphasized that students possessing stronger AI literacy and digital skills derive substantially greater educational benefits from AI-assisted learning environments. Similarly, Colegado (2025) reported that inconsistent technological infrastructure, unstable Internet connectivity, and unequal access to digital devices continue to influence students' experiences with AI integration in vocational education. These findings suggest that the successful implementation of GenAI requires not only technological availability but also comprehensive digital literacy initiatives, teacher professional development, and institutional investments that ensure equitable access to AI-supported learning opportunities.

From the perspective of the Technology Acceptance Model (TAM), the consistently positive ratings across instructional support and content delivery indicate that students perceive Gen AI as both useful and relatively easy to use, two constructs that strongly predict technology acceptance and continued usage. According to the TAM, learners are more likely to adopt educational technologies when they perceive tangible improvements in learning efficiency and academic performance. The present findings therefore suggest that vocational students are willing to embrace AI-assisted instruction because they recognize its practical value in supporting science learning rather than simply because of its technological novelty.

Overall, the findings demonstrate that Generative AI has become a valuable instructional support tool within vocational science education by facilitating personalized content delivery, adaptive learning, and learner autonomy. However, the comparatively lower ratings for assessment and feedback, together with the variability in students' experiences, indicate that effective AI integration depends on more than technology availability alone. Maximizing the educational potential of GenAI requires pedagogically informed instructional design, teacher guidance, ethical AI implementation, and equitable digital access. Consequently, AI should not be viewed as a substitute for teachers but as a complementary instructional partner capable of enhancing personalized science learning when integrated within sound educational practices.

Extent of Students' Perception of Effectiveness of Generative AI Tools

Table 2 presents students' perceptions regarding the effectiveness of Generative Artificial Intelligence (GenAI) tools in supporting personalized Science learning. Overall, the findings indicate that students perceived GenAI as an effective instructional resource across all four dimensions, with all grand mean scores falling within the "Agree" category. These results suggest that students recognize the educational value of AI not only in improving conceptual understanding but also in enhancing motivation, encouraging participation, and providing academic support throughout the learning process. Such findings demonstrate that GenAI has the potential to facilitate personalized learning experiences by responding to learners' individual needs while supporting competency-based Science instruction in vocational education.

Table 2. *Level of Students' Perceived Effectiveness of Generative AI Tools in Personalized Science Learning in Terms of Understanding of Concepts, Motivation, Participation, and Academic Support*

Dimensions and Indicators	M	SD	Interpretation
Understanding of Concepts			
AI tools improve my understanding of Science concepts.	3.82	1.08	Agree
AI-generated examples help clarify difficult lessons.	3.75	1.17	Agree
AI tools help me retain Science information better.	3.80	1.08	Agree
AI tools help connect Science lessons to real-life situations.	3.76	1.11	Agree
AI tools improve my critical thinking in Science subjects.	3.79	1.22	Agree
Grand Mean	3.78	1.13	Agree
Motivation			
AI tools motivate me to learn Science topics.	3.98	1.06	Agree
AI-supported learning increases my confidence in Science.	3.70	1.17	Agree
AI tools encourage me to complete Science activities on time.	3.74	1.12	Agree
AI tools make me more interested in Science learning.	3.76	1.20	Agree
AI tools inspire me to explore additional Science materials.	3.73	1.14	Agree
Grand Mean	3.78	1.14	Agree
Participation			
AI tools encourage me to participate in Science discussions.	3.72	1.18	Agree
I ask more questions during Science learning when using AI tools.	3.86	1.06	Agree
AI tools make me more active in Science-related activities.	3.72	1.07	Agree
AI tools help me collaborate better with classmates.	3.70	1.19	Agree
AI-assisted learning increases my classroom participation.	3.52	1.23	Agree
Grand Mean	3.70	1.15	Agree
Academic Support			
AI tools provide helpful academic assistance in Science subjects.	3.85	1.15	Agree
AI tools help me complete assignments more effectively.	3.59	1.23	Agree
AI tools help me prepare for Science examinations.	3.70	1.17	Agree
AI tools provide reliable information for Science learning.	3.75	1.16	Agree
AI tools support my overall academic performance in Science.	3.68	1.23	Agree
Grand Mean	3.71	1.19	Agree

Likert Scale Interpretation: 4.21–5.00 = Strongly Agree; 3.41–4.20 = Agree; 2.61–3.40 = Neutral; 1.81–2.60 = Disagree; 1.00–1.80 = Strongly Disagree.

Among the four dimensions, Understanding of Concepts and Motivation both obtained the highest grand mean ($M = 3.78$), indicating that students considered AI particularly effective in strengthening conceptual learning while sustaining their interest in Science. These findings suggest that learners value AI primarily because it simplifies abstract scientific concepts, provides individualized explanations, and creates learning experiences that are more engaging and meaningful. Within Constructivist Learning Theory, these results imply that AI promotes knowledge construction by enabling learners to actively interact with scientific ideas, ask questions, receive immediate explanations, and revisit difficult concepts until meaningful understanding is achieved. Rather than functioning as a passive information source, GenAI appears to operate as a cognitive scaffold that supports conceptual change and deeper scientific reasoning.

The findings also align with Self-Determination Theory, which emphasizes that students become more intrinsically motivated when learning environments support autonomy, competence, and relatedness. The positive ratings for motivation indicate that AI-assisted instruction allows learners to control their learning pace, receive individualized assistance, and experience greater confidence in completing Science tasks. These conditions

strengthen students' perceptions of competence and autonomy, which are essential psychological needs associated with sustained academic motivation and self-regulated learning. Consequently, GenAI appears to foster not only cognitive development but also motivational engagement by empowering learners to take greater responsibility for their own learning.

These findings are consistent with recent evidence demonstrating the effectiveness of generative AI in Science education. A meta-analysis by Wang and Zhao (2024) concluded that AI-supported instruction significantly improves conceptual understanding, learner motivation, academic achievement, and engagement when integrated with sound pedagogical strategies. Similarly, the systematic review conducted by Ching Cheung et al. (2026) reported that generative AI enhances science learning by providing adaptive explanations, facilitating inquiry-based learning, and supporting scientific reasoning through conversational interactions. Likewise, Ogata et al. (2023) demonstrated that explainable AI systems improve conceptual learning by delivering personalized instructional support that accommodates learners' varying cognitive needs. Collectively, these studies support the present finding that vocational students perceive AI as particularly effective in improving conceptual understanding and maintaining learning motivation.

At the indicator level, the highest-rated statement was "AI tools motivate me to learn Science topics" ($M = 3.98$, $SD = 1.06$), indicating that students viewed AI as a powerful motivational resource. The interactive, responsive, and personalized nature of AI likely increases learners' curiosity and willingness to engage with scientific content. Unlike conventional instructional materials, GenAI enables immediate dialogue, personalized explanations, and continuous academic support, thereby creating more engaging learning experiences. Previous research similarly found that AI-assisted learning environments increase students' curiosity, self-efficacy, and willingness to explore additional learning materials independently (Bankole & Ayanwale, 2025; Sevgi & Minal, 2025; Torralba, 2025). These findings suggest that AI promotes intrinsic motivation by making Science learning more interactive, accessible, and personally meaningful.

In contrast, Participation obtained the lowest grand mean ($M = 3.70$, $SD = 1.15$), while the lowest-rated indicator was "AI-assisted learning increases my classroom participation" ($M = 3.52$, $SD = 1.23$). Although students generally agreed that AI encouraged participation, the comparatively lower ratings indicate that its influence on collaborative learning and classroom interaction remains limited. One possible explanation is that most interactions with generative AI occur individually rather than socially. Students typically engage with AI through independent questioning, self-paced exploration, and individualized feedback rather than through collaborative discussions with peers or teachers. Consequently, while AI enhances cognitive engagement, it may not necessarily translate into increased interpersonal participation within classroom settings.

This finding is supported by previous literature emphasizing that AI primarily facilitates individualized learning rather than collaborative engagement. Chan and Hu (2023) argued that although AI strengthens cognitive engagement and self-directed learning, it cannot fully replace the social interactions and collaborative learning experiences that occur within teacher-guided classrooms. Similarly, Chan and Zhou (2023) noted that generative AI lacks the social presence necessary to foster meaningful peer interaction and collaborative knowledge construction. Mimoudi (2025) likewise reported that students frequently perceive AI as an effective personal tutor but continue to depend on teachers and classmates for discussion, collaborative problem-solving, and social learning experiences. These findings suggest that AI should complement, rather than replace, collaborative pedagogical strategies in vocational Science education.

The Academic Support dimension also received positive evaluations ($M = 3.71$, $SD = 1.19$), indicating that students considered AI useful for completing assignments, preparing for examinations, and accessing additional learning resources. Nevertheless, relatively lower ratings for assignment completion and overall academic performance suggest that students continue to rely on teachers when performing complex learning tasks requiring higher-order thinking, contextual interpretation, or authentic performance assessment. This finding reinforces the view that AI functions most effectively as a supplementary instructional resource that enhances teacher-guided instruction rather than serving as an autonomous educational system. Previous studies similarly conclude that AI improves learning efficiency and academic productivity while remaining dependent upon effective teacher facilitation and pedagogically sound instructional design (Bai, 2024; Li et al., 2025; Zhou & Zhou, 2024).

Furthermore, the relatively high standard deviations across all dimensions ($SD > 1.00$) indicate moderate

variability in students' perceptions of AI effectiveness. Although the overall evaluations were positive, the variability suggests that students do not experience AI-assisted learning uniformly. Differences in AI literacy, digital competence, access to stable internet connectivity, prior experience with AI technologies, and teacher implementation strategies may explain these variations. Such findings are consistent with research on the second digital divide, which argues that disparities in educational outcomes increasingly result from differences in learners' digital competencies and institutional support rather than simple access to technology. Gabriel (2024) and Kanont et al. (2024) similarly observed that students possessing stronger digital literacy derive greater educational benefits from AI-supported learning environments, whereas limited technological resources reduce the effectiveness of AI integration.

From the perspective of the Technology Acceptance Model (TAM), these findings suggest that students' positive perceptions of GenAI are largely explained by its perceived usefulness and ease of use. The consistently positive ratings across conceptual understanding, motivation, participation, and academic support indicate that learners recognize AI as a valuable educational technology capable of improving learning efficiency and instructional effectiveness. According to TAM, such perceptions significantly influence students' willingness to continue using AI in future learning activities. Therefore, the present findings suggest that vocational students' acceptance of AI is driven primarily by its demonstrated educational value rather than by technological novelty alone.

Overall, the findings demonstrate that Generative AI is perceived as an effective instructional partner that enhances conceptual understanding, increases learning motivation, and provides meaningful academic support in vocational Science education. However, its comparatively weaker influence on classroom participation highlights the continuing importance of collaborative learning, teacher facilitation, and human interaction in Science instruction. Consequently, the educational value of AI lies not in replacing teachers but in complementing evidence-based pedagogical practices that promote personalized, engaging, and equitable learning experiences for vocational students.

Relationship Between Students’ Exposure to Generative AI Tools and their Perceived Learning Experiences

Table 3. *Relationship Between Students’ Exposure to Generative AI Tools and Perceived Effectiveness in Personalized Science Learning*

Variables	Spearman’s rho	p-value	Decision	Level of Relationship	Interpretation
Exposure and Perceived Effectiveness	.055	.443	Fail to Reject H ₀	Very Weak Relationship	No Significant Relationship

The Spearman's rho correlation analysis revealed that the relationship between students' exposure to Generative Artificial Intelligence (GenAI) tools and their perceived effectiveness in personalized Science learning was not statistically significant ($\rho = .055$, $p = .443$), resulting in the failure to reject the null hypothesis. The correlation coefficient indicates a very weak positive relationship, suggesting that the frequency with which students were exposed to GenAI tools had little influence on how effective they perceived those tools to be in supporting their Science learning.

Although students generally reported positive exposure to GenAI and favorable perceptions of its effectiveness (Tables 1 and 2), the absence of a statistically significant association suggests that exposure alone is insufficient to enhance students' learning experiences. Rather than the amount of AI use, the educational value of GenAI appears to depend on how the technology is implemented, the quality of teacher facilitation, students' AI literacy, instructional design, and the alignment of AI activities with competency-based Science learning objectives. In other words, simply increasing students' access to AI does not automatically translate into improved learning outcomes unless meaningful pedagogical practices accompany its integration.

This finding can be interpreted through the lens of Constructivist Learning Theory, which argues that meaningful learning emerges from learners' active construction of knowledge through purposeful interaction, reflection, and authentic learning experiences. Constructivism suggests that technology itself does not produce learning; rather, learning occurs when students meaningfully engage with instructional activities that promote inquiry, critical thinking, and conceptual understanding. Consequently, students who experience similar levels of AI exposure may develop substantially different learning outcomes depending on how they interact cognitively with AI-generated explanations and how effectively teachers facilitate these learning experiences. The present findings therefore reinforce the constructivist view that instructional quality is more influential than technological

exposure alone.

Similarly, the findings are consistent with the Technology Acceptance Model (TAM), which proposes that users' perceptions of usefulness and ease of use are stronger determinants of successful technology adoption than simple frequency of use. Students may interact with AI frequently without perceiving substantial educational benefits if the technology fails to improve conceptual understanding, solve authentic learning problems, or support meaningful engagement. Conversely, even limited exposure may produce highly positive learning experiences when AI is integrated strategically into instruction. The lack of a significant relationship therefore suggests that the educational effectiveness of GenAI depends primarily on students' perceptions of its usefulness rather than the amount of time spent using it.

The findings also support Self-Determination Theory, which emphasizes that meaningful learning occurs when instructional environments satisfy learners' psychological needs for autonomy, competence, and relatedness. Although AI can provide personalized learning opportunities, motivation and perceived effectiveness are unlikely to improve solely because students have access to AI technologies. Instead, learners must perceive that AI enhances their competence, supports independent learning, and complements meaningful interactions with teachers and peers. Therefore, exposure becomes educationally valuable only when AI contributes to learners' intrinsic motivation and meaningful engagement with Science content.

The present findings are consistent with recent literature emphasizing that the educational impact of GenAI depends more on pedagogical integration than technological exposure. Brandão et al. (2024) argued that successful AI implementation requires instructional designs that deliberately integrate AI into meaningful learning activities rather than simply increasing students' opportunities to use digital tools. Likewise, Zhang (2025) reported that AI effectiveness is largely influenced by instructional context, learner readiness, and teacher competence rather than usage frequency. These findings reinforce the growing consensus that AI functions most effectively as a pedagogical resource rather than as an independent instructional solution.

The absence of a significant relationship also aligns with research on the second digital divide, which suggests that differences in digital competence increasingly explain variations in educational outcomes. Gabriel (2024) emphasized that students possessing stronger AI literacy, digital problem-solving skills, and critical evaluation abilities derive substantially greater educational benefits from AI-supported learning than students who merely have access to the technology. Similarly, Mimoudi (2025) found that learners' ability to formulate effective prompts, evaluate AI-generated information critically, and integrate AI responses into meaningful learning activities strongly influences the educational value they obtain from generative AI systems. These findings suggest that AI literacy functions as a mediating factor between technology exposure and educational effectiveness.

Within the Philippine vocational education context, the findings may also reflect institutional and infrastructural constraints affecting AI implementation. Previous studies indicate that many vocational institutions continue to experience unstable internet connectivity, unequal access to digital devices, and limited professional development opportunities for teachers implementing AI-assisted instruction. Consequently, exposure to AI technologies often occurs at a basic or substitution level rather than through transformative pedagogical applications capable of significantly improving learning experiences. Colegado (2025) and Flores and Adlaon (2022) similarly reported that digital technologies in Philippine classrooms frequently supplement existing instructional practices without substantially transforming student learning. Therefore, increasing exposure alone may not be sufficient unless accompanied by improvements in instructional quality, technological infrastructure, and teacher capacity.

Overall, the absence of a statistically significant relationship should not be interpreted as evidence that GenAI lacks educational value. Instead, the findings indicate that effective AI integration depends less on the quantity of exposure and more on the quality of implementation. Meaningful learning outcomes emerge when AI is embedded within pedagogically sound instructional strategies, supported by competent teachers, aligned with curriculum objectives, and accompanied by students' digital literacy and critical AI competencies. These findings contribute to the growing body of evidence suggesting that Generative AI should be viewed as a pedagogical catalyst rather than a standalone educational intervention, emphasizing that successful implementation requires thoughtful instructional design, ethical AI practices, and equitable access to digital learning opportunities.

Qualitative Findings

This thematic analysis explored the lived experiences of vocational students' use of Generative AI tools in science learning. Using Braun and Clarke's six-phase thematic analysis approach, five major themes emerged from the responses: (1) Simplifying Science Learning, (2) Enhancing Academic Efficiency and Performance, (3) Promoting Engagement and Independent Learning, (4) Struggles with Reliability and Overdependence, and (5) Barriers to Accessible AI Learning. These themes collectively describe both the benefits and challenges students experience while integrating AI into their Science education.

Theme 1: Simplifying Science Learning

Many participants described Generative AI as a useful learning tool that simplifies difficult Science concepts through clear explanations, examples, and personalized assistance. Students appreciated how AI translated complex scientific ideas into easier and more understandable language.

"It explains difficult topics in simple words."

(Respondent 1)

"Generative AI helps me understand Physics topics because it provides examples and simplified explanations."

(Respondent 5)

"I use Generative AI to translate difficult scientific terms into simpler language."

(Respondent 8)

"It provides personalized explanations based on my questions."

(Respondent 15)

The findings indicate that Generative AI supports personalized Science learning by adapting explanations to students' learning needs. Vocational students perceived AI as a supportive educational tool that improves comprehension and reduces the difficulty of Science subjects. This suggests that AI has strong potential in assisting students who struggle with complex scientific concepts.

Theme 2: Enhancing Academic Efficiency and Performance

Participants highlighted that AI improved their academic productivity by helping them complete assignments, prepare for reviews, organize notes, and manage study time more effectively. Many students also reported improvements in grades and academic confidence.

"I gained a better understanding of lessons, faster assignment completion, and improved confidence during class discussions."

(Respondent 1)

"It helped me save time and improved my understanding of scientific concepts."

(Respondent 2)

"I learned lessons faster and improved my grades in Science subjects."

(Respondent 4)

"It improved my time management and understanding of lessons."

(Respondent 10)

This theme demonstrates that Generative AI contributes to learning efficiency and academic achievement. Students valued the speed and convenience of AI-generated support, which enabled them to complete tasks more efficiently and prepare effectively for assessments. The findings suggest that AI can enhance students' academic performance when used appropriately.

Theme 3: Promoting Engagement and Independent Learning

Students described AI as motivating, interactive, and helpful in encouraging independent learning. Participants reported becoming more curious, self-directed, and active in their learning experiences.

"I became more independent in learning and more active in doing research activities."
(Respondent 3)

"I gained additional knowledge and became more motivated to learn."
(Respondent 7)

"It increased my curiosity and encouraged self-paced learning."
(Respondent 13)

"I learned lessons more effectively and became more interested in Science."
(Respondent 12)

The findings reveal that AI tools encourage learner autonomy and active participation in Science education. Students were not only passive recipients of information but also became more engaged in exploring lessons independently. This indicates that AI may promote self-directed learning behaviors among vocational students.

Theme 4: Struggles with Reliability and Overdependence

Despite the benefits of AI, participants also expressed concerns about inaccurate information, inconsistent responses, and overdependence on AI-generated answers. Some students were worried that excessive use of AI might reduce critical thinking skills.

"Sometimes the AI gives incorrect answers or explanations."
(Respondent 1)

"I struggle in identifying whether the information is accurate or not."
(Respondent 5)

"Sometimes I become too dependent on AI, which affects my own critical thinking."
(Respondent 3)

"I worry that students may misuse AI by relying on it too much."
(Respondent 10)

This theme highlights the limitations and ethical concerns associated with AI-assisted learning. Although students recognized AI's usefulness, they also acknowledged the need to verify information and maintain independent thinking skills. The findings suggest that responsible and balanced use of AI is necessary to prevent misinformation and excessive dependence on it.

Theme 5: Barriers to Accessible AI Learning

Participants identified several barriers to their effective use of Generative AI, including unstable internet connections, limited access to devices, paid features, and technical issues.

"I experienced internet connectivity problems and limited access to devices."
(Respondent 2)

"I encountered problems when the AI requires payment for advanced features."
(Respondent 7)

"I experienced difficulty when there is no stable internet connection."
(Respondent 9)

"I find it difficult to use sometimes because of technical issues and slow devices."
(Respondent 13)

The findings demonstrate that technological and financial limitations remain significant barriers to AI integration

in vocational education. Students from resource-limited environments may struggle to maximize the benefits of AI tools due to poor connectivity, limited device access, and restricted access to premium features.

The thematic analysis revealed that vocational students generally perceive Generative AI as a beneficial tool for personalized learning in Science. AI supports comprehension, academic performance, motivation, and independent learning. However, students also experience challenges related to information reliability, overdependence, and technological accessibility. These findings suggest that while Generative AI has strong educational potential, its effective use requires proper guidance, digital literacy, and equitable access to technological resources.

The study concludes that Generative AI tools significantly influence vocational students' Science learning experiences by simplifying lessons, improving academic efficiency, and promoting independent learning. Nevertheless, concerns about accuracy, dependence, and accessibility underscore the need for responsible AI integration in educational settings. Schools and educators should provide proper supervision and digital literacy training to ensure that students use AI effectively and critically in Science education.

Integration of Quantitative and Qualitative Findings

The integration of quantitative and qualitative findings revealed both expansive and divergent relationships, deepening the understanding of vocational students' experiences with Generative AI (GenAI) tools in personalized Science learning. While the quantitative strand generally demonstrated positive perceptions of AI exposure and effectiveness, the qualitative findings provided contextual explanations that complicated and nuanced these statistical trends. In particular, the divergence between the non-significant correlation results and the strongly positive qualitative narratives suggests that students' lived experiences with AI cannot be fully explained through frequency-based quantitative indicators alone.

One major finding emerged regarding classroom participation and learner engagement. Quantitatively, Participation obtained the lowest mean among the perceived effectiveness dimensions, suggesting that AI had only a moderate influence on students' classroom involvement. However, the qualitative findings revealed that students experienced increased independence, curiosity, and self-directed learning behaviors when using AI tools. The distinction between behavioral participation and cognitive engagement may explain this apparent discrepancy. Quantitative measures tended to operationalize participation through observable classroom interaction, collaboration, and verbal involvement, whereas students qualitatively emphasized internal forms of engagement such as autonomous exploration, self-paced learning, and independent research. Thus, the qualitative data expanded the meaning of "participation" beyond traditional classroom behaviors.

Another expansive pattern appeared in the area of assessment and feedback. Although students generally agreed that AI tools provided academic assistance, the Assessment and Feedback dimension received the lowest quantitative ratings. The qualitative findings clarified this trend by revealing concerns regarding inaccurate responses, unreliable information, and excessive dependence on AI-generated answers. These findings suggest that while students appreciate the convenience and immediacy of AI-generated support, they remain cautious about its credibility and instructional reliability. The qualitative strand therefore provided explanatory depth that could not be captured solely through numerical ratings.

The most significant divergent finding concerned the absence of a statistically significant relationship between students' exposure to GenAI tools and their perceived effectiveness in learning. Quantitatively, the Spearman's rho analysis indicated that greater exposure to AI tools did not correspond to higher levels of perceived learning effectiveness. In contrast, the qualitative findings portrayed AI as highly beneficial in simplifying lessons, increasing motivation, improving efficiency, and supporting independent learning. This divergence suggests that students' positive experiences with AI may not necessarily depend on the amount of exposure, but rather on the *quality, intentionality, and context* of AI use.

Table 4. Joint Display of Quantitative and Qualitative Findings on Vocational Students' Experiences with Generative AI Tools in Personalized Science Learning

Concept/Dimension	Quantitative Evidence	Qualitative Evidence	Integration Outcome
Instructional Support and Concept Clarification	Students reported high exposure to AI-supported instructional assistance (M = 3.80, SD = 1.12). Students agreed that AI tools help simplify difficult Science concepts (M = 3.87).	Theme 1: <i>Simplifying Science Learning</i> revealed that students perceived AI as helpful in translating complex concepts into understandable explanations. Representative quote: "It explains difficult topics in simple words." (Respondent 1)	Convergent
Personalized and Self-Paced Learning	The highest-rated indicator in RQ1 was "AI tools help deliver lessons according to my learning pace" (M = 3.91, SD = 1.10).	Theme 3: <i>Promoting Engagement and Independent Learning</i> emphasized that AI supports self-paced and autonomous learning. Representative quote: "It increased my curiosity and encouraged self-paced learning." (Respondent 13)	Convergent
Content Delivery and Understanding of Concepts	Content Delivery had the highest mean dimension score (M = 3.81, SD = 1.13), while Understanding of Concepts also received positive ratings (M = 3.78, SD = 1.13).	Theme 1 highlighted that AI-generated explanations and examples improve comprehension of scientific lessons. Representative quote: "Generative AI helps me understand Physics topics because it provides examples and simplified explanations." (Respondent 5)	Convergent
Motivation and Interest in Science Learning	Motivation obtained a high grand mean (M = 3.78, SD = 1.14). The highest-rated item was "AI tools motivate me to learn Science topics" (M = 3.98, SD = 1.06).	Theme 3 demonstrated that AI increases curiosity, interest, and enthusiasm for learning. Representative quote: "I gained additional knowledge and became more motivated to learn." (Respondent 7)	Convergent
Academic Efficiency and Performance	Academic Support was perceived positively (M = 3.71, SD = 1.19), particularly regarding academic assistance and examination preparation.	Theme 2: <i>Enhancing Academic Efficiency and Performance</i> showed that students used AI to complete assignments more quickly, organize study materials, and improve their grades. Representative quote: "It helped me save time and improved my understanding of scientific concepts." (Respondent 2)	Convergent
Participation and Classroom Engagement	Participation received the lowest mean on the RQ2 dimension (M = 3.70, SD = 1.15). The lowest indicator stated that "AI-assisted learning increases my classroom participation" (M = 3.52, SD = 1.23).	Theme 3 indicated that AI mainly promotes independent rather than collaborative learning. Representative quote: "I became more independent in learning and more active in doing research activities." (Respondent 3)	Expansive
Assessment, Feedback, and Reliability Concerns	Assessment and Feedback obtained the lowest dimension mean in RQ1 (M = 3.72, SD = 1.17). The lowest-rated item was "AI tools provide immediate feedback on my Science activities" (M = 3.63, SD = 1.17).	Theme 4: <i>Struggles with Reliability and Overdependence</i> revealed concerns about AI responses that were inaccurate or inconsistent. Representative quote: "Sometimes the AI gives incorrect answers or explanations." (Respondent 1)	Expansive
Variability in Student Experiences	Standard deviations across all dimensions exceeded 1.00, indicating moderate variability in perceptions and experiences.	Theme 5: <i>Barriers to Accessible AI Learning</i> explained that internet instability, limited devices, and paid features affect students' experiences. Representative quote: "I experienced internet connectivity problems and limited access to devices." (Respondent 2)	Expansive
Exposure versus Perceived Effectiveness	Spearman's rho analysis revealed no significant relationship between exposure and perceived effectiveness ($p = .055$, $p = .443$).	Themes 1–5 collectively suggest that effectiveness depends not only on exposure but also on quality of use, digital literacy, accessibility, and responsible AI integration. Representative quote: "Sometimes I become too dependent on AI, which affects my own critical thinking." (Respondent 3)	Divergent
Ethical Concerns and Overdependence	Quantitative findings did not directly measure ethical concerns or dependence on AI.	Theme 4 identified worries regarding misinformation, reduced critical thinking, and excessive reliance on AI-generated responses. Representative quote: "I worry that students may misuse AI by relying on it too much." (Respondent 10)	Expansive

Three theoretical justifications may explain these divergent and expansive findings.

First, the Technology Acceptance Model (TAM) provides a useful explanation. TAM posits that perceived usefulness and perceived ease of use are stronger determinants of technology acceptance than frequency of exposure alone. Students may encounter AI tools frequently without perceiving them as educationally meaningful unless the tools genuinely improve comprehension, efficiency, or motivation. The qualitative findings support this perspective, as students emphasized the usefulness of AI in simplifying concepts and supporting self-paced learning rather than merely the amount of time spent using the technology.

Second, the findings may be interpreted through the lens of Constructivist Learning Theory. Constructivism emphasizes that learners actively construct knowledge through meaningful interaction, reflection, and contextualized experiences. The qualitative data revealed that students valued AI when it enabled independent exploration, curiosity, and personalized understanding. However, quantitative measures of exposure may fail to capture the depth and quality of these learning interactions. Consequently, students with similar levels of exposure may experience substantially different educational outcomes depending on how they engage cognitively with AI tools.

Third, the divergence may also be explained by the Digital Divide and Equity Framework. The qualitative findings identified unstable internet access, limited devices, technical problems, and restricted access to premium AI features as barriers to effective AI integration. These structural inequalities likely contributed to the variability observed in the quantitative data. Even when students are equally exposed to AI tools, differences in technological access, digital literacy, and learning environments may significantly influence the effectiveness of those experiences. Thus, unequal access conditions may weaken the statistical relationship between exposure and perceived effectiveness.

The combined quantitative and qualitative findings reveal that Generative AI has substantial potential to support personalized Science learning among vocational students by enhancing comprehension, motivation, academic efficiency, and independent learning. However, the effectiveness of AI-assisted learning is not determined by exposure alone. Rather, meaningful educational outcomes emerge from the quality of AI integration, students' digital literacy, contextual learning conditions, and the presence of responsible instructional guidance. The integration of both strands suggests that Generative AI functions most effectively not as a replacement for human instruction, but as a supplementary cognitive and motivational support tool that requires critical, ethical, and equitable implementation within vocational Science education.

Conclusion

The integration of Generative Artificial Intelligence (GenAI) into personalized Science instruction demonstrates considerable potential to improve vocational students' conceptual understanding, learning motivation, academic efficiency, and self-directed learning. The quantitative findings revealed that students generally perceived AI-supported instruction positively, particularly in enhancing content delivery, instructional support, and conceptual learning, while the qualitative findings provided deeper insights into how AI simplified complex scientific concepts, promoted learner autonomy, and supported individualized learning experiences. However, the absence of a statistically significant relationship between students' exposure to AI and their perceived learning effectiveness suggests that educational benefits are not determined by technology exposure alone. Rather, meaningful learning outcomes depend on pedagogically sound implementation, teacher facilitation, students' AI literacy, equitable digital access, and the purposeful integration of AI into competency-based Science instruction.

The findings contribute to the growing body of knowledge on AI-enhanced education by extending Constructivist Learning Theory, Self-Determination Theory, and the Technology Acceptance Model, demonstrating that the effectiveness of Generative AI lies in its capacity to support active knowledge construction, learner autonomy, and meaningful engagement rather than replacing the instructional role of teachers. Within the Philippine vocational education context, this study provides empirical evidence that AI should be viewed as a complementary instructional partner that strengthens personalized learning while preserving teachers' central role in facilitating inquiry, critical thinking, ethical decision-making, and authentic assessment.

The findings also have important implications for pre-service and in-service teacher education. Teacher

preparation programs may utilize this study as an evidence-based framework for developing competencies in AI-enhanced pedagogy, personalized instructional design, prompt engineering, ethical and responsible AI use, digital assessment, and critical AI literacy. Professional development initiatives may incorporate the study's findings to train Science and Technical-Vocational teachers in designing learner-centered AI-supported lessons, evaluating AI-generated content, facilitating responsible student use of AI technologies, and integrating AI into competency-based instruction while maintaining academic integrity. Strengthening these competencies will enable teachers to use Generative AI not merely as a technological innovation but as a pedagogical tool that enriches learning experiences and improves instructional quality.

Furthermore, the study provides practical guidance for curriculum developers, school leaders, and policymakers in designing institutional AI integration frameworks that promote equitable access, ethical implementation, and continuous teacher capacity building. As educational systems increasingly embrace digital transformation, investment in teacher professional development should accompany technological adoption to ensure that AI enhances – not replaces – high-quality teaching and learning.

Overall, this study underscores that the educational value of Generative AI is realized not through the frequency of its use but through the quality of its pedagogical integration. Future efforts to implement AI in vocational Science education should therefore prioritize teacher competence, evidence-based instructional design, digital equity, and responsible AI governance to create inclusive, engaging, and sustainable learning environments aligned with the goals of twenty-first-century education and Sustainable Development Goal 4 (Quality Education).

Contributions of Authors

Farrah L. Aminulla: Conceptualization, Data Curation, Formal Analysis, Investigation.

Jocelyn J. Muñoz: Formal Analysis, Data Curation, Investigation.

Al-fahad E. Jadjuli: Methodology, Writing – Original Draft Preparation, Investigation.

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References

- Ahmad, N., Murugesan, S., & Kshetri, N. (2023). Generative artificial intelligence and the education sector. *Computer*, 56(6), 72–76. <https://doi.org/10.1109/mc.2023.3263576>
- Al-Cheikh, C., Tahiri, I., & Khaldi, M. (2025). Educational artificial intelligence and intelligent tutoring systems: Foundations, evolution, and contributions to adaptive learning. *Global Journal of Engineering and Technology Advances*, 25(3), 240–246. <https://doi.org/10.30574/gjeta.2025.25.3.0356>
- Ali, H.Y., & Ekeng, O. (2024). Balancing innovation and ethics: Educators' perspectives on the role of AI in education. *The American Journal of Social Science and Education Innovations*, 6(9), 128–139. <https://doi.org/10.37547/tajsej/volume06issue09-14>
- Annam, S., Syuzita, A., Pratiwi, R., & Sarkingobir, Y. (2024). Mapping research trends on 21st-century problem-solving skills in science learning: A literature review from 2014 to 2023. *Research in Education, Technology, and Multiculture*, 3(1), 52–60. https://doi.org/10.61436/rietm/v3i1_pp52-60
- Bai, J. (2024). The application, challenges, and reflection of generative artificial intelligence in the field of education. *Education Reform and Development*, 6(10), 273–281. <https://doi.org/10.26689/erd.v6i10.8522>
- Bhatta, R. (2026). AI in education for sustainable development: A comprehensive framework for equitable and quality learning. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 12(2), 109–126. <https://doi.org/10.32628/cseit26121335>
- Bonde, L. (2024). A conceptual design of a generative artificial intelligence system for education. *International Journal of Research and Innovation in Applied Science*, 9(4), 457–469. <https://doi.org/10.51584/ijrias.2024.904034>
- Calles, A. (2025). Why technical-vocational education must be a national priority. *PINAS Gazette: Essays, Stories & Poetry*, 1(1). <https://doi.org/10.64591/fgmngw05>
- Ching Cheung, K.K., Zerouali, A., Koenen, J., & Erduran, S. (2026). Do generative artificial intelligence (GenAI) and science education mix? A systematic review of the literature. *Studies in Science Education, ahead-of-print(ahead-of-print)*, 1–29. <https://doi.org/10.1080/03057267.2025.2578091>
- Compen, B., Versteegen, D., Maussen, I., Hülsman, C., & Dolmans, D. (2024). Good practices for differentiated instruction in vocational education: The combined perspectives of educational researchers and teachers. *International Journal of Inclusive Education*, 29(6), 1017–1034. <https://doi.org/10.1080/13603116.2024.2305652>
- De La Cruz, R.J. (2022). Science education in the Philippines. In: Huang, R., *et al.* *Science Education in Countries Along the Belt & Road. Lecture Notes in Educational Technology*. Springer, Singapore. https://doi.org/10.1007/978-981-16-6955-2_20
- Idowu, E. (2024). Personalized learning: Tailoring instruction to individual student needs. Preprints. <https://doi.org/10.20944/preprints202411.0863.v1>
- Juan, H., & Nagappan, R. (2025). A comprehensive literature review on AI-enhanced autonomous learning mechanisms in vocational education. *Malaysian Journal of Social Sciences and Humanities (MJSSH)*, 10(3), e002958. <https://doi.org/10.47405/mjssh.v10i3.2958>
- Kamer, S.T. (2024). Artificial intelligence in education. *Artificial Intelligence* (pp. 235–248). CRC Press. <https://doi.org/10.1201/9781003483571-15>
- Kukreja, J., Morande, S., & Tewari, V. (2025). Empowering self-directed learners by exploring the role of generative AI-language models in fostering autonomy, competence, and relatedness. In M. Tariq & R. Sergio (Eds.), *Convergence of AI, Education, and Business for Sustainability* (pp. 93–118). IGI Global Scientific Publishing. <https://doi.org/10.4018/979-8-3373-1917-9.ch005>
- Leong, W.Y. (2025). Artificial intelligence, automation, and technical and vocational education and training: Transforming vocational training in digital era. *Engineering Proceedings*, 103(1), 9. <https://doi.org/10.3390/engproc2025103009>
- Li, Y., Shan, Z., Raković, M., Guan, Q., Gašević, D., & Chen, G. (2025). When AI explains in natural language: Unveiling the impact of generative AI explanations on educators' grading and feedback practices. *Education and Information Technology*, 30(17), 24931–24964. <https://doi.org/10.1007/s10639-025-13741-z>
- Linn, M., Donnelly-Hermosillo, D., & Gerard, L. (2023). Synergies between learning technologies and learning sciences. *Handbook of Research on Science Education* (pp. 447–498).

- Routledge. <https://doi.org/10.4324/9780367855758-19>
- Luo, Z., Jiang, J., & Zhou, H. (2024). Exploration on the application of artificial intelligence technology in vocational education teaching. *Journal of Higher Vocational Education*, 1(2), 177–182. <https://doi.org/10.62517/jhve.202416231>
- Ogata, H., Flanagan, B., Takami, K., Dai, Y., Nakamoto, R., & Takii, K. (2023). EXAIT: Educational eXplainable Artificial Intelligent Tools for personalized learning. *Research and Practice in Technology Enhanced Learning*, 19, 019. <https://doi.org/10.58459/rptel.2024.19019>
- Pierce, M., & Jiang, P. (2025). Normative influence on the adoption of generative artificial intelligence in higher education. *Journal of Marketing Education*. <https://doi.org/10.1177/02734753251397827>
- Prajuhana, A., Sarimanah, E., Rully, T., Setiawan, M.I., Sukoco, A., Sugeng, S., & Bon, A.T. (2023). Sustainable Development Goals (SDGs), digital education and digital school. *IJEED* (International Journal of Entrepreneurship and Business Development), 6(1), 163–171. <https://doi.org/10.29138/ijeed.v6i1.2114>
- Raflesia, C., Suastra, I.W., Wibawa, I.M.C., & Arnyana, I.B.P. (2026). Transformasi pendidikan sains sebagai penggerak kompetensi masa depan siswa sekolah dasar. *BIOEDUSAINS:Jurnal Pendidikan Biologi dan Sains*, 9(1), 27–34. <https://doi.org/10.31539/q7kzsg68>
- Short, C., & Shemshack, A. (2023). Personalized learning. *EdTechnica*. <https://doi.org/10.59668/371.11067>
- Singh, K.D., Singh, P., Kaur, G., Khullar, V., Chhabra, R., & Tripathi, V. (2023). Education 4.0: Exploring the potential of disruptive technologies in transforming learning. 2023 International Conference on Computational Intelligence and Sustainable Engineering Solutions (CISES), Greater Noida, India, 586–591. <https://doi.org/10.1109/cises58720.2023.10183547>
- Wang, L., & Zhao, M. (2024). Can artificial intelligence technology promote the improvement of student learning outcomes? – Meta analysis based on 50 experimental and quasi experimental studies. <https://doi.org/10.4108/eai.29-3-2024.2347685>
- Wu, Y. (2025). Integrating artificial intelligence into education: Opportunities, challenges, and response strategies. *AI Innovations and Applications*, 1(1), 115–124. <https://doi.org/10.63944/sj51.aia>
- Ye, J.-H., He, Z., Bai, B., & Wu, Y.-F. (2024). Sustainability of technical and vocational education and training (TVET) along with vocational psychology. *Behavioral Sciences* (Basel, Switzerland), 14(10), 859. <https://doi.org/10.3390/bs14100859>
- Zhou, H., & Zhou, D. (2024). Transformation of vocational education based on generative artificial intelligence: Impact, opportunity and countermeasures. <https://doi.org/10.4108/eai.24-11-2023.2343636>