Journal of Education and Learning (EduLearn)
Vol. 20, No. 1, February 2026, pp. 424~430
ISSN: 2089-9823 DOI: 10.11591/edulearn.v20i1.23005

Awareness of generative artificial intelligence in chemistry education among trainee teachers

Thivya Sri Chandran, Yuhanis Mhd Bakri
Department of Chemistry, Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris, Tanjung Malim, Malaysia

Article Info

Article history:

Received Aug 8, 2024
Revised Jan 17, 2025
Accepted Mar 19, 2025

Keywords:

Awareness
Chemistry
Chemistry education
Generative artificial intelligence
Trainee teacher

ABSTRACT

Recent developments in generative artificial intelligence (GenAI) are progressing swiftly, significantly impacting education. Therefore, this survey study aims to identify the level of awareness of GenAI in chemistry education among trainee teachers from the aspects of general knowledge and use in chemistry education through survey. The sample selection was carried out through random sampling involving 100 chemistry trainee teachers in Universiti Pendidikan Sultan Idris. The questionnaire contained three parts, the demographics of the sample, the level of awareness of GenAI in among trainee teachers in the aspect of general knowledge and the level of awareness of GenAI among trainee teachers in the aspect of chemistry education. This research instrument obtained expert validity of 91.9% through percent of agreement and a reliability value of 0.92. The study reveals that trainee teachers exhibit a moderate level of awareness regarding GenAI in chemistry education, encompassing both general knowledge and its application in this domain. The implications underscore the importance of understanding how trainee teachers perceive and utilize GenAI, enabling academic institutions to devise more effective teaching methodologies incorporating GenAI tools.

Corresponding Author:

Yuhanis Mhd Bakri
Department of Chemistry, Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris
35900 Tanjung Malim, Perak, Malaysia
Email: yuhanis.mb@fsmt.upsi.edu.my

1. INTRODUCTION

Over the years, generative artificial intelligence (GenAI) underwent various developments and one of the major breakthroughs of GenAI was developed in 2018 known as generative pre-trained transformers (GPT) by OpenAI. Some other best GenAI tools can be listed such as are Scribe, Jasper, Wordtune, Notion, and GitHub Copilot. GenAI tools including the prominent ChatGPT which is broadly used in education provide instant access to vast amounts of information. They support diverse student needs, accommodating various aptitudes, language backgrounds, and accessibility requirements, while also promoting diverse approaches to problem-solving. According to Aljanabi *et al.* [1], there are many possibilities for ChatGPT in the educational field such as a search engine, an assistant for academic writing, coding developer and social media tools.

In this context, the usage of GenAI tools in chemistry education cannot be neglected. The complexity of chemistry education attracts the students and the educators to use the GenAI tools. ChatGPT, one of the GenAI tool is significance in chemistry education where it can address the challenges in chemistry education, contribute as virtual learning assistant for concepts understanding, complete assignments, increase content knowledge and enhance the conceptual understanding [2]. In addition, GenAI has the potential to enhance active participation and engagement, foster self-directed learning, and optimize teaching and learning methodologies. This technology is anticipated to significantly benefit educators and students alike through personalized support, virtual tutoring,

adaptive assessments, and tailored learning engagements. United Nations Educational, Scientific and Cultural Organization (UNESCO) through its academic conference in UNESCO Regional Office in Bangkok (UNESCO Bangkok), which was held on November 7th, 2023 discussed the importance and capability of GenAI in education [3]. They highlighted that while taking into account potential risks involved with the utilizing AI in education, the expanding the AI capabilities, incorporating cutting-edge AI technology, and creating new methods of teaching and learning are issues need to be addressed.

The knowledge on usage of GenAI in chemistry education among tertiary students especially among trainee teachers are still under discussion and it also might influence their learning process. Students' views on technological innovations like GenAI, along with their opinions, concerns, and experiences with the tool, can shape their willingness to use it and, consequently, its integration into the learning process [4]. Laupichler *et al.* [5] stated that adults pursuing higher education and beyond ought to be acquainted in the fundamentals of artificial intelligence. Not only that, various studies have been done on GenAI which focuses higher education students in general but there is a lack of studies that focuses on trainee teachers [6], [7]. Ivanov *et al.* [8] also examines the possible effects of the use of GenAI tools on the application of these tools in higher education in reality, as well as the interdependence of relationship between the factors in theory of planned behavior and the intention to use them. However, this study used international sample that involved 168 students and130 academic in higher education institutions in several countries.

Additionally, AI-driven molecular generators have emerged as valuable resources in chemical education. These tools enable students to visualize and manipulate complex molecular structures, with improved accuracy and efficiency in computational chemistry, while noting challenges like data quality and model interpretability that must be addressed for broader adoption [9]. Furthermore, the integration of GenAI in chemistry education promotes collaboration among students and researchers by enhancing computational chemistry tools. GenAI can predict molecular properties, simulate reactions, and even suggest new materials or drugs for discovery [10]. This fosters a learning environment where students not only understand theoretical chemistry but also apply it in real-world problem-solving contexts. However, despite these advances, challenges remain. While AI holds significant potential for advancing STEM education, successful integration depends on overcoming challenges such as teacher training and ensuring equitable access to AI tools [11].

To the best of the author's knowledge, a comprehensive search and analysis conducted on Google Scholar did not reveal any existing studies specifically addressing the awareness of GenAI in chemistry education, either in general or with a focus on trainee teachers, particularly within the context of Malaysia. The absence of such research highlights a gap in the literature concerning this emerging area. This study, therefore, aims to bridge the knowledge gap by investigating the level of awareness of GenAI in chemistry education among trainee teachers. Specifically, it seeks to assess their general knowledge of GenAI and how familiar they are with its applications and potential uses in chemistry education. By exploring both of these angles, the study intended to show a clearer understanding of how trainee teachers perceive and engage with GenAI in their educational practice, which could have significant implications for curriculum development and teacher training programs.

2. METHOD

This study employed a survey research design, utilizing a simple random sampling technique to select its population of semester six to eight chemistry trainee teachers. Validity and reliability of the survey was determined. A total of two experts validated the survey. The reliability study involved 30 chemistry trainee teachers which were chosen randomly. A survey with four-point Likert scales, where 1=strongly disagree, 2=disagree, 3=agree, and 4=strongly agree with general knowledge in artificial intelligence and the use of GenAI in chemistry education was adapted from several studies [12]–[15]. The data was evaluated using the survey distributed to 100 chemistry trainee teachers. The sample selection was carried out through random sampling involving 100 chemistry trainee teachers in Universiti Pendidikan Sultan Idris. The questionnaire contained three parts, the demographics of the sample, the level of awareness of GenAI in among trainee teachers in the aspect of general knowledge and the level of awareness of GenAI among trainee teachers in the aspect of chemistry education. The data was analyzed with descriptive statistical analysis and processed using statistical package for social sciences (SPSS). The research methodology is simplified and summarized in Figure 1.

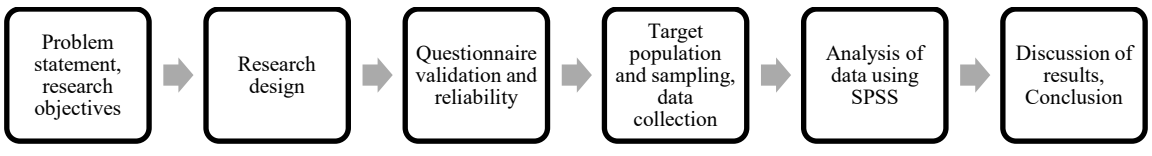

Figure 1. Simplified flowchart of methodology used in the study

3. RESULTS AND DISCUSSION

3.1. Validity and reliability

The method used to analyze the validity aspects was percentage of agreement method. Two experts with chemistry education background have validated the constructs of the survey. Findings as shown in Table 1 revealed that the survey is valid and can be proceeded for next stage of the study. The data shows average of 91.9% percent of agreement which according to Tuckman dan Waheed, an achievement level of 70% is considered reached a high level [16]. Through analysis of reliability study, as shown in Table 2, the reliability coefficient, Cronbach's alpha value was found to be 0.92 which indicates excellent level of internal consistency for the questionnaire items of the survey [17].

Table 1. Percentage of experts' agreement on validation of survey

Expert	Percent of agreement (%)	Expert review
1	95.0	Accepted
2	88.8	Accepted
Total percentage	91.9	Accepted

Table 2. Reliability of research instrument

Construct	Cronbach's alpha (α)	Internal consistency
General knowledge on GenAI	0.88	Good
GenAI use in chemistry education	0.90	Excellent
Average	0.92	Excellent

3.2. Level of awareness of GenAI among chemistry trainee teachers in the aspect of general knowledge

Part B of the survey focus awareness of GenAI among chemistry trainee teachers in the aspect of general knowledge. There were 10 items used to identify the trainee teachers' level of awareness. The descriptive statistic data which are frequency, mean and standard deviation is shown in Table 3.

Analysis of the data revealed that item number B10 which was *"I believe GenAI tools will become the new normal in future"* has the highest mean score, 3.61 where 68 respondents strongly agreed. This shows that respondents believed that GenAI tools will become the new normal in future as they are aware of its rapid growth and development. In fact, after just two months of its launch, the most publicly known GenAI tool, ChatGPT has amassed 100 million monthly users and one million users in just five days, a phenomenal growth that makes it one of the fastest-growing consumer applications [18].

Next, item number B8, *"I believe that responses from GenAI are reliable and accurate"* has moderate low mean score, 2.68 of which 38 respondents disagreed. This indicates that the respondents are aware that the responses generated by the GenAI tools are not really reliable and accurate. This is because GenAI generates responses by an algorithm where it uses the information from all over the data on the internet regardless of the validity of the content [19], [20]. Harrer [21] also mentioned that if there are aspects of bias, inaccuracy, or harm in the dataset used to train a model, the material generated by GenAI may be affected by them. Additionally, this is because GenAI technologies could not assess the accuracy of content or detect whether the output they produce contains mistakes or misinformation and therefore, human monitoring is necessary when using them [22]. The second lowest mean score, 2.97 was from item number B7, *"I understand the limitations of GenAI and its tools"* whereby 36 respondents disagreed with it. This demonstrates that the understanding of respondents regarding the limitations of GenAI and its tools is low. The respondents may recognize that generative AI has limitations, but they lack a deep understanding of the specific constraints and limitations associated with its use. Applications of GenAI are limited in their ability to address intricate, multifaceted societal problems, despite their great output capabilities. Although they do well in specific, limited activities, they are not well-versed in larger issues like strategic decision-making or moral quandaries [23]–[25].

3.3. Level of awareness of GenAI among chemistry trainee teachers in the aspect of chemistry education

Part C of the survey focused on awareness of GenAI among chemistry trainee teachers in the aspect of chemistry education. There were 10 items used to identify the trainee teachers' level of awareness. The descriptive statistic data which are frequency, mean and standard deviation is shown in Table 4.

Item number C9, *"I intend to use GenAI tools as part of my creative activities in chemistry education"* has the highest mean score, 3.43 of which 51 respondents strongly agreed with it. This indicates that the respondents are aware about the use of GenAI tools and have intention to use it as part of their creative activities in chemistry education. GenAI tools have a major influence on the revolution in chemistry education. GenAIbots such as Gemini, Bing Chat, Bard and the largely use ChatGPT can lead philosophical conversations akin to Socrates, promoting introspection, critical thinking, and a better comprehension of the fundamentals,

presumptions, and ethical ramifications of chemistry [26]. In fact, chemistry educators must embrace this new development in technology which provide wide array of applications, and possibly misuse, can assist those looking to innovate their teaching and learning provided by this new technology [27].

In addition, item number C7, *"I would be open to receive instruction about how to use GenAI in chemistry education"* revealed the second highest mean score, 3.36 where 48 respondents show agreement. This proves that the respondents are ready to receive instruction about how to use GenAI in chemistry education as they are aware that it is needed to get guidance on ways to utilize GenAI in chemistry education. This is because when working with language models, prompting the act of providing instructions is essential. Guidance especially the correct and dignified way of using the tools is important. A thorough explanation of prompting, together with extensive examples and thorough comments can be referred through various resources [28]. Although user may initially face challenges in mastering the intricacies of quick prompting, the use of organized frameworks greatly improves their perception of the quality of GenAI-generated responses as well as emphasizes the need for targeted educational guidelines to enhance GenAI interaction in academic settings [29].

Item number C2, *"I am familiar with GenAI tools for chemistry education,"* has the lowest mean score for this construct which was 2.79 and 46 respondents agreed with it. Although this item has the lowest mean score, it was agreed upon by most of the respondents. This demonstrates that respondents are aware of the GenAI tools for chemistry education. There various GenAI tools for chemistry education have been presented as creative answers to enduring problems in chemistry education [30], [31]. In addition, new findings which investigate the responses in assignment of chemistry between authentic students and GenAI tools display detectable trend in engagement of explanation [32], [33].

The analysis of mean scores for general knowledge items indicates a moderate to high level of agreement (Mean=3.10, SD=0.558). Secondly, the analysis of mean scores for items related to GenAI's use in chemistry education also shows a moderate to high level of agreement (Mean=3.18, SD=0.503). Hence, trainee teachers demonstrate a moderately high awareness of GenAI in both general knowledge and its application in chemistry education.

Overall, the descriptive analysis of the items for both variables, general knowledge about GenAI and use of GenAI in chemistry education, summarizes the level of awareness on GenAI among the respondents. This can be seen from the average mean score and the standard deviation for the both variables. Overall awareness is moderately high which indicates that the awareness on GenAI in the aspects of general knowledge and use in chemistry education among trainee teachers should be enhanced to prepare the trainee teachers according to the current trend. The findings are significant to increase the awareness of student especially trainee teachers regarding this aspect to keep up with fast and rapid development of this technology. For example, the image processing capabilities of ChatGPT-4 has been shown to have potential to be utilized for educational purposes, such as tackling the visual challenges in chemistry [34]. It is essential to understand GenAI to recognize its challenges, such as conceptual understanding across various domains, especially in terms of its depth where issues with representations will defeat knowledge transfer effectiveness [35].

Table 3. Analysis of level of awareness of GenAI among trainee teachers in the aspect of general knowledge

No	Item	Frequency				Mean	Standard deviation
		1	2	3	4		
B1.	I am aware of the term GenAI	3 (3.0%)	7 (7.0%)	34 (34.0%)	56 (56.0%)	3.43	0.756
B2.	I am familiar with the concept of GenAI	4 (4.0%)	12 (12.0%)	59 (59.0%)	25 (25.0%)	3.05	0.730
B3.	I am aware of the working principle of GenAI	7 (7.0%)	24 (24.0%)	43 (43.0%)	26 (26.0%)	2.88	0.879
B4.	I know GenAI can be used in various sector	3 (3.0%)	8 (8.0%)	45 (45.0%)	44 (44.0%)	3.30	0.745
B5.	GenAI will play an important role in my field	1 (1.0%)	6 (6.0%)	49 (49.0%)	44 (44.0%)	3.36	0.644
B6.	I have good understanding of the basics of GenAI	7 (7.0%)	12 (12.0%)	57 (57.0%)	24 (24.0%)	2.98	0.804
B7.	I understand the limitations of GenAI and its tools	8 (8.0%)	36 (36.0%)	25 (25.0%)	31 (31.0%)	2.79	0.977
B8.	I believe that responses from GenAI are reliable and accurate	7 (7.0%)	38 (38.0%)	35 (35.0%)	20 (20.0%)	2.68	0.875
B9.	I believe GenAI retrieves the most recent data for generating responses	6 (6.0%)	23 (23.0%)	41 (41.0%)	30 (30.0%)	2.95	0.880
B10.	I believe GenAI tools will become the new normal in future	1 (1.0%)	5 (5.0%)	26 (26.0%)	68 (68.0%)	3.61	0.634
						Mean=3.10, SD=0.558	

Table 4. Analysis of level of awareness of GenAI among trainee teachers in the aspect of chemistry education

No	Item	Frequency				Mean	Standard deviation
		1	2	3	4		
C1.	I have used GenAI in chemistry education	8 (8.0%)	12 (12.0%)	36 (36.0%)	44 (44.0%)	3.16	0.929
C2.	I familiar with GenAI tools for chemistry education	7 (7.0%)	27 (27.0%)	46 (46.0%)	20 (20.0%)	2.79	0.844
C3.	I use GenAI-based tools for studying in chemistry	6 (6.0%)	20 (20.0%)	42 (42.0%)	32 (32.0%)	3.00	0.876
C4.	AI uses better learning and teaching styles than humans do in chemistry education	9 (9.0%)	23 (23.0%)	40 (40.0%)	28 (28.0%)	2.87	0.928
C5.	Incorporating GenAI systems in chemistry education would ease my learning process	0 (0%)	7 (7.0%)	58 (58.0%)	35 (35.0%)	3.28	0.587
C6.	I would be comfortable using GenAI to build a course assignment	0 (0%)	9 (9.0%)	57 (57.0%)	34 (34.0%)	3.25	0.609
C7.	I would be open to receiving instruction about how to use GenAI in chemistry education	0 (0%)	8 (8.0%)	48 (48.0%)	44 (44.0%)	3.36	0.628
C8.	I intend to use GenAI tools as part of my research in chemistry education	0 (0%)	8 (8.0%)	50 (50.0%)	42 (42.0%)	3.34	0.623
C9.	I intend to use GenAI tools as part of my creative activities in chemistry education	0 (0%)	8 (8.0%)	41 (41.0%)	51 (51.0%)	3.43	0.640
C10.	My instructors have addressed the use of GenAI in my courses of chemistry education	3 (3.0%)	10 (10.0%)	42 (42.0%)	45 (45.0%)	3.29	0.769
						Mean=3.18, SD=0.503	

4. CONCLUSION

These findings suggest several positive implications. They underscore the potential need for training initiatives aimed at enhancing trainee teachers' proficiency in utilizing GenAI and their expressed intention to receive instructions on its integration in chemistry education. Such specialized professional development programs could empower educators to effectively employ these tools in their teaching practices, thereby fostering more engaging and personalized learning experiences for students. Furthermore, insights gained from how trainee teachers perceive and utilize GenAI will contribute to the development of further and enhance effective strategies for teaching and learning within academic institutions. Additionally, these findings enable educational institutions to anticipate future trends and prepare for the evolving landscape of chemistry education, particularly regarding the integration of GenAI. It's important to note that this study focused exclusively on trainee teachers at one education focus university in Malaysia limiting its generalizability to other institutions and regions. Future research is recommended to include trainee teachers from diverse universities across various states to broaden the understanding of GenAI awareness in chemistry education. Furthermore, expanding the study to encompass students across all academic semesters and incorporating interview methods alongside questionnaires could provide deeper insights into trainee teachers' awareness and perceptions of GenAI in chemistry education.

ACKNOWLEDGEMENTS

The authors acknowledge Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris, Malaysia for their support.

FUNDING INFORMATION

Authors state no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Thivya Sri Chandran		✓	✓	✓	✓	✓		✓	✓	✓			✓	
Yuhanis Mhd Bakri	✓	✓		✓		✓		✓	✓	✓	✓	✓	✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

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

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional regulations.

DATA AVAILABILITY

Derived data supporting the findings of this study are available from the corresponding author [YMB] on request.

REFERENCES

[1] M. Aljanabi, G. Mohanad, A. H. Ali, S. A. Abed and ChatGPT, "ChatGPT: open possibilities," *Iraqi Journal for Computer Science and Mathematics*, vol 4, no 1, pp 62–64, 2023, doi: 10.52866/20ijcsm.2023.01.01.0018.

[2] M. E. Emenike and B. U. Emenike, "Was this title generated by ChatGPT? considerations for artificial intelligence text-generation software programs for chemists and chemistry educators," *Journal of Chemical Education*, vol. 100, no. 4, pp. 1413–1418, 2023, doi: 10.1021/acs.jchemed.3c00063.

[3] UNESCO Office Bangkok and Regional Bureau for Education in Asia and the Pacific, *Empowering minds: a round table on generative AI and education in Asia-Pacific*. Thailand: UNESCO, 2023, doi: 10.13140/RG.2.2.21933.26082.

[4] C. K. Y. Chan and W. Hu, "Students' voices on generative AI: perceptions, benefits, and challenges in higher education," *International Journal of Educational Technology in Higher Education*, vol. 20, no. 43, 2023, doi: 10.1186/s41239-023-00411-8.

[5] M. C. Laupichler, A. Aster, J. Schirch and T. Raupach, "Artificial intelligence literacy in higher and adult education: a scoping literature review," *Computers and Education: Artificial Intelligence*, vol. 3, p. 100101, 2023, doi: 10.1016/j.caeai.2022.100101.

[6] K. Andrew, M. Sullivan and K. Strampel, "Generative artificial intelligence: university student awareness, experience, and confidence in use across disciplines," *Journal of University Teaching & Learning Practice*, vol. 20, no. 6, pp. 1–16, 2023, doi: 10.53761/1.20.6.12.

[7] W. K. Chiu, "Pedagogy of emerging technologies in chemical education during the era of digitalization and artificial intelligence: a systematic review," *Education Sciences*, vol. 11, no. 11, p. 709, 2021, doi: 10.3390/educsci11110709.

[8] S. Ivanov, M. Soliman, A. Tuomi, N. A. Alkathiri and A. N. Al-Alawi, "Drivers of generative AI adoption in higher education through the lens of the theory of planned behaviour," *Technology in Society*, vol 77, 2024, doi: 10.1016/j.techsoc.2024.102521.

[9] M. I. Jordan and T. M. Mitchell, "Machine learning: trends, perspectives, and prospects," *Science*, vol 349, no. 6245, pp. 256–260, 2015, doi: 10.1126/science.aaa8415.

[10] L. David, A. Thakkar, R. Mercado, O. Engkvist, "Molecular representations in AI-driven drug discovery: a review and practical guide," *Journal of Cheminformatics*, vol 12, no. 56, pp. 1–22, 2020, doi: 10.1186/s13321-020-00460-5.

[11] W. Xu and F. Ouyang, "The application of AI technologies in STEM education: a systematic review from 2011 to 2021," *International Journal of STEM Education*, vol 9, no. 59, pp. 1–20, 2022, doi: 10.1186/s40594-022-00377-5.

[12] G. Doumat, D. Daher, N. N. Ghanem and B. Khater, "Knowledge and attitudes of medical students in Lebanon toward artificial intelligence: A national survey study," *Frontiers in Artificial Intelligence* vol. 5, p. 1015418, 2022, doi: 10.3389/frai.2022.1015418.

[13] C. Almaraz-López, F. Almaraz-Menéndez and C. López-Esteban, "Comparative study of the attitudes and perceptions of university students in business administration and management and in education toward artificial intelligence," *Education Sciences*, vol. 13, no. 6, p. 609, 2023, doi: 10.3390/educsci13060609.

[14] C. Sit, R. Srinivasan, A. Amlani, K. Muthuswamy, A. Azam, L. Monzon and D. S. Poon, "Attitudes and perceptions of UK medical students towards artificial intelligence and radiology: a multicentre survey," *Insights Imaging*, vol. 11, no. 1, p. 14, 2020, doi: 10.1186/s13244-019-0830-7

[15] R. G. Pallivathukal, H. H. K. Soe, P. M. Donald, R. S. Samson and A. R. H. Ismail, "ChatGPT for academic purposes: survey among undergraduate healthcare students in Malaysia," *Cureus*, vol. 16, no. 1, p. 53032, 2024, doi: 10.7759/cureus.53032

[16] B. W. Tuckman and M. A. Waheed, "Evaluating an individualized science programme for community college student," *Journal of Research in Science Teaching*, vol. 18, no. 6, pp. 489–495, 1981, doi: 10.1002/tea.3660180603.

[17] D. George and P. Mallery, *SPSS for Windows step by step: a simple guide and reference*, 4th ed. Boston, MA: Allyn and Bacon, 2023.

[18] T. Trust, J. Wallen, and C. Mouza, "Editorial: ChatGPT: challenges, opportunities, and implications for teacher education," *Contemporary Issues in Technology and Teacher Education*, vol. 23, no. 1, pp. 1–23, 2023.

[19] Y. Liu, Z. Yang, Z. Yu, Zitu Liu, D. Liu, H. Lin, M. Li, S. Ma, M. Avdeev, Siqi Shi, "Generative artificial intelligence and its applications in materials science: current situation and future perspectives," *Journal of Materiomics*, vol. 9, no. 4, pp. 798–816, 2023, doi: 10.1016/j.jmat.2023.05.001.

[20] K. Moulaei, A. Yadegari, M. Baharestani, S. Farzanbakhsh, B. Sabet, M. R. Afrash, "Generative artificial intelligence in healthcare: a scoping review on benefits, challenges and applications," *International Journal of Medical Informatics*, vol.188, p. 105474, 2024, doi: 10.1016/j.ijmedinf.2024.105474.

[21] S. Harrer, "Attention is not all you need: the complicated case of ethically using large language models in healthcare and medicine," *EBioMedicine*, vol. 90, p. 104512, 2023, doi: 10.1016/j.ebiom.2023.104512.

[22] J. H. Lubowitz, "ChatGPT, an artifcial intelligence chatbot, is impacting medical literature," *Arthroscopy,* vol. 39, no 5, pp. 1121–1122, 2023, doi: 10.1016/j.arthro.2023.01.015.

[23] G. Ribeiro, "Understanding the limitations of Generative AI." Forbes, 2024. Accessed: Jun. 15, 2024. [Online]. Available: https://www.forbes.com/sites/forbestechcouncil/2024/05/09/understanding-the-limitations-of-generative-ai/
[24] S. Mulukuntla, "Generative AI - benefits, limitations, potential risks and challenges in healthcare industry," *International Journal of Medical and Health Science*, vol. 8, no. 4, pp. 1–9, 2022, doi: 10.53555/eijmhs.v8i4.211.
[25] L. Z. Knutsen, D. J. Patón-Romero, J. E. Hannay, S. S. Tanilkan, "A survey on the perception of opportunities and limitations of generative AI in the public sector," in *Proceedings of World Conference on Information Systems for Business Management. ISBM 2023. Lecture Notes in Networks and Systems*, vol. 834. Springer, Singapore, doi: 10.1007/978-981-99-8349-0_40.
[26] R. P. D. Santos, "Enhancing chemistry learning with ChatGPT, bing chat, bard, and claude as agents-to-think-with: a comparative case study," *SSRN Electronic Journal*, 2023, doi: 10.2139/ssrn.4629567.
[27] E. Yuriev, D. J. Wink, T. A. Holme, "The dawn of generative artificial intelligence in chemistry education," *Journal of Chemical Education*, vol. 101, pp. 2957–2959, 2024, doi: 10.1021/acs.jchemed.4c00836
[28] E. Mollick, "A guide to prompting AI (for what it is worth)." 2023. Accessed: Jun. 15, 2024. [Online]. Available: https://www.oneusefulthing.org/p/a-guide-to-prompting-ai-for-what.
[29] S. Tassoti, "Assessment of students use of generative artificial intelligence: prompting strategies and prompt engineering in chemistry education," *Journal of Chemical Education*, vol. 101, no. 6, pp. 2745–2482, 2024, doi: 10.1021/acs.jchemed.4c00212
[30] D. Baidoo-Anu and L. O. Ansah, L, "Education in the era of generative artificial intelligence (AI): understanding the potential benefits of ChatGPT in promoting teaching and learning," *SSRN Electronic Journal*, 2023, doi: 10.2139/ssrn.4337484.
[31] O. Taani and S. Alabidi, "ChatGPT in education: benefits and challenges of ChatGPT for mathematics and science teaching practices," *International Journal of Mathematical Education in Science and Technology*, pp. 1–30. 2024, doi: 10.1080/0020739X.2024.2357341.
[32] F. M. Watts, A. J. Dood, G. V. Shultz, and J. G. Rodriguez, "Comparing student and generative artificial intelligence chatbot responses to organic chemistry writing-to-learn assignments," *Journal of Chemical Education*, vol. 100, no. 10, pp. 3806–3817, 2023, doi: 10.1021/acs.jchemed.3c00664.
[33] B. Sorenson and K. Hanson, "Identifying generative artificial intelligence chatbot use on multiple-choice, general chemistry exams using rasch analysis," *Journal of Chemical Education*, vol. 101, no. 8, pp. 3216–3223, 2024, doi: 10.1021/acs.jchemed.4c00165.
[34] E. A. Alasadi, C. R. Baiz, "Multimodal generative artificial intelligence tackles visual problems in chemistry," *Journal of Chemical Education*, vol. 101, no. 7, pp. 2716–2729, 2024, doi: 10.1021/acs.jchemed.4c00138.
[35] D. Wajeeh, H. Diab, A. Rayan, "Artificial intelligence generative tools and conceptual knowledge in problem solving in chemistry," *Information*, vol. 14, no. 7, pp. 409, 2023, doi: 10.3390/info14070409.

BIOGRAPHIES OF AUTHORS

Thivya Sri Chandran is a graduate of teacher training in chemistry education at Universiti Pendidikan Sultan Idris, Malaysia. As a future educator, she has immense curiosity in the current trend in education. Her interest is in educational technology in chemistry and science education. She can be contacted at email: thivyasri207@gmail.com.

Yuhanis Mhd Bakri is a senior lecturer in chemistry at Faculty of Science and Mathematics and Coordinator of Academia Excellence Unit, Centre of Academic Development at Universiti Pendidikan Sultan Idris, Malaysia. She is currently professional chemist at Malaysia Institute of Chemistry, an affiliate of Young Scientist Network-Academy of Sciences Malaysia and a life member of Malaysian Natural Products Society. Her research interest is in organic chemistry, chemistry education, new approach of teaching and learning, educational technology, STEM, and natural products chemistry. She can be contacted at email: yuhanis.mb@fsmt.upsi.edu.my.