

PAPER

EFFECTS OF GENERATIVE AI INTEGRATION ON UNIVERSITY TEACHERS' PROFESSIONAL COMPETENCY DEVELOPMENT: A MIXED-METHODS STUDY

X.N. Agaliyeva^{1,*}

¹Associate Professor of the Department of Educational Technologies, Sectoral Center for Retraining and Advanced Training of Pedagogical Staff under the Tashkent State Technical University named after Islam Karimov

* agaliyeva475@gmail.com

Abstract

This study investigates the effects of generative artificial intelligence (GenAI) tools on the professional competency development of higher education teachers. A mixed-methods design was employed, combining a quasi-experimental approach with semi-structured interviews. A total of 186 university teachers from Uzbekistan participated in the study. Results indicated that GenAI integration significantly enhanced teachers' Technological Pedagogical Content Knowledge (TPACK) scores ($p < .001$), with notable improvements in digital competencies and self-efficacy levels. Qualitative data revealed that GenAI tools facilitated lesson planning, personalized instruction, and assessment optimization. However, concerns regarding ethical issues, academic integrity, and over-reliance on AI were also identified. The study proposes a GenAI-TPACK pedagogical model and provides practical recommendations for teacher preparation programs in higher education contexts.

Key words: generative artificial intelligence, ChatGPT, teacher professional competencies, TPACK, digital competence, higher education, mixed methods.

Introduction

In recent years, artificial intelligence technologies have been bringing revolutionary changes to

the field of education. The launch of ChatGPT in November 2022 sparked widespread discussion and research in educational systems worldwide (Lim et al., 2023; Chan Hu, 2023). Generative artificial

Compiled on: December 17, 2025.

Copyright: ©2025 by the authors. Submitted to *Advances in Science and Education* for possible open access publication under the terms and conditions of the [Creative Commons Attribution \(CC BY\) 4.0 license](#).

intelligence (GenAI) tools have the potential to support teachers in creating instructional materials, organizing personalized learning, and developing assessment mechanisms (Qadir, 2023; Chiu, 2024). However, the impact of these technologies on teachers' professional development has not yet been fully explored. Teachers' professional competencies constitute a complex system that includes subject knowledge, pedagogical skills, and intercultural competencies (Smolikevych, 2019). As AI and GenAI capabilities expand, some competencies evolve while others emerge anew (Wang et al., 2023). The Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra and Koehler (2006) serves as an essential theoretical foundation for integrating technology into education. Nevertheless, the unique characteristics of GenAI—autonomous content generation, real-time adaptability, and ethical challenges—necessitate a re-examination of the traditional TPACK framework (Celik, 2023; Chiu Rospigliosi, 2025). Currently, numerous studies are being conducted on integrating GenAI tools into education. Mai et al. (2024) examined the strengths and weaknesses of using ChatGPT through a systematic review. Moorhouse and Kohnke (2024) analyzed language teachers' experiences of using GenAI tools for professional development. However, empirical studies investigating the complex impact of GenAI on higher education teachers' professional competencies remain scarce. Such research is particularly absent in the Central Asian context. The purpose of this study is to comprehensively examine the effects of GenAI tools on the professional competency development of higher education teachers. The research addresses the following questions: (1) How does GenAI integration affect teachers' TPACK levels? (2) How does the use of GenAI tools influence teachers' self-efficacy and digital competencies? (3) How do teachers perceive GenAI tools and what challenges do they encounter in professional practice? By answering these questions, the study contributes to developing GenAI-based teacher preparation programs.

Theoretical Framework and Literature Review

The TPACK framework explains the interrelationship of teachers' technological, pedagogical, and content knowledge. The AI-

TPACK framework developed by Ning et al. (2024) is specifically designed for integrating GenAI tools into education. This framework encompasses five core components: AI-Technological Knowledge (AI-TK), AI-Technological Pedagogical Content Knowledge (AI-TCK), AI-Technological Pedagogical Knowledge (AI-TPK), and Ethics (Celik, 2023; Hava Babayigit, 2024). Teachers' AI literacy—understanding the technical and ethical aspects of AI systems—and AI competency—the ability to apply AI practically and ethically—serve as fundamental pillars of this framework. Digital competence remains a 21st-century requirement for teachers. Tondeur et al. (2023) developed the HeDiCom framework for higher education teachers, encompassing four dimensions: teaching practice, empowering students for a digital society, professional development, and organizational aspects. Basilotta-Gómez-Pablos et al. (2022) analyzed research on higher education teachers' digital competencies through a systematic literature review and found that most teachers rate their digital competencies at low or medium levels. Teachers' self-efficacy plays a crucial role in technology adoption and integration. According to Bandura's social cognitive theory, self-efficacy levels influence a teacher's willingness to experiment with and apply new technologies in education. Mante et al. (2025), in a study conducted in Ghana, examined the impact of GenAI on teachers' professional competencies and found that while moderate GenAI use enhances professional learning, excessive reliance negatively affects self-regulated engagement and professional values.

Methods

Research design

A mixed-methods design was employed in this study. Based on the convergent parallel design recommended by Creswell and Clark (2017), quantitative and qualitative data were collected in parallel, analyzed separately, and the results were integrated. The quantitative component included a quasi-experimental pretest-posttest design, while the qualitative component consisted of semi-structured interviews and document analysis. This approach enabled comprehensive understanding of the phenomenon and cross-validation of findings (Ivankova Stick, 2007).

Participants

A total of 186 teachers from four higher education institutions in Uzbekistan participated in this study. Participants were recruited through convenience sampling. The sample consisted of 58% females and 42% males. Age distribution was as follows: 25–35 years (34%), 36–45 years (41%), and over 46 years (25%). Teaching experience: less than 5 years (28%), 5–15 years (47%), and more than 15 years (25%). Teachers represented various disciplines: natural sciences (32%), social sciences and humanities (38%), and technical sciences (30%). For interviews, 24 teachers were purposively selected.

Table 1
Demographic Characteristics of Participants (N = 186)

Characteristic	n	%
Gender		
Female	108	58.1
Male	78	41.9
Age group		
25–35 years	63	33.9
36–45 years	76	40.9
46+ years	47	25.2
Teaching experience		
Less than 5 years	52	28.0
5–15 years	87	46.8
More than 15 years	47	25.2
Discipline		
Natural sciences	60	32.3
Social sciences & humanities	70	37.6
Technical sciences	56	30.1

Intervention Program

A 12-week professional development program on GenAI integration was designed for teachers. The program was structured based on the TPACK framework and consisted of three main phases: (1) introduction to GenAI technologies and development of basic skills (weeks 1–4), (2) integration of GenAI tools into pedagogical practice (weeks 5–8), and (3) practical projects and reflection (weeks 9–12). Each phase combined theoretical sessions, practical workshops, and independent work. Teachers learned to use ChatGPT, Claude, and other GenAI tools. Throughout the program, teachers practiced using GenAI tools for creating lesson plans, preparing assessment materials, organizing personalized instruction, and enhancing

student interactions. Each session lasted 3 hours, totaling 36 hours of instruction. The program was delivered in a blended learning format—combining face-to-face and online sessions. This approach aligns with recommendations by Dille and Røkenes (2021), who emphasized the importance of intrinsic motivation and teacher attitudes in online professional development.

Data collection instruments

Three instruments were used for quantitative data collection. First, the TPACK Survey (Schmidt et al., 2009)—this instrument consists of 7 subscales measuring teachers' technological, pedagogical, and content knowledge as well as their integration. Cronbach's alpha coefficients in previous studies ranged from .82 to .92. Second, the Digital Competence Scale based on DigCompEdu (Cabero-Almenara et al., 2020) was employed, comprising 22 items across 6 areas. Third, an adapted version of the Teachers' Sense of Efficacy Scale (Tschannen-Moran Hoy, 2001) was utilized. For qualitative data, a semi-structured interview protocol was developed. Interview questions covered experiences with GenAI tools, perceived benefits and challenges, ethical considerations, and future plans. Each interview lasted 45–60 minutes and was audio-recorded with participants' consent. Additionally, teachers' GenAI interaction histories (chat logs) were collected for analysis. This approach aligns with the methodology used in studies by Atlas (2023) and Moorhouse (2024).

Data analysis

Quantitative data were analyzed using SPSS 28.0. Paired samples t-tests were conducted to determine differences between pretest and posttest scores. Effect sizes were calculated using Cohen's d. One-way ANOVA was employed to analyze differences among groups. Internal consistency was verified through Cronbach's alpha. Qualitative data were analyzed using thematic analysis following Braun and Clarke's (2006) guidelines. The coding process was conducted using NVivo 14. Triangulation enabled verification of consistency between quantitative and qualitative findings.

Results

Quantitative findings

Changes in TPACK levels were statistically significant. Paired samples t-test results indicated

that teachers' overall TPACK scores increased significantly following the intervention ($t(185) = 8.47, p < .001, d = 0.78$). The largest improvement was observed in the Technological Knowledge (TK) subscale ($t(185) = 11.23, p < .001, d = 0.92$), followed by Technological Pedagogical Knowledge (TPK) ($t(185) = 9.86, p < .001, d = 0.84$). These findings are consistent with studies by Kim (2024) and Kim and Kwon (2023), which demonstrated the effectiveness of AI-convergent TPACK educational programs.

Table 2

Pretest and Posttest Results by TPACK Subscales

Subscale	Pre M(SD)	Post M(SD)	t	p	d
TK	3.12 (0.84)	4.18 (0.72)	11.23	<.001	0.92
PK	3.78 (0.69)	4.21 (0.58)	5.87	<.001	0.54
CK	4.02 (0.61)	4.15 (0.54)	2.14	.034	0.18
TPK	3.24 (0.78)	4.09 (0.64)	9.86	<.001	0.84
TCK	3.45 (0.82)	4.02 (0.68)	7.34	<.001	0.67
PCK	3.89 (0.71)	4.11 (0.62)	3.21	.002	0.28
TPACK	3.18 (0.86)	4.06 (0.71)	8.47	<.001	0.78

Note: TK = Technological Knowledge; PK = Pedagogical Knowledge; CK = Content Knowledge; TPK = Technological Pedagogical Knowledge; TCK = Technological Content Knowledge; PCK = Pedagogical Content Knowledge; TPACK = Technological Pedagogical Content Knowledge. M = mean; SD = standard deviation.

Digital competence scores also showed statistically significant improvement ($t(185) = 7.92, p < .001, d = 0.71$). The highest growth was observed in "Creating Digital Resources" ($d = 0.89$) and "Engaging Students" ($d = 0.82$) areas. Teachers' self-efficacy also increased significantly ($t(185) = 6.34, p < .001, d = 0.58$). These findings align with Lu et al. (2024), who demonstrated the potential of GenAI to develop teachers' higher-order thinking and self-efficacy. ANOVA results revealed statistically significant differences by age groups. Younger teachers (25–35 years) demonstrated higher outcomes in GenAI integration compared to their older colleagues (46+ years) ($F(2, 183) = 4.87, p = .009$). This finding is consistent with Harris et al. (2024), who examined the relationship between generational differences and GenAI adoption. However, no significant difference was found by teaching experience ($F(2, 183) = 1.23, p = .295$), suggesting that technological openness

may be more important than experience in GenAI integration.

Qualitative findings

Thematic analysis of interviews identified four major themes: (1) Pedagogical efficiency, (2) Time savings and workload reduction, (3) Ethical concerns, and (4) Technological adaptation challenges. Below is a detailed analysis of each theme. Pedagogical efficiency emerged as the most frequently mentioned theme. The majority of teachers highlighted how GenAI tools helped them create lesson plans, adapt materials, and develop assessment rubrics. One respondent stated: "ChatGPT enables me to quickly generate various lesson plans. What used to take a week now takes just one day. But I always review the results and customize them based on my experience" (Teacher 7, 38 years, social sciences). This finding aligns with Kohnke et al. (2023). Time savings and workload reduction was emphasized by many teachers. 87% of respondents discussed how GenAI tools helped with everyday tasks such as writing emails, preparing reports, and creating presentation materials. "I now spend less time on administrative work and can focus more on students. This has really improved my work-life balance" (Teacher 15, 42 years, natural sciences). However, some teachers also warned about the risks of over-reliance on GenAI. Ethical concerns emerged as a significant theme in the study. Teachers expressed concerns about academic integrity, students' misuse of GenAI, and difficulties in verifying the authenticity of AI-generated content. "I still don't know exactly how to teach my students to use GenAI. Whether they use it for learning or just to get answers—finding the answer to this question is difficult" (Teacher 3, 51 years, humanities). This aligns with the paradoxical situations identified by Lim et al. (2023). Technological adaptation challenges were particularly observed among older teachers. Some respondents described feelings of stress and insecurity in mastering new technologies. "At first, I was afraid of these technologies. But thanks to the training and my colleagues' support, I gradually learned. Now I use ChatGPT in my daily work" (Teacher 21, 56 years, technical sciences). This finding demonstrates the importance of professional development programs and the effectiveness of peer-coaching approaches.

The GenAI-TPACK pedagogical model

Based on the research findings, the GenAI-TPACK pedagogical model was developed. This model adapts the traditional TPACK framework to GenAI's unique characteristics and provides practical guidance for teachers in higher education contexts. The model includes the following components:

Table 3
Core Components of the GenAI-TPACK Model

Component	Description
GenAI-TK	Understanding GenAI technologies, knowing their capabilities and limitations, prompt engineering skills, ability to compare different GenAI tools
GenAI-PK	Strategies for integrating GenAI into pedagogical processes, teaching students to use GenAI effectively, organizing personalized instruction with GenAI assistance
GenAI-CK	Creating and presenting subject content using GenAI, discipline-specific GenAI applications, verifying and validating content accuracy
GenAI-Ethics	Academic integrity and plagiarism issues, data privacy, algorithmic errors and bias, principles of responsible AI use
HAIC-K	Human-AI Collaboration Knowledge: evaluating AI outputs, creative collaboration with AI, critical thinking and validating AI-generated content

The model has a cyclical nature, with all components developing as teachers gain more experience with GenAI. Importantly, "Reflective Practice" is positioned at the center of the model—meaning teachers should continuously analyze and improve their GenAI usage. This approach aligns with the I-TPACK framework proposed by Chiu and Rospigliosi (2025), but accounts for local context and higher education-specific characteristics.

Discussion

The study findings confirmed that GenAI integration has a positive impact on higher education teachers' professional competencies. The significant increase in TPACK scores, particularly in the TK and TPK subscales, indicates development in teachers' technological knowledge and their ability to apply it in pedagogical practice. These results are consistent with studies by Celik (2023) and Hava and Babayigit (2024), confirming the practical significance of the AI-TPACK framework. Qualitative findings revealed the multifaceted benefits of GenAI tools for teachers. Creating lesson materials, optimizing assessment processes, and organizing personalized instruction were identified as the most common applications of GenAI. Such results are consistent with GenAI usage patterns identified by Moorhouse (2024) and Kohnke et al. (2023).

However, the scope of teachers' GenAI use remains limited, with ChatGPT dominating in most cases. Ethical concerns emerged as a significant theme in the study. Teachers expressed concerns about academic integrity, reliability of GenAI outputs, and the risk of students becoming overly dependent on AI. These findings are consistent with studies by Lim et al. (2023) and Chan and Hu (2023), highlighting the need for ethical frameworks and guidelines when integrating GenAI into education. Additionally, the negative impact of excessive GenAI reliance on professional values, as identified by Mante et al. (2025), was also reflected in our findings. Findings regarding age differences deserve special attention. The higher outcomes of younger teachers in GenAI integration are consistent with Harris et al.'s (2024) research on generational differences and technology adoption. However, the lack of significant effect from teaching experience suggests that appropriate professional development programs can develop GenAI competencies among teachers of all age groups. This finding has important implications for education policy and professional development program design. The proposed GenAI-TPACK model adapts existing frameworks to local context and higher education characteristics. Unlike Celik's (2023) Intelligent-TPACK and Chiu and Rospigliosi's (2025) I-TPACK frameworks, the model highlights the ethical component as a separate element and incorporates Human-AI Collaboration Knowledge (HAIC-K). These innovations account for GenAI's evolutionary characteristics and the importance of teacher-student relationships in higher education.

Limitations

The study has several limitations. First, the sample was drawn from a limited geographical area of Uzbekistan, and generalizing results to other contexts requires caution. Second, due to the quasi-experimental design, isolating the pure effect of the intervention is difficult. Third, self-report instruments may introduce subjective bias. Future research should conduct longitudinal studies with randomized control groups.

Practical implications

Based on the study findings, the following practical recommendations are offered: (1) Higher education institutions should implement systematic GenAI professional development programs for

teachers; (2) These programs should cover not only technical skills but also ethical considerations and critical thinking; (3) Peer-coaching and mentoring approaches may be particularly effective for older teachers; (4) GenAI usage policies and guidelines should be developed at the institutional level; (5) Teaching students to use GenAI responsibly should be incorporated into curricula.

Conclusion

This study empirically confirmed that GenAI integration has a positive impact on higher education teachers' professional competencies. The significant improvement in TPACK, digital competencies, and self-efficacy scores demonstrates the effectiveness of GenAI-based professional development programs. At the same time, ethical concerns and technological adaptation challenges were identified, emphasizing the need for a comprehensive approach. The proposed GenAI-TPACK model provides both a theoretical and practical framework for preparing teachers to work with GenAI in higher education. The model integrates international standards and best practices while accounting for local context. Future research may focus on testing this model in other contexts, examining longitudinal effects, and assessing the impact on student outcomes.

References

1. Atlas, S. (2023). ChatGPT for higher education and professional development: A guide to conversational AI. DigitalCommons@URI.
2. Bandura, A. (1997). Self-efficacy: The exercise of control. W.H. Freeman and Company.
3. Basilotta-Gómez-Pablos, V., Matarranz, M., Casado-Aranda, L. A., & Otto, A. (2022). Teachers' digital competencies in higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education*, 19(1), 1-16. <https://doi.org/10.1186/s41239-021-00312-8>
4. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. <https://doi.org/10.1191/1478088706qp0630a>
5. Cabero-Almenara, J., Barroso-Osuna, J., Rodríguez-Gallego, M., & Palacios-Rodríguez, A. (2020). La competencia digital docente: El caso de las universidades andaluzas. *Aula Abierta*, 49(4), 363-372. <https://doi.org/10.17811/rifie.49.4.2020.363-372>
6. Celik, I. (2023). Towards Intelligent-TPACK: An empirical study on teachers' professional knowledge to ethically integrate artificial intelligence (AI)-based tools into education. *Computers in Human Behavior*, 138, 107468. <https://doi.org/10.1016/j.chb.2022.107468>
7. Chan, C. K. Y., & Hu, W. (2023). Students' voices on generative AI: Perceptions, benefits, and challenges in higher education. *International Journal of Educational Technology in Higher Education*, 20(1), 1-18. <https://doi.org/10.1186/s41239-023-00411-8>
8. Chiu, T. K. F. (2024). The impact of generative AI (GenAI) on practices, policies and research direction in education: A case of ChatGPT and midjourney. *Interactive Learning Environments*, 32(10), 6187-6203. <https://doi.org/10.1080/10494820.2023.2253861>
9. Chiu, T. K. F., & Rospigliosi, P. (2025). Developing intelligent-TPACK (I-TPACK) framework from unpacking AI literacy and competency: Implementation strategies and future research direction. *Interactive Learning Environments*. <https://doi.org/10.1080/10494820.2025.2545053>
10. Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research* (3rd ed.). Sage Publications.
11. Dille, K. B., & Røkenes, F. M. (2021). Teachers' professional development in formal online communities: A scoping review. *Teaching and Teacher Education*, 105, 103431. <https://doi.org/10.1016/j.tate.2021.103431>
12. Harris, L., Chen, X., & Williams, J. (2024). ChatGPT adoption in higher education: A study of faculty generation cohort, self-efficacy, and innovativeness. *Technology, Knowledge and*

- Learning. <https://doi.org/10.1007/s10758-025-09865-3>
13. Hava, K., & Babayiğit, Ö. (2024). Exploring the relationship between teachers' competencies in AI-TPACK and digital proficiency. *Education and Information Technologies*, 29, 17683-17705. <https://doi.org/10.1007/s10639-024-12939-x>
 14. Ivankova, N. V., & Stick, S. L. (2007). Students' persistence in a distributed doctoral program in educational leadership in higher education: A mixed methods study. *Research in Higher Education*, 48(1), 93-135. <https://doi.org/10.1007/s11162-006-9025-4>
 15. Kim, S. (2024). Effects of AI-convergence TPACK educational program on pre-service teachers' pedagogical content knowledge. *Computers & Education*, 214, 105024. <https://doi.org/10.1016/j.compedu.2024.105024>
 16. Kim, S., & Kwon, O. (2023). Identifying AI competencies within the TPACK framework for K-12 education. *Educational Technology & Society*, 26(3), 45-59.
 17. Kohnke, L., Moorhouse, B. L., & Zou, D. (2023). ChatGPT for language teaching and learning. *RELJ Journal*, 54(2), 537-550. <https://doi.org/10.1177/00336882231162868>
 18. Lim, W. M., Gunasekara, A., Pallant, J. L., Pallant, J. I., & Pechenkina, E. (2023). Generative AI and the future of education: Ragnarök or reformation? A paradoxical perspective from management educators. *International Journal of Management Education*, 21(2), 100790. <https://doi.org/10.1016/j.ijme.2023.100790>
 19. Lu, J., Zheng, R., Gong, Z., & Huifen, X. (2024). Supporting teachers' professional development with generative AI: The effects on higher order thinking and self-efficacy. *British Journal of Educational Technology*, 55(4), 1523-1541. <https://doi.org/10.1111/bjet.13412>
 20. Mai, D. T. T., Da, C. V., & Hanh, N. V. (2024). The use of ChatGPT in teaching and learning: A systematic review through SWOT analysis approach. *Frontiers in Education*, 9, 1328769. <https://doi.org/10.3389/feduc.2024.1328769>
 21. Mante, D. A., Opoku, O. G., & Chineta, O. M. (2025). Examining the moderating role of generative AI in advancing teachers' professional competencies through self-directed learning: Evidence from Ghana. *Interactive Learning Environments*. <https://doi.org/10.1080/10494820.2025.2556811>
 22. Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017-1054. <https://doi.org/10.1111/j.1467-9620.2006.00684.x>
 23. Moorhouse, B. L. (2024). Beginning and first-year language teachers' readiness for the generative AI age. *Computers and Education: Artificial Intelligence*, 6, 100211. <https://doi.org/10.1016/j.caeai.2024.100211>
 24. Moorhouse, B. L., & Kohnke, L. (2024). Developing language teachers' professional generative AI competence: An intervention study in an initial language teacher education course. *System*, 124, 103376. <https://doi.org/10.1016/j.system.2024.103376>
 25. Ning, Y., Zhang, C., Xu, B., Zhou, Y., & Wijaya, T. T. (2024). Teachers' AI-TPACK: Exploring the relationship between knowledge elements. *Sustainability*, 16(3), 978. <https://doi.org/10.3390/su16030978>
 26. Qadir, J. (2023). Engineering education in the era of ChatGPT: Promise and pitfalls of generative AI for education. *IEEE Global Engineering Education Conference (EDUCON)*, 1-9. <https://doi.org/10.1109/EDUCON54358.2023.10125121>
 27. Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, 42(2), 123-149. <https://doi.org/10.1080/15391523.2009.10782544>
 28. Smolikevych, N. (2019). Teacher professional competencies. *Scientific Research and*

Development: Modern Communication Science,
8(3), 135-139.

29. Tondeur, J., Howard, S., Van Zanten, M., Van Rooij, S. W., & Scherer, R. (2023). The HeDiCom framework: Higher Education teachers' digital competencies for the future. *Educational Technology Research and Development*, 71, 33-53. <https://doi.org/10.1007/s11423-023-10193-5>
30. Tschannen-Moran, M., & Hoy, A. W. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education*, 17(7), 783-805. [https://doi.org/10.1016/S0742-051X\(01\)00036-1](https://doi.org/10.1016/S0742-051X(01)00036-1)
31. Wang, Y., Liu, C., & Tu, Y. F. (2023). Factors affecting the adoption of AI-based applications in higher education. *Educational Technology & Society*, 26(1), 116-131.