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Artificial Intelligence (AI) for Problem-Solving in Chemistry Learning in Vocational High Schools: A Survey of Impact, Self-Efficacy, and Meaningfulness

Annisa Mamluaturrahmatika [a,1], Aqilatun Ni'mah [b,2*], Aldi Pascagama Nurrachman [c,3]

[a] Doctoral Study Program of Chemistry Education, Universitas Negeri Yogyakarta, Yogyakarta, 55281, Indonesia
[b] Sekolah Tinggi Agama Islam Nahdlatul Ulama Rembang, Rembang, 59261, Indonesia
[c] Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan

[1] annismtika@gmail.com ; [2] aqilatunnikmah123@gmail.com; [3] m11301822@mail.ntust.edu.tw
*corresponding author

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Abstract

The rapid development of artificial intelligence (AI) in the 21st century is transforming education into a more interactive, adaptive, and student-centred system. Chemistry instruction in vocational schools is often theoretical, lacks contextualization, and is inadequate at fostering student problem-solving. This gap highlights the mismatch between industry competency demands and current classroom practices, necessitating innovation through AI integration. This study aims to examine the impact of AI use on students' problem-solving, self-efficacy, and perceived meaningfulness in vocational chemistry learning. The study involved 158 students from SMK IPTEK Jakarta selected through cluster random sampling. Data were collected using a questionnaire and analyzed through one-way ANOVA. The ANOVA results showed a significance value of 0.056, indicating no significant differences in AI use across classes. AI integration has a positive impact on student problem-solving, increases self-efficacy, and promotes a more meaningful learning experience. Support from teachers, schools, and policymakers is crucial, along with further research to develop AI-based models and test their long-term impact.

1. INTRODUCTION

The 21st century is marked by a rapid technological revolution, including the emergence of artificial intelligence, which has significantly transformed various aspects of human life (Liu et al., 2018). Artificial Intelligence (AI) has become an integral part of everyday life across the industrial, transportation, healthcare, and education sectors (Zaenudin & Riyan, 2024). This technology not only enhances automation and efficiency but also creates a new paradigm for how humans work, think, and learn (Dita et al., 2025). This development requires the education sector to adapt and produce relevant, competent human resources to address the challenges of the digital era.

The advent of AI has brought significant changes to the education system (Popenici & Kerr, 2017). AI is not only a tool but can also serve as a learning companion, making the teaching and learning process more engaging and varied (Wardhana et al., 2024). Various AI applications enable more dynamic, interactive, and student-centred learning (Fajriati et al., 2024). AI technology can quickly analyze learning data to help teachers understand each student's strengths and weaknesses, enabling more targeted learning strategies (Oktavianus et al., 2023). AI is a crucial tool for realising more effective, efficient, and student-centred education.

Chemistry is a science subject taught at various levels of education, including vocational high schools. Chemistry learning in vocational high schools has its own characteristics, as it must connect scientific concepts with work skills relevant to students' areas of expertise (Yulistia et al., 2024). Chemistry learning in vocational high schools is oriented towards the application of scientific concepts in a vocational context that supports work competencies. However, chemistry instruction in vocational high schools is often theoretical, less engaging, and inappropriate for the vocational context students face (Purwati et al., 2022). This results in low student engagement and underdevelopment of problem-solving skills essential to technical and industrial jobs (Aisyah & Hidayatullah, 2024). Innovation in chemistry learning in vocational high schools is needed to increase student engagement relevant to the world of work.

Although various studies have shown that AI plays a significant role in improving students' scientific literacy, learning motivation, learning attitudes, and self-efficacy in English, science, and health (Chen, 2025; Fitriana, 2025; Jia & Tu, 2024; Lee et al., 2022; Ria et al., 2025), studies on the use of AI in chemistry learning are still relatively limited, especially in the context of vocational high schools. This is even though chemistry learning in vocational high schools demands contextual, workplace-relevant problem-solving, necessitating an innovative, adaptive learning approach. Although students with high self-efficacy tend to be more able to utilize AI as a learning tool effectively (Rizka, 2025; Syafitri & Pahlevi, 2026; Toha & Astuti, 2026), there has been little research specifically analyzing the relationship between AI use and problem-solving, self-efficacy, and meaningful learning in vocational chemistry learning. Therefore, this research is important for filling the empirical gap in the integration of AI into chemistry learning in vocational high schools.

Curriculum restructuring is necessary for professional development in vocational schools (Wiyarsi, 2017). The use of AI in chemistry learning in vocational schools plays a strategic role in improving learning quality, particularly in student problem-solving, thereby influencing learning impact, self-efficacy, and meaningfulness. The use of AI technology in chemistry learning offers significant opportunities to improve the quality of education. AI can bridge the gap between industry needs and meaningful classroom learning. However, integrating this technology requires in-depth research through surveys to assess its effectiveness in the context of vocational education. This research is crucial for examining students' problem-solving, which influences the impact, self-efficacy, and meaningfulness of AI use in chemistry learning in vocational schools.

2. METHOD

This study used a cross-sectional survey design, collecting data at a single point in time (Cohen et al., 2018). This study was conducted on 158 students at SMK IPTEK Jakarta, which uses AI in its learning. The sampling technique used was cluster random sampling. Data were collected using a questionnaire instrument on AI Usage, adapted from the research of Kong et al. (2025), as shown in Table 2. The questionnaire instrument was piloted on 63 samples before being used as a data collection tool. The pilot test results were used for Confirmatory Factor Analysis (CFA), as shown in Table 1.

Table 1. Goodness of Fit Indicators, CFA Results, and Their Cut-Offs

Goodness of Fit Indices	Result	Minimum requirements	Information
RMSEA	0.071	< 0.08	Fit
GFI	0.910	≥ 0.9	Fit
CFI	0.977	≥ 0.9	Fit
TLI	0.959	≥ 0.9	Fit

(Hair Jr et al., 2019)

Validity of the instrument was assessed using a Confirmatory Factor Analysis (CFA) in AMOS 26. The fit model met the goodness-of-fit criteria shown in Table 1. Table 1 presents the implications if the proposed model fits and the questionnaire items are valid and reliable in measuring the latent variable. Items can only be included in one particular factor if the minimum loading factor for each item is ≥ 0.5 (Hair Jr et al., 2019). The results of the confirmatory factor analysis indicate that 11 questionnaire items are valid and significant, with loadings above 0.5, and can be used to measure AI use for problem-solving. The resulting CFA fit model comprises three factors (dimensions) and 11 questionnaire items adapted from Kong et al. (2025), as shown in Table 2.

Table 2. AI Usage Questionnaire

Items	Number Question	Loading Factor
Impact of using AI for problem-solving		
I want to apply my AI knowledge and skills to solve problems in daily life.	Q1	0.849
I want to solve problems with AI to improve people's lives.	Q2	0.770
I want to solve problems with AI to make daily life easier.	Q3	0.789
I want to apply my AI knowledge and skills to develop interesting solutions to problems.	Q4	0.740
Self-efficacy in using AI for problem-solving		
I am good at solving problems with AI.	Q5	0.708
I am someone who can solve problems with AI.	Q6	0.884
I have the knowledge and skills to solve AI-related problems.	Q7	0.795
I have confidence in my ability to solve problems with AI.	Q8	0.803
Meaningfulness in using AI for problem-solving		
Using AI to solve problems will help me achieve my goals.	Q9	0.860
I want to be good at solving problems with AI.	Q10	0.706
Using AI to solve problems is important to me.	Q11	0.835

The research used a one-way ANOVA, which previously indicated that the data were normally distributed and homogeneous (p-value> 0.05). The normally distributed data are shown in Table 3. The significance value in the homogeneity test was 0.072. The significance value of the ANOVA test was 0.056, as shown in Table 4. A further post hoc test was then conducted, as shown in Table 5. The frequency of the results for each item was calculated as a percentage and is shown in Table 6.

Table 3. Kolmogorov-Smirnov Test Results

Class	Statistic	df	Sig.
1R1	.166	26	.065
1R2	.152	27	.114
1R3	.116	25	.200
1R4	.152	25	.138
1R5	.157	26	.098
1R6	.158	29	.063

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3. RESULTS AND DISCUSSION

Analysis of research data using a one-way ANOVA across 6 classes (1R1-1R6) showed that the data were normally distributed and homogeneous (p-value > 0.05). The ANOVA test significance value was 0.056, as shown in Table 4, indicating no difference in the use of AI across classes. This result implies that similar AI use across classes may provide equitable opportunities for all students to benefit from learning with AI, allowing them to learn anytime, anywhere and to develop new skills according to current needs (Anas & Zakir, 2024).

Table 4. One-way ANOVA Test Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	197.67	5	39.53	2.21	0.056
Within Groups	2715.52	152	17.87		
Total	2913.19	157			

Learning should not only focus on technology but also help shape students' character and social skills. For example, when using AI in the classroom, teachers should also encourage students to think critically, collaborate in problem-solving, and apply values useful in everyday life (Pratiwi & Yunus, 2025). Personalized learning supported by AI can significantly improve self-efficacy, motivation, and digital literacy (Lyu & Salam, 2025). The post hoc test results showed a p-value> 0.05, indicating no significant difference between each class and the others. The post hoc test results are shown in Table 5.

Table 5. Post Hoc Test Results

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.
1R1	1R2	-1.566	1.161	.758
	1R3	-.669	1.184	.993
	1R4	.611	1.184	.995
	1R5	-.231	1.172	1.000
	1R6	-2.718	1.142	.170
1R2	1R1	1.566	1.161	.758
	1R3	.896	1.173	.973
	1R4	2.176	1.173	.434
	1R5	1.335	1.161	.860
	1R6	-1.152	1.130	.911
1R3	1R1	.669	1.184	.993
	1R2	-.896	1.173	.973
	1R4	1.280	1.196	.892
	1R5	.438	1.184	.999
	1R6	-2.048	1.154	.485
1R4	1R1	-.611	1.184	.995
	1R2	-2.176	1.173	.434
	1R3	-1.280	1.196	.892
	1R5	-.842	1.184	.980
	1R6	-3.328	1.154	.050
1R5	1R1	.231	1.172	1.000
	1R2	-1.335	1.161	.860
	1R3	-.438	1.184	.999
	1R4	.842	1.184	.980
	1R6	-2.487	1.142	.254
1R6	1R1	2.718	1.142	.170
	1R2	1.152	1.130	.911
	1R3	2.048	1.154	.485
	1R4	3.328	1.154	.050
	1R5	2.487	1.142	.254

One of the primary challenges in chemistry learning in vocational high schools is students' ability to apply learned concepts to real-life contexts and to apply them practically in the workplace (Fahmi, 2019). This situation demands the development of logical, analytical, and strategic thinking in solving contextual problems. Problem-solving is a crucial aspect of chemistry learning because it reflects students' capacity for critical, analytical, and reflective thinking (Azizah & Nasrudin, 2022). Several studies have shown that vocational high school students still face difficulties in solving chemistry problems that require integrating scientific concepts and logical reasoning (Mubarika & Yaniawati, 2019). This study employed a 5-point Likert-scale questionnaire, ranging from "strongly disagree" to "strongly agree", and the results for each item are presented in Table 6.

Table 6. Results of Each Item

Items	Scale	Percentage (%)
Impact of using AI for problem-solving		
I want to apply my AI knowledge and skills to solve problems in daily life.	1	0.6
	2	7.6
	3	22.2
	4	59.5
	5	10.1
I want to solve problems with AI to improve people's lives.	1	0
	2	10.1
	3	24.7
	4	49.4
	5	15.8
I want to solve problems with AI to make daily life easier.	1	1.3
	2	10.1
	3	15.2
	4	60.8
	5	12.7
I want to apply my AI knowledge and skills to develop interesting solutions to problems.	1	0
	2	5.1
	3	24.1
	4	62.7
	5	8.2
Self-efficacy in using AI for problem-solving		
I am good at solving problems with AI.	1	0
	2	13.3
	3	29.1
	4	47.5
	5	10.1
I am someone who can solve problems with AI.	1	1.3
	2	22.8
	3	32.9
	4	40.5
	5	2.5
I have the knowledge and skills to solve AI-related problems.	1	1.3
	2	10.8
	3	32.9
	4	48.7
	5	6.3
I have confidence in my ability to solve problems with AI.	1	0.6
	2	5.7
	3	37.3
	4	51.3
	5	5.1

Items	Scale	Percentage (%)
Meaningfulness in using AI for problem-solving		
Using AI to solve problems will help me achieve my goals.	1	1.3
	2	7.6
	3	26.6
	4	57.6
	5	7
I want to be good at solving problems with AI.	1	0
	2	7
	3	29.1
	4	53.8
	5	10.1
Using AI to solve problems is important to me.	1	0
	2	7.6
	3	33.5
	4	50.6
	5	8.2

Chemistry is a challenging field (O'Dwyer & Childs, 2017; Rohayah, 2022) because it requires an understanding of complex, abstract concepts and the application of higher-order thinking skills (Salame & Makki, 2021; Suparwati, 2022). AI technology can help overcome these challenges, for example, by visually displaying molecular shapes, simulating chemical reactions, and providing problem-solving guidance through AI-based learning programs (Muhammad et al., 2024).

Students, with the help of AI, can more easily and realistically understand chemistry material, become more engaged in lessons, and simultaneously develop scientific skills aligned with current demands (Prastika et al., 2024). AI can create a more engaging learning environment tailored to each student's needs (Rissi & Sinaga, 2025). AI technology also encourages students to learn actively and think more critically in solving problems (Amelia et al., 2024; Szmyd & Mitera, 2024).

Learning success is determined not only by the material and methods, but also by the student's psychological condition (Nugraha, 2018). One important factor influencing learning success is the extent to which students feel confident in understanding and completing academic tasks. Self-efficacy in completing learning tasks significantly predicts students' academic success (Neroni et al., 2022). It is important to evaluate how AI technology use affects students' self-efficacy in understanding and solving chemistry problems. Students with high self-efficacy tend to be more motivated, persistent, and able to develop better learning strategies to face learning challenges (Miranda et al., 2022; Taufik & Komar, 2021).

The statement "I am good at solving problems with AI" reflects students' perceived competence in using AI, reflecting high average self-efficacy, which can encourage persistence, optimism, and the courage to try new strategies in learning. More students are being encouraged to use AI technology. Structured engagement with AI for problem-solving can strengthen self-confidence in one's ability to utilize technology to complete tasks effectively. These findings extend previous research by providing further evidence on the use of AI in learning, the role of self-efficacy, and perceived ease of use (Ahmed et al., 2025; Bergdahl & Sj, 2025; Collie et al., 2024). Students tend to feel pessimistic about achieving success and cannot develop self-efficacy if they do not have it in their lives (Wiarsana, 2020).

The statement, "I think of myself as someone who can solve problems with AI, emphasizes students' self-identity as individuals capable of utilising AI, where positive self-perceptions will increase intrinsic motivation and readiness to face academic challenges. This finding aligns with previous research that has received widespread attention and can further enhance students' confidence in learning and self-efficacy. Students can use AI to personalise learning according to their individual learning progress, which can increase confidence and self-efficacy in the task-solving process. Educators can further consider students' use of AI to foster greater confidence in the actual educational process (Ren et al., 2026).

Meanwhile, the statement "I have confidence in my ability to solve problems with AI" directly reflects students' confidence in facing complex tasks, making them more persistent in finding solutions when they encounter difficulties. Students with high self-efficacy tend to have more effective learning strategies and better academic outcomes (Tukiran et al., 2020). The statement, "Using AI to solve problems will help me achieve my goals", suggests that learning will be more optimal when students perceive a connection between the material being studied and real-life situations (Adipat et al., 2021; Haryadi & Nurmala, 2021). Therefore, learning experiences need to be designed not only to deliver information but also to ensure the material is relevant and aligned with students' learning objectives. The meaningfulness of learning reflects the extent to which the material can be understood, applied, and connected to students' real-life experiences. In chemistry learning, this aspect is crucial so that students are not merely memorizing concepts but also able to apply them in their daily lives and work environments (Gupte et al., 2021).

The statement "I want to be good at solving problems with AI" suggests that artificial intelligence has great potential to support personalised, student-oriented learning, according to research by Díaz & Nussbaum (2024). Social factors also play a significant role in encouraging positive user behaviour, enabling users to utilise AI responsibly and effectively in educational settings (Agyare et al., 2025). Furthermore, AI technology can support various learning approaches, such as critical thinking, constructivist, inquiry-based, collaborative, visual, and auditory learning, and problem-solving (Filiz et al., 2025).

It is important to balance the use of AI with learning activities that foster critical thinking and student creativity. Schools can also consider integrating AI technology to support problem-solving and student collaboration (Filiz et al., 2025). The statement "Using AI to solve problems is important to me" indicates that AI can tailor learning materials to each student's needs, thereby making the learning process more focused. Technology is not simply an additional tool but a crucial part of preparing students to face the challenges of the digital age (Fajriati et al., 2024). Furthermore, other research suggests that AI enables adaptive learning by tailoring materials based on students' needs, interests, and abilities (Anas & Zakir, 2024).

The use of AI in chemistry learning has implications for improving the quality of learning through the visualisation of abstract concepts, simulations, and personalised learning, thereby increasing student engagement, critical thinking, problem-solving, and self-efficacy in understanding the material more meaningfully and contextually, with real-world and work-world applications. Teachers and schools need to integrate AI in a balanced way alongside learning strategies that encourage social interaction, creativity, and character development. Further research is recommended to develop AI-based learning models integrated with constructivist, inquiry-based, and collaborative approaches, and to conduct experimental and longitudinal studies to examine long-term impacts while expanding research on variables such as creativity, digital literacy, and social factors that influence the application of AI in education.

4. CONCLUSION

This study shows that the use of AI in chemistry instruction in vocational high schools positively impacts students' problem-solving, self-efficacy, and the meaningfulness of learning. One-way ANOVA results showed no differences in AI use between classes, indicating equitable acceptance and the potential for widespread AI implementation. AI provides flexibility to learn anytime, anywhere and supports the development of students' character and social skills. Concept visualisations, reaction simulations, and AI-based guidance can facilitate students' understanding of the material, increase their interest in participating in lessons, and develop the critical, logical, and strategic thinking needed in the workplace. AI also strengthens the meaningfulness of learning by connecting the subject matter to students' real-life and vocational contexts. The integration of AI into chemistry learning in vocational high schools has great potential to create a more adaptive, interactive, and contextually relevant learning process, aligned with the needs of the times and the demands of the workplace. AI not only addresses learning challenges but also opens new opportunities for sustainable innovation in vocational education. The use of AI in chemistry learning has the potential to improve learning quality through visualisation of abstract concepts, simulations, and personalised learning that encourage student engagement, critical thinking, problem-solving, and self-efficacy. Teachers and schools need to balance AI implementation with learning strategies that foster social interaction, creativity, and character development in students. Further research is recommended to develop AI-based learning models integrated with constructivist, inquiry-based, and collaborative approaches and to test their long-term impact through experimental and longitudinal studies.

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REFERENCES

Adipat, S., Laksana, K., Busayanon, K., Asawasowan, A., & Adipat, B. (2021). Engaging students in the learning process with game-based learning: The fundamental concepts. *International Journal of Technology in Education (IJTE)*, *4*(3), 542–552. https://doi.org/https://doi.org/10.46328/ijte.169

Agyare, B., Asare, J., Kraishan, A., Nkrumah, I., & Adjekum, D. K. (2025). A cross-national assessment of Artificial Intelligence (AI) chatbot user perceptions in collegiate physics education. *Computers and Education: Artificial Intelligence*, *8*. https://doi.org/10.1016/j.caeai.2025.100365

Ahmed, S., Faisal, M., Hasan, S. S. F., & Ghazi, M. A. (2025). Impact of Artificial Intelligence (AI) on teacher self-efficacy: A systematic literature review. *Social Science Review Archives*, *3*(4), 3406–3415. https://doi.org/https://doi.org/10.70670/sra.v3i4.626

Aisyah, S. B. F. N. A., & Hidayatullah, R. S. (2024). Pengaruh guru perempuan dalam penerapan model project based learning di sekolah vokasi. *Journal of Vocational and Technical Education (JVTE)*, *6*(1), 37–45. https://doi.org/https://doi.org/10.26740/jvte.v6n1.p37-45

Amelia, N., Khasanah, M. N., Hidayah, N., Nizzah, H., Indra, G., & Zulherman, Z. (2024). Pemanfaatan teknologi Artificial Intelligence (AI) dalam media pembelajaran IPA untuk meningkatkan keterampilan berpikir kritis siswa SD. *J-CEKI: Jurnal Cendekia Ilmiah*, *4*(1), 303–312. https://doi.org/https://doi.org/10.56799/jceki.v4i1.6166

Anas, I., & Zakir, S. (2024). Artificial intelligence: Solusi pembelajaran era digital 5.0. *Jurnal Sains Komputer & Informatika (J-SAKTI)*, *8*(1), 35–46. https://doi.org/10.30645/j-sakti.v8i1.764

Azizah, U., & Nasrudin, H. (2022). Problem-solving thinking skills: Effectiveness of the problem-solving model in teaching chemistry college students. *Jurnal Penelitian Pendidikan IPA*, *8*(3), 1462–1469. https://doi.org/https://doi.org/10.29303/jppipa.v8i3.1700

Bergdahl, N., & Sj, J. (2025). Attitudes, perceptions and AI self-efficacy in K-12 education. *Computers and Education: Artificial Intelligence Journal*, *8*(January), 4–11. https://doi.org/10.1016/j.caeai.2024.100358

Chen, X. (2025). The Impact of Artificial Intelligence Tools on College Students' Academic Self-Efficacy *Transactions on Materials, Biotechnology and Life Sciences*, *8*, 142–148. https://doi.org/10.62051/4sgyh834

Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education (8th ed.)*. London: Routledge.https://doi.org/10.62051/4sgyh834

Collie, R. J., Martin, A. J., & Gasevic, D. (2024). Teachers' generative AI self-efficacy, valuing, and integration at work: Examining job resources and demands. *Computers and Education: Artificial Intelligence*, *7*. https://doi.org/10.1016/j.caeai.2024.100333

Díaz, B., & Nussbaum, M. (2024). Artificial intelligence for teaching and learning in schools: The need for pedagogical intelligence. *Computers and Education*, *217*. https://doi.org/10.1016/j.compedu.2024.105071

Dita, O. P., Antara, R. M., & Winarno, A. (2025). Tanggung jawab etis penggunaan artificial intelligence di tanah pendidikan: Formulasi paradigma baru untuk teknologi otonom. *MASMAN: Master Manajemen*, *3*(2), 57–83. https://doi.org/https://doi.org/10.59603/masman.v3i2.816

Fahmi, K. N. (2019). Pengembangan modul kimia berbasis teaching factory pada materi redoks terintegrasi kompetensi keahlian teknik fabrikasi logam dan manufaktur. *Journal of Educational Chemistry (JEC)*, *1*(2), 107–117. https://doi.org/https://doi.org/10.21580/jec.2019.1.2.4433

Fajriati, A., Wisroni, W., & Handrianto, C. (2024). Pemanfaatan teknologi Artificial Intelligence (AI) dalam pembelajaran berbasis peserta didik di era digital. *Wahana Pedagogika: Jurnal Ilmiah Pendidikan dan Pembelajaran*, *6*(2), 71–85. https://doi.org/https://doi.org/10.52166/wp.v6i2.7890

Filiz, O., Kaya, M. H., & Adiguzel, T. (2025). Teachers and AI: Understanding the factors influencing AI integration in K-12 education. *Education and Information Technologies*. https://doi.org/10.1007/s10639-025-13463-2

Fitriana, N. (2025). Empowering artificial intelligence literacy, motivation, and self-efficacy for education: SEM study. *Education and Human Development Journal*, *10*(2), 202–219. https://doi.org/10.33086/ehdj.v10i2.8109

Gupte, T., Watts, F. M., Schmidt-McCormack, J. A., Zaimi, I., Gere, A. R., & Shultz, G. V. (2021). Students' meaningful learning experiences from participating in organic chemistry writing-to-learn activities. *Chemistry Education Research and Practice*, *22*(2), 396–414. https://doi.org/https://doi.org/10.1039/D0RP00266F

Hair Jr, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate Data Analysis (8th ed.)*. United Kingdom: Cengage Learning.

Haryadi, R., & Nurmala, R. (2021). Pengembangan bahan ajar fisika kontekstual dalam meningkatkan motivasi belajar siswa. *SPEKTRA: Jurnal Kajian Pendidikan Sains*, *7*(1), 32–39. https://doi.org/http://dx.doi.org/10.32699/spektra.v7i1.168

Jia, X.-H., & Tu, J.-C. (2024). Towards a new conceptual model of AI-enhanced learning for college students : The roles of artificial intelligence capabilities, general self-efficacy, learning motivation, and critical thinking awareness. *Systems*, *12*. https://doi.org/https://doi.org/10.3390/systems12030074

Kong, S. C., Zhu, J., & Yang, Y. N. (2025). Developing and validating a scale of empowerment in using artificial intelligence for problem-solving for senior secondary and university students. *Computers and Education: Artificial Intelligence*, *8*. https://doi.org/10.1016/j.caeai.2024.100359

Lee, Y. F., Hwang, G. J., & Chen, P. Y. (2022). Impacts of an AI-based chatbot on college students' after-class review, academic performance, self-efficacy, learning attitude, and motivation. *Educational Technology Research and Development*, *70*(5), 1843–1865. https://doi.org/10.1007/s11423-022-10142-8

Liu, J., Kong, X., Xia, F., Bai, X., Wang, L., Qing, Q., & Lee, I. (2018). Artificial intelligence in the 21st century. *IEEE Access*, *6*, 34403–34421. https://doi.org/https://doi.org/10.1109/ACCESS.2018.2819688

Lyu, W., & Salam, Z. A. (2025). AI-powered personalized learning: Enhancing self-efficacy, motivation, and digital literacy in adult education through expectancy-value theory. *Learning and Motivation*, *90*(January), 102129. https://doi.org/10.1016/j.lmot.2025.102129

Miranda, V., Faslah, R., & Rachmadania, R. F. (2022). Self-efficacy and achievement motivation on student learning independence. *Jurnal Pendidikan Ekonomi, Perkantoran, dan Akuntansi*, *3*(1), 218–227. https://doi.org/https://doi.org/10.21009/jpepa.0301.17

Mubarika, M. P., & Yaniawati, R. P. (2019). Implementasi pendekatan Science Technology Engineering and Mathematics (STEM) untuk meningkatkan kemampuan pemecahan masalah siswa SMK. *Pasundan Journal of Mathematics Education: Jurnal Pendidikan Matematika*, *9*(2), 56–67. https://doi.org/https://doi.org/10.23969/pjme.v9i2.2713

Muhammad, R., Larasati, H. A., Susanti, R., Pakaenoni, F., & Rahmadani, A. (2024). Kajian literatur peran artificial intelligence dalam mendukung strategi pembelajaran diferensiasi pada mata pelajaran kimia di sekolah. *Jurnal Pendidikan Kimia Undiksha*, *8*(1). https://doi.org/https://doi.org/10.23887/jjpk.v8i1.72163

Neroni, J., Meijs, C., Kirschner, P. A., Xu, K. M., & Groot, R. H. de. (2022). Academic self-efficacy, self-esteem, and grit in higher online education: Consistency of interests predicts academic success. *Social Psychology of Education*, *25*(4), 951–975. https://doi.org/https://doi.org/10.1007/s11218-022-09696-5

Nugraha, M. (2018). Manajemen kelas dalam meningkatkan proses pembelajaran. *Tarbawi: Jurnal Keilmuan Manajemen Pendidikan*, *4*(1), 27–44. https://doi.org/https://doi.org/10.32678/tarbawi.v4i01.1769

O'Dwyer, A., & Childs, P. E. (2017). Who says organic chemistry is difficult? Exploring perspectives and perceptions. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3599–3620. https://doi.org/https://doi.org/10.12973/eurasia.2017.00748a

Oktavianus, A. J. E., Naibaho, L., & Rantung, D. A. (2023). Pemanfaatan artificial intelligence pada pembelajaran dan asesmen di era digitalisasi. *Jurnal Kridatama Sains dan Teknologi*, *5*(2), 473–

486. https://doi.org/10.53863/kst.v5i02.975

Popenici, S. A., & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and Practice in Technology Enhanced Learning*, *12*(1). https://doi.org/10.1186/s41039-017-0062-8

Prastika, N. D., Anjarwati, D., Awaliah, M. A. S., Hartandi, D., Rahmadani, A., & Erika, F. (2024). Kajian literatur pemanfaatan teknologi artificial intelligence untuk meningkatkan keterampilan abad 21 siswa dalam pembelajaran kimia. *Jambura Journal of Educational Chemistry*, *6*(1), 47–60. https://doi.org/10.37905/jjec.v6i1.23644

Pratiwi, R. T. L., & Yunus, M. (2025). Manfaat dan tantangan penggunaan Artificial Intelligence (AI) bagi guru dan peserta didik di era society 5.0. *Journal of Innovation and Teacher Professionalism*, *3*(2), 488–494. https://doi.org/10.17977/um084v3i22025p488-494

Purwati, Y. S., Subandowo, M., & Gunawan, W. (2022). E-modul kimia perubahan materi dan pemisahan campuran untuk pembelajaran daring di SMK. *JIPI (Jurnal Ilmiah Penelitian Dan Pembelajaran Informatika)*, *7*(2), 332–339. https://doi.org/10.29100/jipi.v7i2.2682

Ren, L., Stephens, J. M., & Lee, K. (2026). The impact of AI on learners' self-efficacy: A meta-analysis. *Behavioural Sciences*, *16*. https://doi.org/https://doi.org/10.3390/bs16010158

Ria, T. N., Hartono, R., & Wahyuni, S. (2025). The impact of AI-supported case-based learning on students' self-efficacy. *Jurnal Pemberdayaan Masyarakat*, *4*(4), 995–1009. https://doi.org/10.46843/jpm.v4i4.588

Rissi, A. R. Y., & Sinaga, D. (2025). AI dan pembelajaran mendalam (deep learning): Meningkatkan kualitas pendidikan di era digital. *Cetta: Jurnal Ilmu Pendidikan*, *8*(4), 10–23. https://doi.org/10.37329/cetta.v8i4.4386

Rizka, C. (2025). Motivation to use artificial intelligence and technology self-efficacy among biology education students at an Indonesian university. *Journal of Science and Technological Education*, *4*(2), 114–132. Retrieved from https://meta.amiin.or.id/index.php/meta/article/view/170

Rohayah, D. (2022). Analisis kemampuan pemecahan masalah pada pembelajaran kimia. *Jurnal Wahana Pendidikan*, *9*(2). https://dx.doi.org/10.25157/wa.v9i2.8243

Salame, I. I., & Makki, J. (2021). Examining the use of PhET simulations on students' attitudes and learning in general chemistry II. *Interdisciplinary Journal of Environmental and Science Education*, *17*(4). https://doi.org/10.21601/ijese/10966

Suparwati, N. M. A. (2022). Analisis reduksi miskonsepsi kimia dengan pendekatan multi level representasi: Systematic literature review. *Jurnal Pendidikan MIPA*, *12*(2), 341–348. https://doi.org/10.37630/jpm.v12i2.591

Syafitri, D. A., & Pahlevi, T. (2026). The effect of artificial intelligence on learning outcomes through students' self-efficacy: A study of students in the office management and business services program. *Ainara Journal (Jurnal Penelitian Dan PKM Bidang Ilmu Pendidikan)*, *7*(1), 123–132. https://doi.org/10.54371/ainj.v7i1.1329

Szmyd, K., & Mitera, E. (2024). The impact of artificial intelligence on the development of critical thinking skills in students. *European Research Studies Journal*, *27*(2), 1022–1039. https://doi.org/10.35808/ersj/3876

Taufik, T., & Komar, N. (2021). Hubungan self efficacy terhadap peningkatan motivasi belajar dan hasil belajar matematika siswa di sekolah. *Andragogi: Jurnal Pendidikan Islam Dan Manajemen Pendidikan Islam*, *3*(2), 183–200. https://doi.org/10.36671/andragogi.v3i2.220

Toha, A. M., & Astuti, W. (2026). Hubungan self efficacy terhadap penggunaan chatbot AI dalam pengerjaan tugas mahasiswa semester 7 tadris matematika UIN Raden Mas Said tahun ajaran 2025/2026. *Imajiner: Jurnal Matematika dan Pendidikan Matematika*, *8*(1), 171–179.

Tukiran, Nikmah, C., & Nasrudin, H. (2020). Improving students' self-efficacy and learning outcomes through argument-driven inquiry learning. *Jurnal Pendidikan Sains (JPS) Vol.*, *8*(2), 133–138.https://doi.org/10.26877/imajiner.v8i1.26175

Wardhana, D. E. C., Sarwono, S., Yulistio, D., Subakti, A., & Jamaludin, J. (2024). Implementasi AI dalam proses pembelajaran di perguruan tinggi: Studi kasus penggunaan AI di prodi ilmu fisika. *Jurnal Pengabdian Multidisiplin*, *2*(2), 24–34. https://doi.org/10.62383/fundamentum.v2i2.124

Wiarsana, I. G. S. (2020). Pengaruh self efficacy, motivasi berprestasi, dan study habits terhadap literasi sains siswa. *Jurnal Pendidikan Sains (JPS)*, *8*(2), 110–120. https://doi.org/10.26714/jps.8.2.2020.110-120

Wiyarsi, A. (2017). Enhancing preservice chemistry teachers' self-efficacy through the preparation of pedagogical content knowledge in a vocational context. *Jurnal Pendidikan Sains (JPS)*, *5*(2), 14–23. https://doi.org/10.26714/jps.6.1.2018.14-23

Yulistia, H. R., Anwar, S., & Munawaroh, H. S. H. (2024). Analisis kebutuhan materi kimia untuk siswa SMK kompetensi agribisnis perikanan air tawar. *Jurnal Riset dan Praktik Pendidikan Kimia*, *12*(1), 74–83. https://doi.org/10.17509/jrppk.v12i1.69415

Zaenudin, I., & Riyan, A. B. (2024). Perkembangan kecerdasan buatan (AI) dan dampaknya pada dunia teknologi. *Journal Informatika Utama*, *2*(2), 128–153. https://doi.org/10.55903/jitu.v2i2.240