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Development and validation of teacher artificial intelligence (AI) competence self-efficacy (TAICS) scale

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Abstract
Evaluating teacher AI competence levels and building effective, safe, and healthy learning environment are crucial steps in transitioning to AI-based education. Current established digital competence frameworks may indirectly address AI competence but often overlook the impact of AI on society, ethics, and assessment. Research on teacher AI competence is at its first stage, primarily focusing on theoretical and professional discussions, along with qualitative investigations. This study aims to propose and confirm the reliability and validity of a scale measuring teacher AI competence self-efficacy (TAICS) in K-12 education. The scale was developed using a Delphi method, and includes six dimensions: AI knowledge, AI pedagogy, AI assessments, AI ethics, human-centered education, and professional engagement. Each dimension contains four items. The scale was evaluated on a sample of 434 K-12 teachers through confirmatory factor analysis and model comparisons. The analyses showed that the scale is consistent across male and female teachers, as well as scientific and non-science teachers. The completed TAICS scale consists of 24 items and encompasses six dimensions of AI competence. It can be used to examine interventions and correlational research, as well as to inform the creation of new strategies and policies for AI in relation to teacher AI competence development.

Keywords Scale development · Teacher AI competence · Teacher digital competence · TPACK · Self-efficacy beliefs · Delphi method

1 Introduction

Generative artificial intelligence (AI) impacts education, and its tools are here to stay for students and teachers. Teachers should learn what AI is and how to use AI to support teaching and learning (Chiu, 2023, 2024; Falloon, 2020). Compared to

Extended author information available on the last page of the article non-AI tools, AI tools are more disruptive and bring more ethical, privacy, and security challenges to teachers and students. Teachers should be competent to safely and effectively use AI in learning and teaching (Falloon, 2020). They should have a new set of competencies to create healthy, safe, and effective student learning environments. However, teacher AI competence is still under development (see UNESCO); we lack well-recognized teacher AI competence and measures. It is vital to clarify what teacher AI competence is, especially in K–12 education, because K–12 students are at the development stage and require teacher guidance and support (Chiu, Moorhouse, et al., 2024).

AI is viewed as a digital technology. Its integration into learning and teaching can be guided by Mishra and Koehler's (2006) technological pedagogical content knowledge (TPACK) framework. TPACK is one of the well-recognized teacher digital competence frameworks that is included in most pre-service teacher teaching programs and in-service professional development activities (Chiu, Falloon, et al., 2024). Other than TPACK, teacher digital competence is addressed by the policy documents in different regions: Australia's National Professional Standards for Teachers, the European Commission's Digital Education Action Plan, the European Framework for the Digital Competence of Educators (DigCompEdu), see Redecker (2017), and the International Society for Technology in Education's Standards for Educators (ISTE). However, AI is an emerging technology that extends beyond non-AI technologies and involves enormous amounts of diverse data. TPACK alone may not be able to capture the complexity of teacher knowledge and competencies in using AI in education. This is supported by Falloon's (2020) teacher digital competence framework, which adds two sets of competencies—personal-ethic and personal-professional—to TPACK. The two sets highlighted the importance of personal and socio-cultural aspects that address the impact of AI on teacher digital competence (Chiu, Falloon, et al., 2024; Falloon, 2020). In other words, Falloon's (2020) teacher digital competence framework includes AI competencies needed for teachers. Accordingly, this study used Falloon's (2020) study as an initial framework to propose a teacher AI competence framework and develop and validate its instruments. Its main goal is to develop and validate the teacher AI competence self-efficacy (TAICS) scale. The findings contribute to teacher professional development and digital education by providing a reliable and valid scale for evaluating research such as intervention and correlation studies and helping teachers understand their competencies to use AI in education.

2 Literature review

2.1 Teacher digital competence and TPACK

Digital competence refers to the skills, knowledge, and attitudes required to use and communicate with digital technologies critically, creatively, and responsibly in a variety of contexts (Hatlevik et al., 2015; Ilomäki et al., 2016; Janssen et al., 2013). Individuals with great digital competence have a sound understanding of the role that digital technologies play in contemporary society, as well as a positive outlook on their worth. They are aware of the legal, moral, privacy, and ethical issues the technologies cause. They are able to use the technologies wisely, responsibly, and healthily. Teacher digital competence describes a teacher's capacity to plan, organize, implement, and evaluate learning activities using digital technologies, capacity to foster student digital competence, and engagement in professional learning (Caena & Redecker, 2019; Chiu, Falloon, et al., 2024; Redecker, 2017). This competence can be described in literature such as TPACK, DigCompEdu, and Falloon's (2020) teacher digital competence framework.

The TPACK framework proposed by Mishra and Koehler (2006) suggests that successful technology integration in teaching and learning requires teachers' thoughtful interweaving of content, pedagogy, and technology. It has three main knowledges: CK refers to the subject content knowledge and concerns "what is being taught"; PK refers to learning and instructional designs and concerns "how the teacher delivers that content"; and TK refers to the knowledge of various technologies and concerns "how the technology is being implemented to communicate the content and support the pedagogy." This framework suggests that to enhance the student learning experience, teachers should use technology to communicate the content and support the pedagogy in their context (Chiu et al., 2021; Chiu, Falloon, et al., 2024; Rosenberg & Koehler, 2015; Tondeur et al., 2017). TPACK is a tool for diagnosing and assessing the digital competency of teachers (Demeshkant et al., 2022; Falloon, 2020). However, some studies suggest that TPACK may not be able to define teacher digital competences in contemporary and complex worlds (Falloon, 2020; Valtonen et al., 2017). Due to its lack of a precise definition, whether TPACK is integrative or transformative in a diverse and complex context is arguable (Voogt et al., 2013). TPACK can be viewed as the curriculum capacity of teachers to make wise judgments about the design and use of digital materials for effective digitally enhanced teaching and learning practices. It did not explicitly consider the impact of emerging technologies such as AI on misinformation, fake news, ethics, and morality. These components are critical in the implementation of contemporary digital technology; teachers must provide children with not only effective but also safe and healthy learning environments (Chiu, Falloon, et al., 2024; Falloon, 2020).

Another framework for addressing teacher digital competence is DigCompEdu (Caena & Redecker, 2019; Redecker, 2017). It is a scientifically sound framework to support the development of educator-specific digital competences in Europe. It aims to cover all levels of education, from pre-K16 to adult education, and both formal and non-formal learning contexts. This framework suggests 22 competencies organized in six dimensions: professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence. Compared to TPACK, DigCompEdu provides a more precise definition and addresses some digital dangers such as cyberbullying and information harvest (Redecker, 2017). It still did not explicitly address all the challenges, such as ethical and moral issues, AI brought to teachers, students, and society.

Falloon's (2020) teacher digital competence framework could address the AI challenges. He extended the TPACK framework into a broadly based TDC framework that addresses the challenges by adding two new sets of competencies: personal-ethical and personal-professional. Personal-ethical competencies are seen as the ability to access and use relevant digital resources in a safe and ethical manner (e.g., awareness, concern, and action). Personal-professional competencies are seen as the ability to manage digital resources and to actively participate in productive continuous professional learning through a variety of channels (e.g., attending conferences, sharing ideas). These two competencies move beyond prevailing curriculum capacity and technical knowledge, acknowledging the progressively complex knowledge and skills that young students need in order to learn and live in sustainable, safe, productive, moral, and ethical environments. They are important to commendatory education (e.g., remote, distance, and online learning) and emerging technologies (e.g., AI, IoT, and the metaverse) (Chiu, Ahmand, et al., 2024; Falloon, 2020). This framework could cover most of the challenges AI brings, but it also did not explicitly and directly address AI competence.

2.2 Teacher AI competence and its measures

UNESCO (2024) directly suggests an AI competence framework for K–12 teachers. This framework is still in its draft version and has five aspects: human-centered mindset (e.g., impact of AI on society), ethics of AI, AI foundations and applications, AI pedagogy, and AI for professional development. There are three levels for each aspect. This is one of the first studies directly and appropriately addressing teacher AI competence. This framework emphasizes teachers' comprehension of AI-related knowledge, the use of AI in education, and their professional learning. This is aligned with the studies of Falloon's (2020) teacher digital competence framework and Yau et al. (2023) conducted one of the first empirical studies defining K–12 AI teachers' conceptions of AI. However, these studies did not address the influence of AI on assessment. AI tools have the potential to provide feedback to students and promote self-regulated learning. They have influenced teacher assessment literacy according to Chiu (2023, 2024). Teachers should be proficient in utilizing AI to aid in many types of assessment, including formative and summative assessment, as well as student self-assessment. Hence, the enhancement of teachers' AI proficiency should consider assessment.

Literature has suggested some instruments to measure teacher digital competence that are closely related to teacher AI competence (Chiu, Falloon, et al., 2024; Demeshkant et al., 2022; Schmidt et al., 2009). Chiu, Falloon, et al. (2024) suggested and validated measures for personal-ethical and personal-personal aspects mentioned in Falloon's (2020) framework. Demeshkant et al. (2022) used the TPACK and self-reflection items from DigComEdu to develop and validate an instrument tool to determine the digital competence levels of higher education teachers; Schmidt et al. (2009) developed a set of questionnaire items to measure TPACK. They are able to measure teacher digital competence in their context, but they do not directly address the competencies needed to address the challenges AI brings to education. More of them are too complicated for K–12 teachers as they were originally designed for higher education (Demeshkant et al., 2022) or all education levels (DigCompEdu). More studies are needed to develop and validate instruments for AI competencies, particularly in K–12.

2.3 Research gaps

The teacher digital competence framework and its instruments may assess some teacher AI competencies as AI is digital. Most research on teacher digital competence may not directly and explicitly tackle the challenges, such as ethical and moral dilemmas, posed by this new technology for teachers and students. Furthermore, research on teacher AI competence is in its first phase, focusing mostly on theoretical and professional dialogues, together with qualitative inquiries. The study was mostly done from the researchers' perspectives, such as Demeshkant et al. (2022), Falloon (2020), Özgür (2020), and Schmidt et al. (2009). Practitioners' perspectives are crucial in this competence as they are users. Moreover, most of the existing framework for teachers (such as Falloon, 2020; Redecker, 2017) are very complicated for K-12 education. Furthermore, a study attempted to use a scale to investigate how its professional development affects teacher AI competence (Kitcharoen et al., 2024); however, it did not validate the scale. A simpler framework with rigorous method and its scale are needed for K-12 teachers. To our understanding, there are no established K-12 teacher AI competence scales using a rigorous method that have been validated for use in research and practices. More research is required to define teacher AI competence and validate its assessment tools.

3 This study and method

3.1 Research goals and questions

Teacher AI competence is a critical component of successful universal education systems, i.e., K–12 (e.g., UNESCO, 2024). Enhancing teachers' understanding of this competence enables them to efficiently integrate AI into teaching and learning, empower students in AI-driven learning settings, and cultivate student competence in AI. This two-phase study is to (i) define what teacher AI competence is, and (ii) use the findings to develop and validate the TAICS scale. The three research questions are:

RQ1: What are the AI competencies required for K–12 teachers?

RQ2: Is the TAICS scale quantitatively validated?

RQ1: Are there any significant differences in the TAICS scale based on teachers' gender and major teaching subject?

This study used the Delphi method and confirmatory factor analysis (CFA) to develop the scale, which is supported by Tickell and Klassen's (2024) study on developing a teacher self-efficacy in mentoring scale and Zhan's (2022) study on developing a feedback literacy scale. The Delphi method was used to answer RQ1 and construct a set of teacher AI competencies. The set was rated for importance for effective teacher AI by a group of panelists who have expertise in using digital technologies, including

AI, in learning and teaching. RQ2 and RQ3 were answered by a quantitative design - CFA.

3.2 Phrase 1: the Delphi method

This Delphi method used three rounds that create an equilibrium where more rounds do not affect findings significantly for most studies (Teixeira et al., 2020). The panel of Delphi studies should have expertise in the same area (Okoli & Pawlowski, 2004). Therefore, the expert panel of this study consisted of K–12 teachers with expertise in educational technology in Hong Kong. The panel had a minimum of five years' experience in leading digital learning and had experience in using and leading AI in teaching and learning. The participants had the requisite knowledge and expertise needed to contribute to this Delphi study (Powell, 2003). The participants were identified in a number of ways: (a) the corresponding author's ten school partnership projects; (b) the teacher participants of a seven-year project for AI K–12 education (started in 2019); and (c) the teachers already known to the researchers. In Hong Kong, all the students learn AI in Grades 7–9, i.e., teachers are more familiar with teaching AI. It was decided that all panelists should be based in Hong Kong, which is aligned with other Delphi studies on teacher education conducted in one region (Tickell & Klassen, 2024).

Of the 34 teachers contacted, 30 accepted the invitation to participate, with 5 later withdrawing, resulting in a final panel size of 30. The 30 panelists (age: M = 35.2 years; SD = 6.2; gender: male = 23; female = 7) had extensive expertise teaching with digital technologies, including AI, as well as teaching AI. There is no consensus on the minimum sample size for a Delphi study (Hsu & Sandford, 2007; Iqbal & Pipon-Young, 2009). Previous related studies involved 10–30 people (e.g., Tickell & Klassen, 2024). The major factor is the panel members' knowledge and representativeness (Powell, 2003). The panel members were chosen for their strong expertise and representation of a broader range of schools' academic performance. As a result, the panel's representativeness is good.

To answer RQ1, The corresponding author worked with two AI education researchers to draft a list consisting of initial competencies and a diagram to show the relationships among the competencies. We used Bandura's (2006) self-efficacy scale development guidelines to draft the initial list. All the items were designed to measure the teachers' beliefs about their competencies to use AI in teaching and learning effectively and safely and their engagement in professional learning. In each Delphi round, the panelists were provided with an initial list or an overview of the analysis from the previous round. They rated each competency in terms of importance for teacher AI competence using a Likert scale, from 1 "unimportant" to 4 "very important." They also gave comments on items and the diagram by adding items or modifying item wordings and the diagram. The agreement level (i.e., important and very important) was 80%, aligned with previous similar Delphi studies (e.g., Teixeira et al., 2020; Tickell & Klassen, 2024). Any changes in the items and diagram were presented in the next round. Throughout this Delphi study, the panelists maintained their anonymity to prevent more dominant group members from influencing the judgments of others overtly or covertly.

3.3 Phrase 2: the quantitative study

The participants were teachers from nine K–12 Hong Kong schools with varying social and economic backgrounds. The schools were selected from three school-university partnership projects led by the corresponding author. This encompasses all types of schools. Four hundred thirty-four teachers, aged 22 to 58 years (M = 37.3, SD = 8.5), participated in the survey. Of the participants, 165 were male and 268 were female, and 145 were science, 288 were non-science major teachers.

Table 1 shows the questionnaire items used in this study. The 24 items were classified into six dimensions: AI knowledge (AIK), AI pedagogy (AIP), AI assessment (AIA), AI ethics (AIE), Human-centred education (HCE), and professional engagement (PEN). The items were assessed on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). We developed a measurement model and analyzed it using CFA inside the Structural Equation Modeling framework (Gefen et al., 2011). To answer RQ2, the measurement model was assessed using conventional fit indices and standards, such as Kline (2015), which involve the Chi-square tests of fit, the comparative fit index (CFI), and the root mean square error of approximation (RMSEA) with its 90% confidence interval.

To answer RQ3, we used changes in CFI are recommended for comparing models to examine if the TAICS scale is consistent across the gender groups and the major teaching groups. (Cheung & Rensvold, 2002; Zhan, 2022).

4 Results

4.1 Phase 1: three rounds in the Delphi study

Table 1 shows the results of the initial list, and the results of the three rounds. Another panel, consisting of a scholar and five experienced researcher-teachers, developed the initial list used for the survey in Delphi Round 1. The panel had extensive expertise in doing research and teaching in the field of AI in education. The list included six dimensions and 27 items for the TAICS scale: AIK, AIP, AIA, AIA, HCE, and PEN. Sixteen out of 27 items on the initial list reached a consensus (i.e. 80%+ agreement level). We revised or combined six items, and eliminated six items in response to the qualitative feedback. We forwarded the six items that did not reach an agreement to the teachers in Round 2 for further feedback. The items that were agreed upon are solely available for viewing. All the teachers finished the survey. All six the items provided reached a consensus. Five additional items were suggested and forwarded to the teachers for further feedback. All the teachers finished Round 3 survey, reached a consensus on all the items. This Delphi study after three rounds identified six dimensions and 24 items for the TAICS scale (RQ1).

Table 1 The initial list and the results of round 1, 2, and 3 in the self-efficacy questionnaire (self-reported items) note: # reach agreement level; @ removed; ^ combined or revised; + added

Teacher AI competence self-efficacy scale (TAICS SCALE).

Items	Initial list	Round 1	Round 2	Round 3
I can distinguish whether a tool is AI-based or not. (AIK1)	AI knowledge (AIK)	#	#	#
I can create content with AI. (AIK2)		#	#	#
I can explain what AI is (AIK3)		^	#	#
I can explain what deep learning is.		@	#	#
I can explain what generative AI is.		^		
I know how to choose the right AI tools to effectively complete a task. (AIK4)		#		
I can explain what machine learning is.		@		
I can explain what cloud computing is.		@		
I can explain what big data is.		@		
I can choose an AI tool to use in my classroom that enhances what I teach, how I teach, and what students learn. (AIP1)	AI pedagogy (AIP)	#	#	#
I can choose an AI tool that enhances my teaching subject content for a lesson. (AIP2)		#	#	#
I can teach lessons that appropriately combine my teaching subject, AI tools, and teaching approaches. (AIP3)		#	#	#
I can help others coordinate the use of subject content, AI tools, and teaching approaches. (AIP4)		#	#	#
I can teach lessons that appropriately combine my teaching subject, AI tools, and teaching approaches.		@		
I can use AI tool to foster assessment for learning. (AIA1)	AI assessment (AIA)	^	#	#
I can design an assessment approach to improve student learning in an AI-based environment (e.g., learning with ChatGPT). (AIA2)		#	#	#
I can assess student learning in an AI-based environment. (AIA3)		^	#	#
I can choose an AI tool to foster student self-assessment. (AIA4)		@	+	#
I can use an AI tool to grade an assignment				
I can teach students ethics (AIE1)	AI ethics (AIE)	#	#	#
I can protect sensitive content from AI tools (e.g., exams, students' grades and personal data). (AIE2)		^	#	#
I can ensure my health and well-being while using AI tools. (AIE3)		#	#	#
I teach students how to behave safely and responsibly when learning with AI tools. (AIE4)			+	#
I understand all the ethical principles.			+	#
I can assess the benefits of an AI tool. (HCE1)	Human-centred education (HCE)	#	#	#
I can assess the risks of an AI tool. (HCE2)		#	#	#
I recognise human is responsible for AI bias. (HCE3)		^	#	#
I can explain how AI impact our society. (HCE4)			+	#
I can use different websites and search strategies to find and select a range of different AI tools. (PEN1)	Professional engagement (PEN)	#	#	#
I actively look for continuous professional development activities outside my educational organization. (PEN2)		#	#	#
I actively share my AI teaching experience with other colleagues within and outside my educational organization. (PEN3)		#	#	#
I love to help my colleagues design learning activities with AI. (PEN4)			+	#

Table 2 Descriptive statistics and correlation among all the items in measurement model

Scale	Alpha	Mean (SD)	S, K	1	2	3	4	5	6
1. AIK	0.88	3.13 (0.95)	−0.13, −0.57	-					
2. AIP	0.89	3.15 (0.98)	−0.04. −0.33	0.61**	-				
3. AIA	0.89	3.18 (0.92)	−0.14, −0.35	0.60**	0.65**	-			
4. AIE	0.88	3.09 (0.89)	0.01, −0.37	0.65**	0.61**	0.62**	-		
5. HCE	0.88	3.03 (0.96)	0.01, −0.39	0.51**	0.59**	0.59**	0.55**	-	
6. PEN	0.90	2.99 (1.00)	−0.01, −0.60	0.58**	0.51**	0.56**	0.61**	0.54**	-

Notes ** $p<0.01$; S: skewness; K: kurtosis

Table 3 Invariance tests across teachers of different gender and major teaching subjects

Model	x^2/df	RMSEA	PNFI	CFI	Change in CFI	Change in df
Invariance across male and female teachers						
Baseline model	2.325	0.055	0.745	0.919		
Invariant measurement weight model	2.256	0.054	0.773	0.921	0.002	18
Invariant structural covariances model	2.226	0.053	0.802	9.19	0.000	39
Invariance across science and non-science teachers						
Baseline model	2.133	0.051	0.751	0.928		
Invariant measurement weight model	2.093	0.050	0.777	0.928	0.000	18
Invariant structural covariances model	2.066	0.050	0.807	0.927	0.001	39

4.2 Phrase 2: the quantitative study

4.2.1 Internal consistency, variability and validity of the TAICS scale

As showed in Tables 2, TAICS scores were internally consistent for all the six dimensions – AIK, AIP, AIA, AIE, HCE, PEN, all Cronbach's alpha values > 0.87. All the dimensions were close to normal distributions (skewness and kurtosis) and showed adequate variability (range and standard deviation). All of the dimensions had strong factor loadings, ranging from 0.72 to 0.93 (> 0.80). Moreover, the correlation matrix between the TAICS scale scores were used to support its convergent validity of the TAICS scale, with all moderately correlated dimensions ($r > 0.50$; $p < 0.01$).

4.2.2 CFAs

In the CFAs, the fitness indices of the measured items suggested a good model fit with regard to the measurement model's goodness-of-fit: x^2/df = 2.24 (< 5.0); RMSEA = 0.054 (< 0.08); SRMR = 0.031 (< 0.05); PNFI = 0.796 (> 0.50); CFI = 0.96 (> 0.90) (Kline, 2015; Zhan, 2022). Figure 1 depicts the path relations and coefficients among the items. These indicate that the TAICS scale's measurement model has strong validity and reliability scores (RQ2).

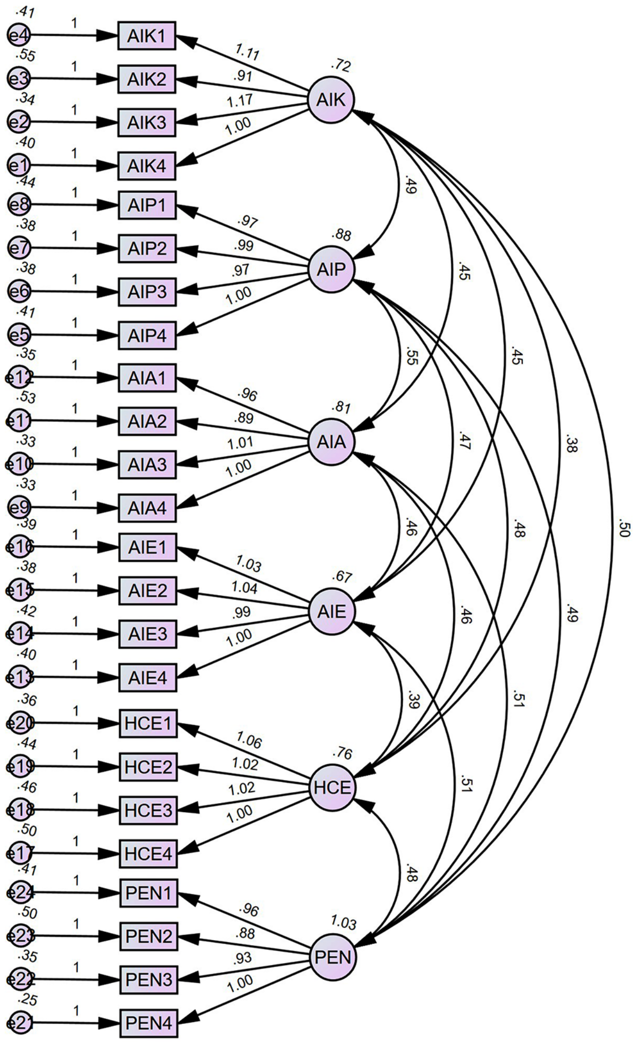

Fig. 1 Confirmatory factor analyses of 24 items of the TAICS scale

4.2.3 Gender, teaching subjects differences across the TAICS scale dimensions

This study also examined the potential differences in teacher groups according to gender and major teaching subjects, across the six dimensions, as defined in RQ3. Multiple group CFAs were used to examine whether the measurement models have significant differences across gender (male vs. female) and major teaching subject (science vs. non-science) groups. A decrease of 0.01 in CFI is considered suitable for detecting lack of invariance across multiple groups in Structural Equation Modeling (Cheung & Rensvold, 2002); therefore, changes in CFI are recommended for comparing models with reasonably high sample sizes (Zhan, 2022).

The first multiple group CFA was conducted to examine whether the structure of the TAICS scale was consistent across the male and female teachers, see Table 3. The results indicated that the baseline model has a great fit with the RMSEA values of 0.055, the PNFI values of 0.745, and the CFI value of 0.919.The invariant measurement weight model has a great fit with the RMSEA values of 0.054, the PNFI values of 0.773, and the CFI value of 0.921. Similarly, the invariant structural covariances model has a great fit with the RMSEA values of 0.053, the PNFI values of 0.802, and the CFI value of 0.919. Therefore, all the models are good for comparing. The model comparison analyses showed less than 0.01 changes in both models of invariant measurement weight (change in CFI = 0.002) and invariant structural covariances (change in CFI = 0.000), compared to the baseline model. These indicate the measurement model is consistent between the male and female teachers.

The second multiple group CFA was conducted to see if the structure of the TAICS scale remained consistent between science and non-science teachers, see Table 3. The results show that the baseline model fits well with RMSEA values of 0.051, PNFI values of 0.751, and CFI value of 0.928. Additionally, the invariant measurement weight model fits well with RMSEA values of 0.050, PNFI values of 0.777, and CFI value of 0.927. Lastly, the invariant structural covariances model fits well with RMSEA values of 0.050, PNFI values of 0.807, and CFI value of 0.927. Thus, all the models are suitable for comparing models in the analysis. The model comparison analysis revealed minimal changes (less than 0.01) in both models of invariant measurement weight (CFI change = 0.000) and invariant structural covariances (CFI change = 0.001) when compared to the baseline model. The measurements show that the model is consistent among both science and non-science teachers.

5 Discussion and implication

The two main objectives of this study are to propose an appropriate AI competence framework for K-12 teachers and develop and validate the TAICS scale, a new teachers'.

AI competence scale. Teacher AI competence is a crucial concept that highlights teachers' capacity to create and maintain n a safe, healthy and effective AI based learning environment. (Chiu, 2024; Falloon, 2020; UNESCO, 2024). It is related to the teachers' proficiency in AI, their capacities to use AI for educational purposes and to nurture students' AI literacy or competence, and their engagement in related professional development (Falloon, 2020; UNESCO, 2024). However, research on teacher AI competence is currently in its early stage and mostly centers on theoretical and professional discussions, as well as qualitative investigations. Developing the TAICS scale can advance the research agenda in the field of AI in education and provide insights into policies and practices related to teacher AI and digital education.

5.1 Six dimensions in this proposed teacher AI competence framework

The results of the Delphis method confirm the six dimensions: AI knowledge (AIK), AI pedagogy (AIP), AI assessment (AIA), AI ethics (AIE), Human-centred education (HCE), and professional engagement (PEN). AIK, AIP, AIE, HCE, and PEN are aligned with the five aspects suggested in UENSCOs' (2024) draft of AI competence for school teachers, and the competencies suggested in Falloon's (2020) teacher digital competence framework. They all highlight the importance of AI knowledge and its use in classrooms (AIK and AIP), and AI impact and ethics (AIKE and HCE), and continuous professional engagement (PEN). However, assessment is not clearly addressed in the frameworks. Generative AI technologies like ChatGPT and other educational chatbots have impact assessment (Chiu, 2023, 2024). They can provide students with feedback and promote self-regulated learning. Students may use generative AI to create new questions for their learning and request feedback for revising their work. Teachers should possess the abilities to utilize AI in order to enhance assessment practices. Our results revealed the assessment is an important dimension in the teacher AI competence framework. TAICS reveals teachers' beliefs that reflect how teachers integrate AI in education (Oran, 2023).

5.2 Teacher AI competence self-efficacy scale (TAICS scale)

Our findings revealed that the TAICS scale we created using the Delphi technique was reliable and valid. The TAICS scale showed consistency across both female and male teachers, as well as both science and non-science teachers. Our analyses confirmed the proposed six-dimensional scale, indicating that the six dimensions of AI knowledge (AIK), AI pedagogy (AIP), AI assessment (AIA), AI ethics (AIE), Human-centred education (HCE), and professional engagement (PEN) are able to measure teacher AI competence. Refer to the appendix for more details. Detailed explanations of each dimension are presented in the following.

- AIK: The capacity to discern between AI-based tools and traditional ones is crucial for maximizing efficiency and productivity. With a keen understanding of AI, teachers not only create compelling content using AI but also articulate its fundamental principles and applications. This knowledge empowers teachers to select the most suitable AI tools tailored to specific tasks, ensuring that they leverage the best resources available.
- AIP: The capacity to select AI tools significantly enhances teaching practices, enriching both the content delivered and student learning experiences. By carefully choosing AI applications that align with the subject matter of each lesson, teachers can create a more engaging and interactive classroom environment. This integration allows them to design lessons that effectively combine their subject expertise, innovative AI tools, and diverse teaching methodologies, fostering a deeper understanding of the material. Teachers should equip themselves to assist their colleagues in coordinating the use of subject content, AI technologies, and pedagogical strategies, fostering a collaborative approach to education that benefits both teachers and students.
- AIA: The capacity to leverage AI tools in fostering assessment for learning. By thoughtfully designing assessment approaches tailored to AI-based environments, such as learning with ChatGPT, teacher can effectively monitor and improve student learning outcomes. This mastery extends to assessing student performance

within AI-enhanced settings, ensuring that the integration of these technologies aligns with learning objectives and promotes academic growth. Moreover, teachers can strategically select AI tools that empower students to engage in self-assessment, encouraging them to take an active role in their learning journey and develop essential metacognitive skills. Through these AI-driven assessment practices, teachers create a dynamic and supportive learning environment that empowers students to reach their full potential.

- AIE: The capacity to effectively teach students about ethics, emphasizing the importance of integrity and accountability in their interactions with technology. Teachers should be committed to navigating this landscape with a strong ethical foundation. They should prioritize protecting sensitive content, such as exams, grades, and personal data, and implement best practices to safeguard this information from potential AI vulnerabilities. Additionally, they recognize the importance of maintaining their health and well-being while using AI tools, ensuring that they model a balanced approach to technology for their students. Teachers empower their students by teaching them how to engage safely and responsibly with AI, allowing them to make informed decisions and develop a conscientious attitude towards their digital interactions. Together, teachers and students can foster a learning environment that values ethical considerations, privacy, and well-being in the age of AI.
- HCE: The capacity to critically evaluate both the benefits and risks associated with the use of AI tools in learning environments. Teachers possess the ability to assess how these tools can enhance educational experiences, from personalized learning to increased engagement, while also recognizing the potential risks they pose, such as privacy concerns and the perpetuation of biases. Understanding that humans are ultimately responsible for AI bias allows teachers to foster discussions about ethical AI use and the importance of diverse perspectives in technology development. Furthermore, teachers should articulate the broader societal impacts of AI, including its influence on employment, communication, and social dynamics. By integrating these insights into teaching, teachers aim to cultivate a generation of learners who are not only adept at using AI but also critically aware of its implications, ensuring that education remains centered on human values and ethical considerations.
- PEN: the commitment to professional growth. Teachers should actively seek out opportunities to expand my knowledge and skills in the realm of AI integration. They can effectively utilize various websites and search strategies to discover and evaluate a diverse array of AI tools, ensuring that they stay at the forefront of technological advancements in education. Teachers proactively engage in continuous professional development activities, attending workshops, conferences, and online courses to deepen their understanding of AI and its applications in teaching and learning. Moreover, teachers enthusiastically share their experiences and insights with colleagues both within and outside my institution, fostering a collaborative environment where best practices and innovative ideas can be exchanged. Teachers' passion for AI-driven education extends to actively assisting their fellow educators in designing engaging and effective learning activities that leverage the power of these cutting-edge technologies. By continuously learning,

sharing, and supporting others, teachers contribute to the collective growth and success of the educational community in harnessing the potential of AI.

This scale limits the number of items to ensure it is manageable for K-12 instructors who are busy with their teaching responsibilities. As far as we know, this is the first scale that pertains to AI competence of K-12 teachers.

5.3 The TAICS scale serves as a reference for research and practices

Teacher AI competency is linked to the successful integration of AI in education and their professional engagement (UNESCO, 2024; Chiu, 2024; Falloon, 2020). The effectiveness, safety, and health of the AI learning environment created by teachers, together with their engagement in ongoing professional growth, rely on their level of AI competence. Teacher AI competence is a crucial factor that impacts students' growth of AI literacy and competence, according to Chiu (2023, 2024). A call has been made to incorporate teacher AI competence into professional development according to Celik (2023), Chiu (2023, 2024), and Sun et al. (2023). The TAICS scale in this study will allow K-12 education researchers and practitioners to methodically analyze teacher AI competence. The TAICS scale can be applied in the following proposed areas, among others.

- Researchers can use the scale to get data on teachers' perceptions of AI competence for interventions and correlation research.
- Policymakers and decision-makers at national and international levels can use the scale to gather data for developing policies about AI in education.
- Directors of teacher education institutions can use this scale to evaluate the continuous professional development for in-service teachers, and programs for pre-service teachers.
- Teachers can use the scale to reflect their AI practices, enhancing their competence to effectively integrate AI technology into their teaching strategies.
- Teachers who recognize their students' AI competence needs and respond accordingly.

5.4 Limitations and future research directions

Future research should address the five limitations of the current study when using and improving the TAICS scale, see the followings.

- The TAICS scale is reliable and valid but lacks specificity across disciplines, focusing solely on assessing teachers' competence in learning and using AI for teaching purposes. There might be variations in the level of AI competence among teachers in different disciplines, particularly in cases when teachers are implementing certain teaching methods, assessments, and ethical considerations. Research on the competence of AI in teaching certain subjects is necessary for the future.

- This study only examined any the TAICS scale's score differences with respect to gender and major teaching subject age. Future studies should investigate other factors such as teaching experience, educational qualification, and job position that may affect the TAICS scale and how they examine each dimension.
- Since the participants were Chinese instructors, this scale may not be suitable for a non-Chinese population. Future research ought to modify the language to suit their specific environment and be validated in many communities, including non-Chinese or multiracial groups in regions like Australia, the USA, Europe, and the UK.
- This study aims to provide a simple, reliable valid the TAICS scale for K-12 teachers, and keep a reasonable number of dimensions and items, i.e. six dimensions and 24 items. This scale may not cover other essential dimensions; hence, future studies may consider to expand the TAICS scale by including more dimensions such as nurturing student AI competence.
- AI competence is interconnected with modern literacies including data, mathematical, scientific, and computational. This study primarily focuses on the scale of AI competency. Future study should aim to offer a comprehensive perspective by including all pertinent literacy aspects.

6 Conclusions

The study develops and validates the TAICS scale for assessing teacher AI competence. The scale considers teachers' comprehension of AI, engagement in learning AI, and ability to use AI for educational purposes. This scale serves as the foundation for comprehending the primary teaching skills inside AI-driven learning settings. The scale consists of six dimensions: AI knowledge, AI pedagogy, AI evaluation, AI ethics, Human-centred education, and professional engagement. The TAICS scale is suitable for K-12 teachers and perhaps applicable for higher education instructors.

7 Appendix. Teacher AI competence self-efficacy scale (TAICS scale)

AI knowledge (AIK).

- I can distinguish whether a tool is AI-based or not. (AIK1)
- I can create content with AI. (AIK2)
- I can explain what AI is (AIK3).
- I know how to choose the right AI tools to effectively complete a task. (AIK4)

AI pedagogy (AIP).

- I can choose an AI tool to use in my classroom that enhances what I teach, how I teach, and what students learn. (AIP1)
- I can choose an AI tool that enhances my teaching subject content for a lesson.

(AIP2)
- I can teach lessons that appropriately combine my teaching subject, AI tools, and teaching approaches. (AIP3)
- I can help others coordinate the use of subject content, AI tools, and teaching approaches. (AIP4)

AI assessment (AIA).

- I can use AI tool to foster assessment for learning. (AIA1)
- I can design an assessment approach to improve student learning in an AI-based environment (e.g., learning with ChatGPT). (AIA2)
- I can assess student learning in an AI-based environment. (AIA3)
- I can choose an AI tool to foster student self-assessment. (AIA4)

AI ethics (AIE).

- I can teach students ethics (AIE1).
- I can protect sensitive content from AI tools (e.g., exams, students' grades and personal data). (AIE2)
- I can ensure my health and well-being while using AI tools. (AIE3)
- I teach students how to behave safely and responsibly when learning with AI tools. (AIE4)

Human-centred education (HCE).

- I can assess the benefits of an AI tool. (HCE1)
- I can assess the risks of an AI tool. (HCE2)
- I recognise human is responsible for AI bias. (HCE3)
- I can explain how AI impact our society. (HCE4)

Professional engagement (PEN).

- I can use different websites and search strategies to find and select a range of different AI tools. (PEN1)
- I actively look for continuous professional development activities outside my educational organization. (PEN2)
- I actively share my AI teaching experience with other colleagues within and outside my educational organization. (PEN3)
- I love to help my colleagues design learning activities with AI. (PEN4)

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Declarations

Ethical approval This study got ethical clearance from the author's university.

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