Kinestetik : Jurnal Ilmiah Pendidikan Jasmani 9 (4) (2025)
**Kinestetik : Jurnal Ilmiah Pendidikan Jasmani**
https://ejournal.unib.ac.id/index.php/kinestetik/index
**DOI : 10.33369/jk.v9i4.46439**

# Digital Competence and AI-TPACK of Lecturers: Implications for the Professional Development of Sports Education Lecturers

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**Article Info**

Article History :

Received : December 2025
Revised : December 2025
Accepted : December 2025

**Keywords:**

AI-TPACK, Artificial Intelligence, Digital Competence, Lecturer

**Abstract**

Evaluating lecturers competence in Artificial Intelligence, Technological, Pedagogical, and Content Knowledge (AI-TPACK) and identifying key influencing factors are critical steps toward ensuring effective AI integration. Purpose: This study aims to explore the predictive effect of digital competence on AI-TPACK among sports education lecturers in Indonesia. Materials and methods: A correlational survey design was employed, involving 105 lecturers from Physical Education, Health, and Recreation programs (PJKR) across five teacher education institutions in West Java. Data were collected using two structured scales: AI-TPACK and digital competence. Structural Equation Modeling (SEM) was applied to analyze the relationships between variables. Results: The analysis revealed that while lecturers demonstrated above-average digital competence, their AI-TPACK competence remained below average. A significant positive correlation (r = 0.533) was found between digital competence and AI-TPACK, with digital competence emerging as a primary predictor. These findings suggest that lecturers who are more digitally competent are also more capable of integrating AI into their pedagogical practice. Conclusions: Strengthening digital competence can be a strategic foundation for building AI-related pedagogical skills. Future training programs should integrate both technical and pedagogical components of AI, tailored to the teaching context of physical education lecturers in higher education.

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ISSN 2685-6514 (Online)
ISSN 2477-331X (Print)

## INTRODUCTION

In the last decade, the development of artificial intelligence (AI) and machine learning has brought major changes in various fields, including education (Sheikh et al., 2024; Sun et al., 2024). AI is capable of mimicking human cognitive functions such as understanding, inferring, and making decisions (Zhang et al., 2024), and support complex thinking processes through data analysis and adaptive learning (Dai & Ke, 2022; Forero-Corba & Bennasar, 2024). In the world of education, AI opens up new opportunities in the learning and teaching process, both through chatbots, learning management systems (LMS), and automated evaluation systems (Kavitha & Joshith, 2024; Yim & Su, 2024). In various countries, including Indonesia, the adoption of this technology is increasingly encouraged through policies and the development of digital infrastructure for education (Ivanova et al., 2024; Utina et al., 2024; Zarei et al., 2024).

The potential of AI to improve the quality of learning outcomes and teaching efficiency is the main attraction in its application in higher education institutions. Based on the HolonIQ report (2023), more than 75% of AI adoption in the education sector is driven by the desire to improve student learning outcomes. AI supports learning personalization, automated feedback, and mapping of student needs based on actual data (Dogan et al., 2023; Gligorea et al., 2023). For lecturers, AI plays a role as a tool that not only simplifies administrative tasks, but also supports teaching reflection, adjustment of learning methods, and more targeted professional development (Al-Zahrani & Alasmari, 2024; Ifenthaler et al., 2024). However, the use of AI in teaching demands pedagogic and technological capabilities that are integrated with each other, which are conceptually described within the framework of Technological Pedagogical Content Knowledge (TPACK) (Mishra et al., 2023). With the advent of AI-based technologies, the TPACK framework evolved into an AI-TPACK that involves not only knowledge of technology and content, but also an ethical and pedagogical understanding of the use of AI in the classroom (Kindenberg, 2025; Xu et al., 2024).

Digital competencies are also an important part of the profile of 21st-century lecturers. In the era of Higher Education 4.0, lecturers are not only tasked with conveying knowledge, but also acting as facilitators, designers, and innovators in the digital learning environment (Jarjabka et al., 2024; Lan et al., 2024; Lucas et al., 2024). Lecturers' digital competencies include the ability to use technology, think critically about its use, and understand digital ethics in the context of teaching (Basantes-Andrade et al., 2022; Nguyen et al., 2024). The digital competency model developed by

Teo (2013) explains that individuals who grow up with technology have a tendency to multitask, rely on visual communication, and need for instant feedback. These characteristics are relevant in understanding how lecturers interact with AI-based technologies in their teaching.

Many studies show a positive relationship between digital competencies and technology-based pedagogic abilities, such as TPACK (Demissie et al., 2022; Ramirez-Asis et al., 2024). However, studies that specifically associate digital competence with lecturer AI-TPACK, especially in the context of sports education, are still very limited. Therefore, the literature review shows the need for research that examines the influence of digital competence on AI-TPACK lecturers, considering the lack of focus on AI integration skills in teaching (Al-Abdullatif, 2024; Al-Zahrani & Alasmari, 2024; Ayanwale et al., 2022; Crompton & Burke, 2023; Kalniņa et al., 2024; Kim, 2024; Lee et al., 2024; Ning et al., 2024; Salleh et al., 2022; Wagner et al., 2024; Xie et al., 2023; Yue et al., 2024). This study aims to test whether digital competencies correlate and significantly predict the competencies of AI-TPACK lecturers.

The rapid development of artificial intelligence (AI) over the past decade has transformed higher education through learning personalization, automated feedback, and data-driven decision support, directly influencing learning outcomes and teaching efficiency. The integration of AI requires an alignment of pedagogical and technological competencies, which has evolved into the AI-TPACK framework-an extension of TPACK that emphasizes pedagogical, technological, and ethical understanding of AI use in the classroom. In the context of Higher Education 4.0, lecturers are expected to possess digital competencies that go beyond technical skills to include critical and ethical engagement with technology. Although prior studies have reported positive relationships between digital competence and TPACK, research that specifically examines the link between digital competence and AI-TPACK among physical education lecturers remains very limited. This gap is particularly important given the distinctive characteristics of physical education learning, which emphasizes motor skill practice, movement analysis, performance assessment, and data-based technologies, requiring AI integration approaches different from those in more theory-oriented disciplines. This research gap underlines the necessity of the present study, which explicitly aims to examine the relationship and predictive power of digital competence on the AI-TPACK of physical education lecturers, thereby contributing empirical evidence and informing professional development tailored to the disciplinary context of physical education.

## METHODS

This study employed a Research and Development (R&D) approach aimed at developing a professional development model for sports education lecturers based on digital competence and AI-TPACK. The R&D method was selected because the study not only examined relationships between variables but also produced a practical and validated development product, namely an AI-TPACK–based professional development framework tailored to the context of sports education. The R&D procedure was adapted from the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), which is widely used in educational research and lecturer professional development.

### PARTICIPANTS

This study involved 105 Physical Education, Health, and Recreation (PJKR) lecturers from five STKIP in West Java Province, who were selected through a convenience sampling method based on their willingness and certain criteria. Of the total respondents, only complete data from 105 lecturers (aged 29–50 years) were analyzed, with a gender composition of 85% men and 15% women. This research aims to explore the competence of AI-TPACK and the digital skills of lecturers in PJKR teaching. Data was collected through online surveys that included demographic information, education level, teaching experience, and the use of technology in learning. The survey began with a brief explanation of AI-based technology to improve participants' understanding, considering that many lecturers are not aware of the application of AI in the technology they use daily.

### Materials and Apparatus

This study used an online survey method through Google Forms to collect data reported by the participants themselves. The instruments used included personal information forms, AI-TPACK questionnaires, and digital competency scales. The survey link is shared with lecturers who are willing to volunteer, with an introduction explaining the purpose and scope of the research. Each participant gives consent after reading the information. This research follows ethical guidelines based on the Helsinki Declaration, including maintaining the confidentiality of data without asking for personal identity such as name or institution of origin. The survey is estimated to take about 20 minutes to complete. The personal information form includes variables of age, department, gender, and level of use of technology. The AI-TPACK scale used is a modification of the scale developed by Celik (2023), consisting of 27 items assessed on a 5-point Likert scale, and divided into five sub-scales: AI-TK, AI-TCK, AI-TPK, and AI-TPACK, which are used to measure lecturers' competence in integrating AI applications into learning.

### Design or Data Analysis

This study applied descriptive statistics, such as mean scores and standard deviations, to evaluate the level of AI-TPACK competence and digital competence of participants. The reliability of the instrument was measured using the Cronbach alpha coefficient, which indicates a very high level of reliability: 0.99 for the AI-TPACK scale and 0.94 for the digital competency scale. To analyze the relationship between the two variables, the Structural Equation Modeling (SEM) approach is used, which allows the identification of causal relationships between latent and endogenous variables based on the theoretical framework. Model fit was evaluated with several indices such as chi-square ($\chi^2$), RMSEA, CFI, TLI, and NFI. Skewness and kurtosis values that are in the range of -1 to +1 indicate that the data is normally distributed. The relationship between digital competence and AI-TPACK was also analyzed using the Pearson Product Moment correlation. The impact of digital competence on AI-TPACK was further analyzed through path analysis in the SEM model, using the Maximum Likelihood Estimation technique run with AMOS software version 26. All analyses were performed at a significance level of 0.05.

## RESULT

The findings regarding the AI-TPACK competence of lecturers are shown in Table 2. Based on the results of the descriptive analysis, the average score for each statement item was in the range of 4,038 to 4,286, with an overall average score of 4.15. This shows that the level of AI-TPACK competence of lecturers in general is relatively high. The median score for all items was consistent at 4,000, indicating a relatively uniform perception among respondents. The variation in minimum and maximum scores indicates diversity in perception, but remains within the range of 1–5 scales. Of all the items, the item with the highest average value was AI6 (4,286), while the lowest was AI8 and AI14 (4,038 respectively). These findings reflect that lecturers have a relatively good understanding and application of AI-TPACK competencies, although there is still room for improvement in certain items.

**Table 1. Descriptive Statistics for AI-TPACK**

| | Mean | Median | Observed min | Observed max | Standard deviation |
|---|---|---|---|---|---|
| **AI1** | 4.105 | 4.000 | 1.000 | 5.000 | 0.850 |
| **AI2** | 4.181 | 4.000 | 2.000 | 5.000 | 0.727 |
| **AI3** | 4.181 | 4.000 | 2.000 | 5.000 | 0.814 |
| **AI4** | 4.133 | 4.000 | 1.000 | 5.000 | 0.874 |
| **AI5** | 4.200 | 4.000 | 1.000 | 5.000 | 0.877 |
| **AI6** | 4.286 | 4.000 | 2.000 | 5.000 | 0.765 |
| **AI7** | 4.190 | 4.000 | 2.000 | 5.000 | 0.852 |
| **AI8** | 4.038 | 4.000 | 1.000 | 5.000 | 0.850 |
| **AI9** | 4.171 | 4.000 | 1.000 | 5.000 | 0.889 |
| **AI10** | 4.114 | 4.000 | 1.000 | 5.000 | 0.919 |
| **AI11** | 4.095 | 4.000 | 1.000 | 5.000 | 0.787 |
| **AI12** | 4.181 | 4.000 | 2.000 | 5.000 | 0.790 |
| **AI13** | 4.229 | 4.000 | 2.000 | 5.000 | 0.796 |
| **AI14** | 4.038 | 4.000 | 1.000 | 5.000 | 0.839 |
| **AI15** | 4.152 | 4.000 | 2.000 | 5.000 | 0.790 |
| **AI16** | 4.229 | 4.000 | 2.000 | 5.000 | 0.772 |
| **AI17** | 4.238 | 4.000 | 2.000 | 5.000 | 0.775 |
| **AI18** | 4.095 | 4.000 | 1.000 | 5.000 | 0.811 |
| **AI19** | 4.181 | 4.000 | 2.000 | 5.000 | 0.934 |
| **AI20** | 4.076 | 4.000 | 2.000 | 5.000 | 0.836 |
| **AI21** | 4.162 | 4.000 | 1.000 | 5.000 | 0.794 |
| **AI22** | 4.210 | 4.000 | 2.000 | 5.000 | 0.765 |
| **AI23** | 4.124 | 4.000 | 1.000 | 5.000 | 0.789 |
| **AI24** | 4.133 | 4.000 | 2.000 | 5.000 | 0.769 |
| **AI25** | 4.095 | 4.000 | 1.000 | 5.000 | 0.834 |
| **AI26** | 4.181 | 4.000 | 2.000 | 5.000 | 0.848 |
| **AI27** | 4.133 | 4.000 | 2.000 | 5.000 | 0.840 |

Table 1 presents descriptive results related to the level of digital competence among lecturers. Based on the analysis, the overall average of digital competence was at 4.17, with a consistent median score of 4,000 for all items. This indicates that lecturers show a high level of digital competence and are relatively even. The highest average scores were found in items KD6, KD9, and KD14, amounting to 4,257 each, which showed strength in certain aspects of the use of digital technology. Meanwhile, the lowest average score was found in KD12 (3,990), although it was still in the high category. The relatively low variety of scores is also reflected in the relatively small standard deviation, ranging from 0.718 to 0.859, indicating the consistency of responses between respondents.

**Table 2. Descriptive Statistics for Digital Competence**

| | Mean | Median | Observed min | Observed max | Standard deviation |
|---|---|---|---|---|---|
| **KD1** | 4.114 | 4.000 | 2.000 | 5.000 | 0.760 |
| **KD2** | 4.219 | 4.000 | 2.000 | 5.000 | 0.730 |
| **KD3** | 4.152 | 4.000 | 2.000 | 5.000 | 0.837 |
| **KD4** | 4.076 | 4.000 | 2.000 | 5.000 | 0.765 |
| **KD5** | 4.152 | 4.000 | 1.000 | 5.000 | 0.753 |
| **KD6** | 4.257 | 4.000 | 2.000 | 5.000 | 0.718 |
| **KD7** | 4.229 | 4.000 | 2.000 | 5.000 | 0.734 |
| **KD8** | 4.190 | 4.000 | 2.000 | 5.000 | 0.770 |
| **KD9** | 4.257 | 4.000 | 2.000 | 5.000 | 0.805 |
| **KD10** | 4.133 | 4.000 | 2.000 | 5.000 | 0.782 |
| **KD11** | 4.152 | 4.000 | 1.000 | 5.000 | 0.837 |
| **KD12** | 3.990 | 4.000 | 1.000 | 5.000 | 0.787 |
| **KD13** | 4.181 | 4.000 | 2.000 | 5.000 | 0.766 |
| **KD14** | 4.257 | 4.000 | 2.000 | 5.000 | 0.731 |
| **KD15** | 4.114 | 4.000 | 2.000 | 5.000 | 0.772 |
| **KD16** | 4.181 | 4.000 | 1.000 | 5.000 | 0.859 |
| **KD17** | 4.133 | 4.000 | 2.000 | 5.000 | 0.731 |
| **KD18** | 4.133 | 4.000 | 2.000 | 5.000 | 0.757 |
| **KD19** | 4.152 | 4.000 | 2.000 | 5.000 | 0.826 |
| **KD20** | 4.200 | 4.000 | 2.000 | 5.000 | 0.761 |

This study uses Cross Loadings analysis to evaluate the validity of discrimination between constructs, especially in investigating the relationship between AI-TPACK competencies and digital competencies in lecturers. The results of the analysis are presented in Table 2, which shows the extent to which each indicator loads higher on its own construct compared to the other, as evidence of a clear difference between the constructs measured.

**Table 3. Cross Loadings between AI-TPACK and Digital Competence (n = 105)**

| | AI-TPACK | Digital Competence | | AI-TPACK | Digital Competence |
|---|---|---|---|---|---|
| **AI1** | 0.805 | 0.343 | **KD1** | 0.388 | 0.744 |
| **AI2** | 0.784 | 0.504 | **KD2** | 0.383 | 0.748 |
| **AI3** | 0.804 | 0.376 | **KD3** | 0.420 | 0.800 |
| **AI4** | 0.715 | 0.287 | **KD4** | 0.458 | 0.759 |
| **AI5** | 0.735 | 0.395 | **KD5** | 0.449 | 0.748 |
| **AI6** | 0.759 | 0.349 | **KD6** | 0.475 | 0.734 |
| **AI7** | 0.753 | 0.461 | **KD7** | 0.455 | 0.762 |
| **AI8** | 0.739 | 0.369 | **KD8** | 0.304 | 0.746 |
| **AI9** | 0.735 | 0.394 | **KD9** | 0.323 | 0.743 |
| **AI10** | 0.779 | 0.402 | **KD10** | 0.323 | 0.739 |
| **AI11** | 0.752 | 0.453 | **KD11** | 0.464 | 0.800 |
| **AI12** | 0.745 | 0.473 | **KD12** | 0.385 | 0.733 |
| **AI13** | 0.749 | 0.359 | **KD13** | 0.383 | 0.728 |
| **AI14** | 0.731 | 0.369 | **KD14** | 0.401 | 0.744 |
| **AI15** | 0.781 | 0.429 | **KD15** | 0.301 | 0.745 |
| **AI16** | 0.739 | 0.419 | **KD16** | 0.394 | 0.792 |
| **AI17** | 0.716 | 0.272 | **KD17** | 0.326 | 0.727 |
| **AI18** | 0.784 | 0.451 | **KD18** | 0.459 | 0.757 |
| **AI19** | 0.776 | 0.415 | **KD19** | 0.408 | 0.768 |
| **AI20** | 0.735 | 0.407 | **KD20** | 0.412 | 0.781 |
| **AI21** | 0.745 | 0.401 | | | |
| **AI22** | 0.730 | 0.334 | | | |
| **AI23** | 0.756 | 0.317 | | | |
| **AI24** | 0.745 | 0.379 | | | |
| **AI25** | 0.805 | 0.448 | | | |
| **AI26** | 0.773 | 0.479 | | | |
| **AI27** | 0.820 | 0.441 | | | |

Table 3 shows the results of *cross loadings* analysis to assess the discriminative validity between AI-TPACK constructs and Digital Competence. Discriminant validity can be said to be fulfilled if each indicator has a higher loading value to the construct in question compared to other constructs (Hair et al., 2022). Based on the results of the analysis, all AI-TPACK indicators (AI1–AI27) had the highest loading value in the AI-TPACK construct compared to Digital Competence, with the highest value of 0.820 (AI27) and the lowest value of 0.715 (AI4). Similarly, all Digital Competency indicators (KD1–KD20) show the highest loading of the Digital Competency construct, with the highest values of 0.800 (KD3 and KD11) and the lowest of 0.727 (KD17). No indicators were found that showed a higher loading value in other constructs compared to the original constructs, so it can be concluded that the discriminant validity between the two constructs has been met. This reinforces that the instruments used can clearly distinguish between AI-TPACK competencies and lecturers' digital competencies.

After finding a significant correlation between AI-TPACK competence and digital competence in the analysis, this study proceeded to test the predictive influence of digital competency level on lecturers' AI-TPACK competence using structural equation modeling. To achieve this goal, an initial confirmatory measurement model was built to assess the alignment between AI-TPACK competencies and digital competency models. A visual representation of this model can be seen in Figure 1. The fit index for the measurement model can be found in Table.

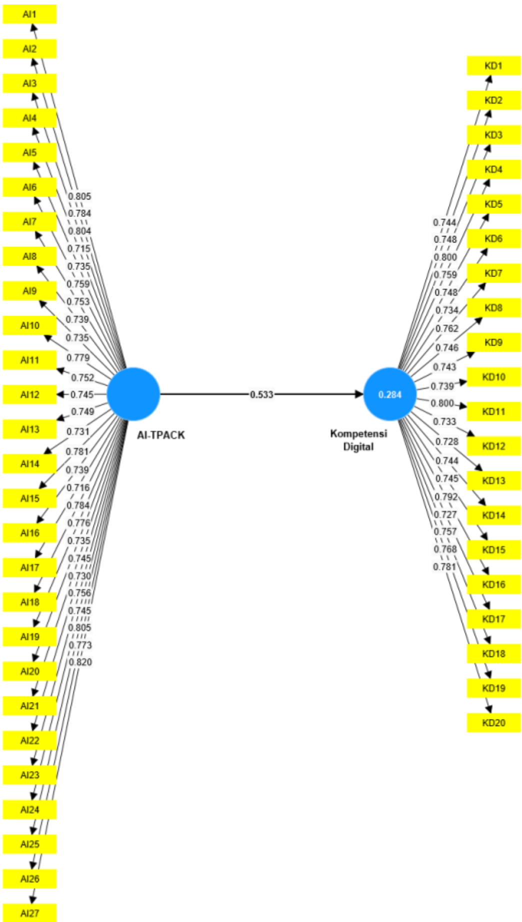


**Figure 1. Measurement Model**

Figure 1 shows the results of the cross loadings analysis used to test the validity of the discrimination between the two main constructs in this study, namely AI-TPACK and Digital Competence. The validity of the discriminator is said to be fulfilled if each indicator has a higher loading value to its own construct than to other constructs. Based on the visualization in Figure 1, all AI-TPACK indicators (AI1–AI27) show the highest loading values in the AI-TPACK construct, with values between 0.715 to 0.820, while their loading against the Digital Competency construct is relatively lower, ranging from 0.272 to 0.504. On the other hand, the Digital Competency indicators (KD1–KD20) have the highest loading of the Digital Competency construct, with values ranging from 0.727 to 0.800, and the cross-loading of AI-TPACK is in the range of 0.301 to 0.475.

This difference in loading confirms that each indicator consistently contains the appropriate construct. For example, the AI27 indicator has a loading of 0.820 for AI-TPACK and only 0.441 for Digital Competence. Likewise, the KD11 indicator has a loading of 0.800 for Digital Competency and 0.464 for AI-TPACK. In addition, the correlation value between constructs shown in the middle of the diagram shows a correlation between AI-TPACK and Digital Competency of 0.533, which indicates a moderate positive relationship, but each construct still stands discriminatory.

**Table 4. Goodness of Fit**

| | Saturated model | Estimated model |
|---|---|---|
| SRMR | 0.059 | 0.059 |
| d_ULS | 3.869 | 3.869 |
| d_G | 2.883 | 2.883 |
| Chi-square | 1293.594 | 1293.594 |
| NFI | 0.719 | 0.719 |

The evaluation of the Goodness of Fit model was carried out to assess the extent to which the structural model in this study was in accordance with the data obtained. Based on Table 4, the Standardized Root Mean Square Residual (SRMR) value for both saturated and estimated models is 0.059. This value is below the threshold of 0.08, which is generally used as a good model fit criterion, thus indicating that the difference between the observed and predicted covariance matrices is quite small. Furthermore, the d_ULS and d_G values, which were 3,869 and 2,883, respectively, were also identical between the saturated and estimated models. The consistency of these values indicates that the estimated model does not degrade in terms of match quality. The Chi-square value of 1293,594 in both models is used as a statistical measure of the overall fit of the model, although in the context of Partial Least Squares Structural Equation Modeling (PLS-SEM), this value is not the primary benchmark in evaluating the model.

Finally, the Normed Fit Index (NFI) value obtained is 0.719. Although this value has not reached the ideal standard ≥ 0.90 as used in the covariance SEM approach, the ≥ value of 0.70 is still acceptable in the context of PLS-SEM (Hair et al., 2022), and indicates a moderate level of model suitability. Thus, it can be concluded that the structural model used in this study has an adequate level of compatibility and is feasible to be used in further analysis of the relationship between constructs

## DISCUSSION

The results of the analysis showed a significant positive correlation between digital competence and AI-TPACK competence in sports education lecturers, with a correlation value of 0.533 which reflects a moderate but consistent relationship. This shows that the improvement of digital competencies, such as comfort and skills in the use of technology, is closely related to the increasing ability of lecturers to integrate AI-based applications into the learning process. These findings support previous studies by Demissie et al. (2022) and Cao et al. (2023), which highlights the significant relationship between digital competence and technological pedagogic readiness.

The results of structural equation modeling (SEM) analysis showed that digital competence played a significant role as a significant predictor of AI-TPACK, with an SRMR value of 0.059 and an NFI of 0.719 indicating adequate model compatibility. Lecturers who are able to evaluate and apply digital technology reflexively and strategically tend to be better prepared to use AI-based pedagogic principles in their teaching. This capability enables the effective implementation of AI tools such as learning dashboards and machine learning-based feedback systems. Therefore, lecturer training should not only emphasize technical aspects, but should also include contextual and ethical pedagogic approaches.

This study has limitations, including the use of convenience sampling that limits generalization, the potential bias of self-report, and cross-sectional design that does not capture the dynamics of competence over time. For this reason, follow-up studies are recommended using a mixed-methods approach and triangulating data through observation or teaching portfolios. From a practical perspective, this result implies the importance of preparing a professional training program for lecturers that is contextual, ethical, and supported by digital infrastructure and cross-disciplinary collaboration so that the integration of AI in higher education runs optimally and sustainably.

## CONCLUSION

This study confirms that digital competencies have a significant role in shaping lecturers' readiness to integrate artificial intelligence (AI) into their pedagogical practices. The finding of a moderate but consistent positive correlation between digital competence and AI-TPACK in sports education lecturers shows that fluency in technology not only improves technical skills, but also cognitive and affective readiness in the face of technology integration in learning. The findings of structural equation modeling (SEM) further reinforce that digital competencies significantly predict AI-TPACK, thus emphasizing the importance of contextual, ethical, and pedagogical teacher training.

More broadly, these results show that improving digital competence is a strategic step in building AI-based pedagogical literacy in higher education. Institutions need to provide not only digital infrastructure, but also a supporting ecosystem that includes peer mentoring, cross-disciplinary collaboration, as well as training models that are responsive to the context of lecturer teaching. As the role of AI continues to evolve in education, equipping lecturers with the right digital and pedagogical knowledge will be key in creating a meaningful and equitable learning experience for all students.

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