The Impact of Junior High School Science Teachers' Professional Development on Beliefs and Practices of AI in Assessment

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Abstract: *International competency-based assessment has become a key indicator for evaluating the effectiveness of educational policies. PISA 2025 emphasizes decision-making and problem-solving, while AI offers potential to enhance teaching and science assessment. This study examined junior high school science teachers' beliefs about AI in assessment and their willingness to adopt it through a professional development program. Thirty science teachers participated in a three-hour workshop. Research results indicated a significant increase in teachers' recognition of AI as a learning tool (AILT), demonstrating the effectiveness of the workshop in deepening teachers' understanding and application of AI in science assessment. The findings affirm the potential of AI in science education assessment and offer valuable insights for future educational policy and professional development initiatives.*

Keywords: Teacher Professional Development, AI in Assessment, Teacher Beliefs, PISA 2025, Science Assessment

1. Introduction

In the context of science education, "assessment" typically refers to the process of collecting, analyzing, and interpreting data on students' performance during their learning journey. Its primary purpose is to evaluate students' comprehension and learning outcomes, as well as the effectiveness of teaching strategies and instructional methods (Kruit et al., 2020). With the increasing globalization and diversification of education, numerous international comparative studies have been developed to examine the effectiveness and impact of educational policies across countries. For example, the Trends in International Mathematics and Science Study (TIMSS) focuses on content knowledge, reasoning, and application, while the Progress in International Reading Literacy Study (PIRLS) tracks global trends in reading comprehension. Both assessments are administered by the International Association for the Evaluation of Educational Achievement (IEA). In contrast to curriculum-based evaluations, the Programme for International Student Assessment (PISA), conducted by the Organisation for Economic Co-operation and Development (OECD), is held every three years and targets 15-year-old students. It assesses competencies in mathematics, reading, and science literacy, with the primary domain rotating with each cycle. In response to evolving educational priorities, PISA has incorporated competency-based assessments that go beyond national curricula, aiming to reflect the outcomes of educational development and policy implementation on a global scale (Kim, 2021; Xu, 2023).

In PISA 2025, scientific literacy will again be the primary domain, following the previous focus in PISA 2015. Compared to the earlier framework, the 2025 assessment expands its scope to not only include constructing scientific inquiry and interpreting data and evidence, but also newly incorporates the ability to research, evaluate, and apply scientific information in decision-making and action. Additionally, a new component—Learning in the Digital World (LDW)—has been introduced. These structural updates reflect broader shifts in the educational landscape and signal evolving international expectations for both student competencies and related educational policies. PISA 2025 places particular emphasis on students' data analysis, critical thinking, and problem-solving skills. In this context, artificial intelligence holds significant potential for application in the design and implementation of assessments (Deta et al., 2024; Wang et al., 2024; White et al., 2023).

The rapid advancement of artificial intelligence is reshaping the educational landscape, particularly in how teaching and assessment are approached. AI technologies are increasingly being applied to educational assessment through adaptive learning systems, intelligent tutoring, and learning analytics (Dogan et al., 2023; Ejjami, 2024; Hamal et al., 2022). However, in the context of science education, many teachers remain unfamiliar with AI tools and are skeptical about their accuracy (Choi et al., 2022; Gurer & Akkaya, 2021). Teachers' beliefs play a pivotal role in shaping their willingness and attitudes toward adopting AI in practice. Furthermore, inconsistencies in how AI is applied in assessments, along with misalignment with the principles outlined in science curricula, often require teachers to invest additional preparation time. These factors highlight the challenges and barriers to integrating AI into assessment practices (Herold et al., 2024; Holmes, 2019; Williamson, 2020). Ultimately, providing opportunities for professional development is key to enabling science teachers to effectively adopt and implement AI in assessment (Celik, 2023; Nazaretsky et al., 2022; Wang et al., 2023).

1.1. Research Objectives

1. To investigate the challenges and issues junior high school science teachers face when integrating AI into assessment.
2. To analyze the relationship between science teachers' beliefs and their willingness to adopt AI in assessment.
3. To design and implement a professional development workshop aimed at enhancing teachers' application of AI in assessment, and to examine its impact on teacher beliefs and practices.

1.2. Research Questions

1. What are the main challenges faced by junior high school science teachers in applying AI to assessment?
2. How do science teachers' beliefs influence their willingness to adopt AI in assessment?
3. How can professional development workshops enhance science teachers' understanding and use of AI in assessment?

2. Literature Review

2.1. The Relationship Between International Assessments and AI-Based Assessment

The PISA 2025 framework for scientific literacy emphasizes students' ability to investigate, evaluate, and apply scientific information in decision-making and action. This focus aligns with the timely integration of AI technologies into assessment, which is actively redefining both its methods and scope. Through automated scoring, adaptive testing, data analytics, and innovative item design, AI enhances assessment efficiency, captures student interest, and offers personalized learning feedback based on individual performance levels. Moreover, AI-driven simulations and interactive formats provide more authentic representations of students' capabilities in solving complex problems (Hao et al., 2024; Heeg & Avraamidou, 2023).

Despite these advantages, the application of AI in science education still faces challenges. Teachers' acceptance of such technologies, along with the appropriateness of their timing and context of use, can significantly influence their willingness to adopt AI-based assessments. In summary, AI introduces innovative potential to international assessments, yet its successful implementation depends on the development of supporting educational resources and infrastructure (Azari et al., 2024; Yılmaz, 2024).

2.2. Applications of AI Technology in Science Education Assessment

Artificial intelligence is considered a subfield of computer science within the broader domain of information and communication technology (ICT). Its integration into science education involves technologies such as neural networks, intelligent tutoring systems, deep learning, speech and image recognition, and natural language processing (Colchester et al., 2017; Lu et al., 2018). AI is applied in educational contexts through scenario simulations, automated feedback, adaptive learning, and chatbot-based tutoring systems (Heeg & Avraamidou, 2023; Mahligawati et al., 2023; Vierhauser et al., 2024). As such, both AI and ICT can be regarded as functional tools for teaching and assessment.

Studies on instructional practices suggest that teachers' ICT competencies and pedagogical beliefs have a measurable impact on students' scientific reasoning and data interpretation skills. While ICT proficiency alone does not directly influence academic performance, pedagogical beliefs aligned with inquiry-based instruction and the implementation of constructivist professional development activities can strengthen teachers' sense of efficacy in using AI for assessment. In other words, science teachers' engagement in targeted professional development enhances their ability to implement constructivist teaching approaches supported by AI tools in the classroom (Alt, 2018; Hu et al., 2021; Wilson, 2013).

2.3. The Relationship Between Teacher Beliefs and Professional Development Activities

Teacher professional development is a vital means of enhancing both teaching and learning. Teachers' attitudes and stances toward new instructional methods or strategies significantly influence the effectiveness of such activities. Factors such as the goals of professional development, the format of participation, collaboration among teachers, appropriate duration, and content relevance all affect whether teachers can successfully integrate what they have learned into classroom practice. Consequently, teachers' pedagogical beliefs shape both how they engage in professional development and how they apply new knowledge in their teaching (Hubers et al., 2020; Smith & Lindsay, 2016; You et al., 2024).

The integration of AI-based assessment tools into professional development can further support teachers through instructional material analysis, classroom interaction, and reflective practice. For instance, AI tools can document teaching processes, analyze classroom interaction patterns, and generate formative assessment resources such as visuals, videos, audio, and contextual scenarios tailored to science instruction. These tools also offer specific suggestions and guidance to promote reflection and the refinement of teaching strategies (Baysal & Mutlu, 2021; Lumpe et al., 2012).

3. Research Methodology

This study adopted a one-group pretest-posttest design to examine the effects of a professional development workshop on junior high school science teachers. The workshop was designed to enhance teachers' understanding and application of AI in assessment and to provide practical guidance for implementation. The study focused on analyzing changes in teachers' beliefs and attitudes before and after the activity, with particular emphasis on how AI-based assessment influences their willingness to adopt such technologies and how it may strengthen their capacity to apply AI in science education assessment.

3.1. Participants

The participants of this study were 30 junior high school science teachers from northern Taiwan, with an equal gender distribution. In terms of age, 2 teachers (6.67%) were under 29, 13 (43%) were between 30 and 39, 14 (46%) were between 40 and 49, and 1 (3.33%) was aged 50–59. Regarding teaching experience, 5 teachers (16.6%) had less than 5 years of experience, 12 (40%) had 5 to 10 years, 10 (33.3%) had 10 to 15 years, and 3 (10%) had more than 15 years. As for school type, 18 teachers (60%) taught in urban schools and 12 (40%) in non-urban schools. In terms of school size, 5 teachers (16.6%) worked in schools with fewer than 12 classes, 14 (46.6%) in schools with 12 to 29 classes, and 11 (36.6%) in schools with more than 30 classes.

3.2. Process of Professional Development Activities

The workshop spanned a total of three hours and was structured into three sequential stages. The primary objectives were to help teachers understand the differences between the scientific literacy focus of PISA 2025 and previous assessment frameworks, enhance their confidence and comprehension of AI applications in assessment, and demonstrate practical AI-supported assessment scenarios in science education.

In the first stage (30 minutes), participants completed a pretest and were introduced to the core competencies of PISA 2025 scientific literacy, including the new dimension of Learning in the Digital World (LDW). Case examples were presented, building upon Taiwan's prior assessment experiences and data to contextualize the upcoming framework.

The second stage (90 minutes) addressed the newly added competencies in PISA 2025—specifically, investigating, evaluating, and applying scientific information for decision-making and action, along with LDW components. Teachers were prompted with the guiding question, "How can we implement this?” to stimulate engagement. Various AI-supported assessment methods and case studies were shared, including data visualization, simulations, modeling, personalized learning, language-based learning, and virtual environments. A hands-on demonstration using Google Colab and Python guided teachers through generating scientific data visualizations (e.g., temperature or environmental data). Participants modified sample Python code to analyze real datasets (such as CO_2 emissions), then created new visual outputs and discussed their scientific implications.

In the final stage (60 minutes), teachers applied the introduced tools and strategies to design their own science teaching case. They collaborated in groups to develop and refine their ideas, uploaded their lesson plans for peer sharing, and completed a posttest to evaluate changes in understanding and attitudes following the workshop.

3.3. Measurement Tools

The pretest and posttest questionnaires used in this study contained identical items and consisted of three sections: the Teacher Epistemic Beliefs Scale (TEBS), the Teacher Pedagogical Beliefs Scale (TPBS), and the AI for Assessment Scale. A total of 28 items were included, all rated on a 5-point Likert scale, where 1 indicated "strongly disagree" and 5 indicated "strongly agree."

3.3.1. Teacher Epistemic Beliefs Scale (TEBS)

This scale comprises two dimensions: Authority and Expert Knowledge (AEK) and Certainty of Knowledge (CK). The AEK subscale, with a Cronbach’s α of .80, includes six items (e.g., “I have no doubt about what experts say”), while the CK subscale, with a Cronbach’s α of .61, includes three items (e.g., “If scientists work hard enough, they can find the truth to nearly all problems”). This scale, adapted from Chai et al. (2010), was used to examine science teachers’ epistemic beliefs related to the use of AI in assessment.

3.3.2. Teacher Pedagogical Beliefs Scale (TPBS)

The TPBS includes two dimensions: Constructivist Pedagogical Beliefs (CPB) and Traditional Pedagogical Beliefs (TPB). Developed by Chai & Teo (2008), this scale was designed to assess teachers’ instructional beliefs in the context of AI-supported assessment. The CPB subscale, with a Cronbach’s α of .88, consists of five items (e.g., “Students’ ideas are important and should be taken seriously”), while the TPB subscale, with a Cronbach’s α of .84, also contains five items (e.g., “Learning mainly occurs through practice and repetition”).

3.3.3. AI for Assessment Scale (AIAS)

This scale includes two dimensions: AI as an Information Tool (AIIT) and AI as a Learning Tool (AILT). The AIIT subscale includes five items and has a Cronbach’s α of .83, while the AILT subscale includes four items with a Cronbach’s α of .84. Adapted from Tondeur et al. (2007), this instrument aimed to explore whether science teachers perceive AI as primarily an information-processing tool or a tool for enhancing student learning within the context of assessment.

4. Results

The pretest and posttest scales each comprised six dimensions, with response patterns summarized in Table 1. All subscales demonstrated acceptable internal consistency, with Cronbach’s α values exceeding 0.7. Notably, both AIIT (AI as an Information Tool) and AILT (AI as a Learning Tool) received mean scores above 4 in both pretest and posttest. Post-workshop feedback further revealed a high level of teacher willingness to apply AI in science assessment, with a mean score of 4.1 (SD = 0.57).

Table 1. Response Patterns Across Six Dimensions in Pretest and Posttest Questionnaires.

Pretest	Mean	SD	Skewness	Kurtosis	No. of items
Teacher Epistemic Beliefs Scale (TEBS)					
AEK	2.43	.52	.49	.74	6
CK	2.81	.80	-.12	-.96	3
Teacher Pedagogical Beliefs Scale (TPBS)					
CPB	4.23	.57	-.52	-.33	5
TPB	3.39	.64	-.01	.59	5
AI for Assessment Scale (AIAS)					
AIIT	4.06	.54	-.34	.07	5
AILT	4.01	.56	-.05	-.20	4
Posttest	**Mean**	**SD**	**Skewness**	**Kurtosis**	**No. of items**
Teacher Epistemic Beliefs Scale (TEBS)					
AEK	2.28	.51	.72	2.04	6
CK	2.7	.83	.04	-.97	3
Teacher Pedagogical Beliefs Scale (TPBS)					
CPB	4.34	.49	-.45	.26	5
TPB	3.41	.78	-.01	.49	5
AI for Assessment Scale (AIAS)					
AIIT	4.18	.73	-1.75	4.68	5
AILT	4.36	.62	-.61	-.68	4

Table 2. Paired Sample T-Test Results.

Category	Mean (SD)		df	t	p
	Pretest	Posttest			
Teacher Epistemic Beliefs Scale (TEBS)					
AEK	2.43 (.52)	2.28 (.51)	29	3.07	.005*
CK	2.81 (.80)	2.7 (.83)	29	1.22	.231
Teacher Pedagogical Beliefs Scale (TPBS)					
CPB	4.23 (.57)	4.34 (.49)	29	-1.43	.165
TPB	3.39 (.64)	3.41 (.78)	29	-.21	.835

Table 2 (continued).

Category	Mean (SD)		df	t	p
	Pretest	Posttest			
AI for Assessment Scale (AIAS)					
AIIT	4.06 (.54)	4.18 (.73)	29	-.90	.375
AILT	4.01 (.56)	4.36 (.62)	29	-3.99	.000*

According to the paired sample t-test results (see Table 2), several key differences were observed between the pretest and posttest scores. The AEK (Authority and Expert Knowledge) dimension showed a significant decline in the posttest, indicating a reduced level of trust in expert knowledge after participating in the AI-focused professional development. In contrast, the AILT (AI as a Learning Tool) dimension showed a significant increase, suggesting that the workshop effectively strengthened teachers' beliefs in AI as a tool for supporting student learning.

No statistically significant differences were found in the CK (Certainty of Knowledge), CPB (Constructivist Pedagogical Beliefs), TPB (Traditional Pedagogical Beliefs), or AIIT (AI as an Information Tool) dimensions. This suggests that teachers' views in these areas remained relatively stable, possibly due to the influence of long-standing beliefs or the limited duration of the intervention.

5. Conclusion

This study set out to explore the challenges and concerns faced by junior high school science teachers in integrating AI into assessment practices, to analyze how their pedagogical beliefs influence their willingness to adopt AI-based assessment tools, and to enhance their application competencies through a professional development program framed around the evolving focus of PISA 2025 scientific literacy. The findings confirm that well-structured professional development can meaningfully influence teachers' beliefs and attitudes (De Vries et al., 2014; Sari et al., 2020; Vries et al., 2013), with particularly notable gains in their recognition of AI as a learning tool (AILT). Moreover, although the shift in perceptions of AI as an information tool (AIIT) was not statistically significant, there was observable growth, underscoring the potential of such interventions to expand teachers' understanding and practical use of AI in science assessment.

However, a significant decline in trust toward authority and expert knowledge (AEK) was observed post-intervention, indicating ongoing skepticism about the accuracy and reliability of AI technologies (Nazaretsky et al., 2022; Nazaretsky et al., 2021). Minor, non-significant increases in constructivist (CPB) and traditional pedagogical beliefs (TPB) suggest that deeply rooted teaching beliefs may require longer-term engagement to shift meaningfully (Meschede et al., 2017; Valcke, 2010). Overall, this study affirms the transformative potential of AI in science assessment and highlights the critical role of teacher professional development in supporting its effective adoption. At the same time, it brings to light persistent challenges—such as limited familiarity with AI tools, high preparation demands, and misalignment with existing curricular goals—that must be addressed to ensure sustainable integration of AI technologies in classroom assessment practice.

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References

Alt, D. (2018). Science teachers' conceptions of teaching and learning, ICT efficacy, ICT professional development and ICT practices enacted in their classrooms. *Teaching and Teacher Education*.

Azari, A., Rochintaniawati, D., & Agustin, R. (2024). Can Web-Based AI Be Implemented in the Middle School Science Classroom? A Critical Review. *Jurnal Inovasi Pendidikan IPA*. https://doi.org/10.21831/jipi.v10i2.75364.

Baysal, Y., & Mutlu, F. (2021). The Effect of Professional Development Programs on Teachers' Science Teaching Self Efficacy Beliefs: A Meta-Analysis Study. *International Journal of Contemporary Educational Research*.

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.

Chai, C. S., & Teo, T. (2008). Confirmatory Factor Analysis of the Conception for Teaching and Learning Questionnaire (CTLQ). *The Asia-Pacific Education Researcher, 17*(2), 1-1.

Chai, C. S., Deng, F., Wong, B., & Qian, Y. (2010). South China education majors' epistemological beliefs and their conceptions of the nature of science. *The Asia-Pacific Education Researcher*.

Choi, S., Jang, Y., & Kim, H. (2022). Influence of Pedagogical Beliefs and Perceived Trust on Teachers' Acceptance of Educational Artificial Intelligence Tools. *International Journal of Human–Computer Interaction*, 39, 910 - 922.

Colchester, K., Hagras, H., Alghazzawi, D., & Aldabbagh, G. (2017). A survey of artificial intelligence techniques employed for adaptive educational systems within e-learning platforms. *Journal of Artificial Intelligence and Soft Computing Research*, *7*(1), 47-64.

De Vries, S., Van De Grift, W., & Jansen, E. (2014). How teachers' beliefs about learning and teaching relate to their continuing professional development. *Teachers and Teaching*, 20, 338 - 357.

Deta, U., Ayun, S., Laila, L., Prahani, B., & Suprapto, N. (2024). PISA science framework 2018 vs 2025 and its impact in physics education: Literature review. *Momentum: Physics Education Journal*.

Dogan, M., Dogan, T., & Bozkurt, A. (2023). The Use of Artificial Intelligence (AI) in Online Learning and Distance Education Processes: A Systematic Review of Empirical Studies. *Applied Sciences*.

Ejjami, R. (2024). The Future of Learning: AI-Based Curriculum Development. *International Journal For Multidisciplinary Research*. https://doi.org/10.36948/ijfmr.2024.v06i04.24441.

Gurer, M., & Akkaya, R. (2021). The influence of pedagogical beliefs on technology acceptance: a structural equation modeling study of pre-service mathematics teachers. *Journal of Mathematics Teacher Education*, 25, 479 - 495.

Hao, M., Wang, Y., & Peng, J. (2024). Empirical Research on AI Technology-Supported Precision Teaching in High School Science Subjects. *Applied Sciences*. https://doi.org/10.3390/app14177544.

Heeg, D., & Avraamidou, L. (2023). The use of Artificial intelligence in school science: a systematic literature review. *Educational Media International*, 60, 125 - 150. https://doi.org/10.1080/09523987.2023.2264990.

Herold, D., Murphy, G., & Buck, C. (2024). *Preparing the next generation: Integrating generative AI in entrepreneurship education for graduate capability development.*

Holmes, W. (2019). Artificial intelligence in education: Promises and implications for teaching and learning. *Center for Curriculum Redesign*.

Hu, D., Yuan, B., Luo, J., & Wang, M. (2021). A review of empirical research on ICT applications in teacher professional development and teaching practice. *Knowledge Management & E-Learning: An International Journal*.

Hubers, M., D.Endedijk, M., & Van Veen, K. (2020). Effective characteristics of professional development programs for science and technology education. *Professional Development in Education*, 48, 827 - 846.

Kim, J. (2021). 'In numbers we trust': Statistical data as governing technologies in the era of student achievement and school accountability. *Educational Philosophy and Theory*, 54, 1442 - 1452.

Kruit, P., Oostdam, R., van den Berg, E., & Schuitema, J. (2020). Performance assessment as a diagnostic tool for science teachers. *Research in Science Education*, *50*(3), 1093-1117.https://doi.org/10.1007/s11165-018-9724-9.

Lu, H., Li, Y., Chen, M., Kim, H., & Serikawa, S. (2018). Brain intelligence: go beyond artificial intelligence. *Mobile Networks and Applications*, *23*, 368-375.

Lumpe, A., Czerniak, C., Haney, J., & Beltyukova, S. (2012). Beliefs about Teaching Science: The relationship between elementary teachers' participation in professional development and student achievement. *International Journal of Science Education*, 34, 153 - 166. https://doi.org/10.1080/09500693.2010.551222.

Mahligawati, F., Allanas, E., Butarbutar, M., & Nordin, N. (2023). Artificial intelligence in Physics Education: a comprehensive literature review. *Journal of Physics: Conference Series*, 2596.

Meschede, N., Fiebranz, A., Möller, K., & Steffensky, M. (2017). Teachers' professional vision, pedagogical content knowledge and beliefs: On its relation and differences between pre-service and in-service teachers. *Teaching and Teacher Education*, 66, 158-170. https://doi.org/10.1016/J.TATE.2017.04.010.

Nazaretsky, T., Ariely, M., Cukurova, M., & Alexandron, G. (2022). Teachers' trust in AI-powered educational technology and a professional development program to improve it. *British journal of educational technology*, *53*(4), 914-931.

Nazaretsky, T., Cukurova, M., & Alexandron, G. (2021). An Instrument for Measuring Teachers' Trust in AI-Based Educational Technology. LAK22: 12th International Learning Analytics and Knowledge Conference.

Sari, S., Nurkamto, J., & Rochsantiningsih, D. (2020). Teacher Professional Development: The Story of English Teacher's Beliefs and Practices. *ELS Journal on Interdisciplinary Studies in Humanities*.

Smith, K., & Lindsay, S. (2016). Building Future Directions for Teacher Learning in Science Education. *Research in Science Education*, 46, 243-261. https://doi.org/10.1007/S11165-015-9510-X.

Tondeur, J., Van Braak, J., & Valcke, M. (2007). Towards a typology of computer use in primary education. *Journal of computer assisted learning, 23*(3), 197-206.

Valcke, M., Sang, G., Rots, I., & Hermans, R. (2010). Taking Prospective Teachers' Beliefs into Account in Teacher Education. , 622-628. https://doi.org/10.1016/B978-0-08-044894-7.00668-0.

Vierhauser, M., Groher, I., Antensteiner, T., & Sauerwein, C. (2024). Towards Integrating Emerging AI Applications in SE Education. *2024 36th International Conference on Software Engineering Education and Training (CSEE&T)*, 1-5. https://doi.org/10.1109/CSEET62301.2024.10663045.

Vries, S., Grift, W., & Jansen, E. (2013). Teachers' beliefs and continuing professional development. *Journal of Educational Administration*, 51, 213-231. https://doi.org/10.1108/09578231311304715.

Wang, S., Li, J., & Yuan, Y. (2024). The power of convergence: STEM education in the era of artificial intelligence. In *Disciplinary and Interdisciplinary Education in STEM: Changes and Innovations* (pp. 63-80). Cham: Springer Nature Switzerland.

Wang, X., Li, L., Tan, S. C., Yang, L., & Lei, J. (2023). Preparing for AI-enhanced education: Conceptualizing and empirically examining teachers' AI readiness. *Computers in Human Behavior*, *146*, 107798.

White, P. J., Ardoin, N. M., Eames, C., & Monroe, M. C. (2023). Agency in the Anthropocene: Supporting document to the PISA 2025 Science Framework.

Williamson, B. (2020). New digital laboratories of experimental knowledge production: Artificial intelligence and education research. *London Review of Education*, *18*(2), 209-220.

Xu, Z. (2023). PISA's Impact on China's education policy. *Journal of Education, Humanities and Social Sciences*.

Yılmaz, Ö. (2024). Personalised learning and artificial intelligence in science education: current state and future perspectives. *Educational Technology Quarterly*. https://doi.org/10.55056/etq.744.

You, H., Park, S., Hong, M., & Warren, A. (2024). Unveiling effectiveness: A meta-analysis of professional development programs in science education. *Journal of Research in Science Teaching*.