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## ORIGINAL RESEARCH ARTICLE

# TPACK implementation in higher education: an assessment of teacher educators' competence

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The study aimed to assess the perceived competency of Technological Pedagogical Content Knowledge (TPACK) among teacher educators in Ethiopian higher education institutions. The TPACK framework by Mishra and Koehler was employed to assess its implementation. In doing so, a quantitative research method was employed, involving 245 teacher educators from the selected higher education institutions. The study utilized the stratified random sampling technique to systematically select the participants. A structured questionnaire was used to collect data. Validity and reliability tests were conducted to ensure the questionnaire's appropriateness and consistency. Both descriptive and inferential statistics were used to analyse the data. Results revealed that teacher educators' technology level of competence is the lowest when compared with the other TPACK subscales. Besides, the results indicated that there were no statistically significant differences between male and female teacher educators across the TPACK components, but significant differences were observed in Content Knowledge (CK), Technological Knowledge (TK) and overall TPACK based on their qualifications and teaching experiences. The findings also showed that there were significant differences in CK, TK and TCK across fields of study, though PK, PCK, TPK and overall TPACK showed no significant differences across the groups. The study highlights the fact that teacher educators' current practices do not fully embrace the technological dimension of TPACK, which means there is a need for professional development in this area.

**Keywords:** teacher educators; TPACK; competence; practices; Ethiopia

## Introduction

In the rapidly evolving digital age, higher education institutions in Ethiopia face increasing demands to prepare teachers equipped with robust technological and digital competencies. This study focuses on improving teacher training programs by assessing the Technological Pedagogical Content Knowledge (TPACK) competencies of teacher educators in Ethiopian higher education institutions. In Ethiopia, teacher educators in higher education typically hold advanced degrees (e.g. MA/MSc or PhD),

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but there is no mandatory requirement for formal teacher training or pedagogical certification to teach at this level. This context differs from some global settings where pedagogical training is not a prerequisite for higher education teaching, potentially leading to lower competencies in Pedagogical Knowledge (PK) and Technological Knowledge (TK) (Omoso & Odindo, 2020; Stokes-Beverley & Simoy, 2016).

The absence of structured teacher training programs that emphasize technology integration highlights the need to evaluate current TPACK competencies to inform curriculum enhancements. Specifically, this study investigates whether incorporating a stronger focus on TK within teacher training could enhance teacher educators' ability to prepare future teachers for technology-integrated classrooms. The TPACK framework is not currently a formal component of teacher training in Ethiopian higher education, making this assessment critical for identifying gaps and supporting evidence-based reforms.

The TPACK framework, developed by Mishra and Koehler (2006), emphasizes the integration of TK, PK, and Content Knowledge (CK) to enhance teaching effectiveness (Soler-Costa et al., 2021; Tseng et al., 2020). This model is particularly relevant in the 21st century, where technology is integral to education (Van der Klink et al., 2017). Studies indicate that while teacher educators often possess strong PK and CK, their use of instructional technologies remains limited (Amhag et al., 2019; Chee et al., 2017; Thinzarkyaw, 2019; Youm & Corral, 2019). Conversely, Voithofer and Nelson (2021) noted increasing technology integration but inconsistent TPACK adoption. In Ethiopia, prior research highlights limited TPACK implementation, with educators relying heavily on traditional methods (Abera, 2014; Birhanu, 2014; Demissie et al., 2022; Getenet, 2015). This scenario necessitates a more thorough investigation of TPACK application and its effects on teacher preparation programs (Foulger et al., 2017; Moreno et al., 2019).

On the other hand, the TPACK levels of higher education instructors differ considerably depending on their experience, demographics and context. Studies show that while certain educators display strong TPACK integration, others only show average competence, highlighting the need for targeted professional development (Akram et al., 2021; Akturk & Ozturk, 2019; Aswathy, 2022; Bingimlas, 2018; Castéra et al., 2020; Jang & Chang, 2016; Schmid et al., 2020; Seifu, 2020; Irele, 2021).

In Ethiopia, teacher training has experienced various reforms aimed at improving teachers' skills, especially regarding the integration of technology (Barnes & Kennewell, 2017; Ministry of Education [MoE], 2017). These changes highlight the significance of technological skills for teacher trainers, who are vital in equipping upcoming educators to successfully integrate technology into their instructional methods (Tondeur et al., 2019; Uerz et al., 2018).

This study aims to assess teacher educators' TPACK competency to identify areas for improvement, addressing the following research questions:

- What is the current level of TPACK competence among teacher educators?
- Is there a statistically significant relationship between teacher educators' TPACK competence and their demographic characteristics?

## Theoretical framework

TPACK is a framework for technology integration created by Mishra and Koehler at Michigan State University in 2006 and serves as the theoretical basis for this


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research. The TPACK framework expands upon Shulman's (1986) pedagogical content knowledge (PCK), incorporating TK in connection with both content and teaching methods. It is made up of three essential elements: CK, PK and TK. Moreover, the combination of PCK, technological content knowledge (TCK) and technological pedagogical knowledge (TPK) establishes the basis of TPACK, which is crucial for higher education educators to successfully integrate technology into their teaching practices (Mishra, 2019).

The model (Figure 1) highlights the significance of grasping the connections between these knowledge elements for effective technology integration, as shown in TPACK diagrams (Harris & Hofer, 2011; Mishra & Koehler, 2006). In higher education, incorporating technology is a crucial duty in training future educators (Schlebusch et al., 2024), so teachers must possess the required expertise and abilities to blend technology into their instructional methods (Padmavathi, 2017).

## Research methods and procedures

A research method encompasses the series of procedures and investigations utilized in a particular study, involving sampling, participant selection, data collection and analysis and result interpretation (Creswell, 2014). A quantitative approach has

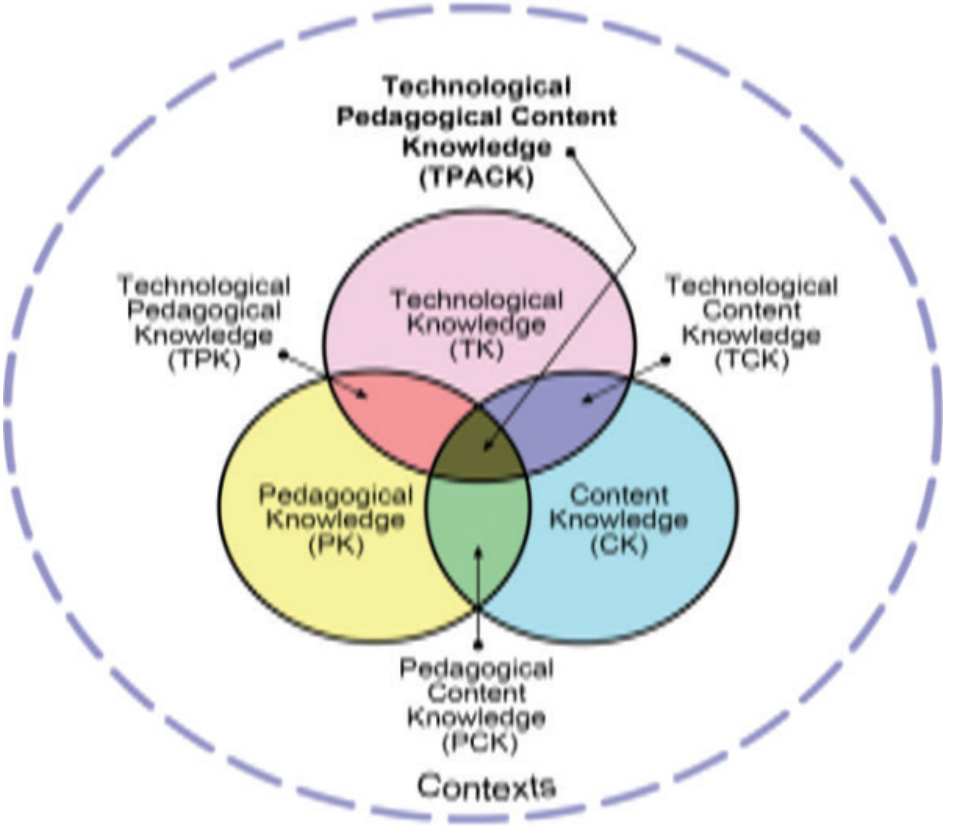


Figure 1. TPACK framework (taken from http://tpack.org).

been utilized in this research to meet its aims and respond to its inquiry questions. Baho et al. (2017) explain that a quantitative approach is a means of examining a specific group of individuals to gain further insights about them using numbers and figures. Therefore, to assess the perceived TPACK competency level of teacher educators, a quantitative approach consisting of structured questionnaire was utilized.

## Research design

A research design refers to the researcher's overall plan for answering the research questions and evaluating the study hypothesis (Creswell & Creswell, 2012). It consists of a method for gathering, evaluating, interpreting and summarizing data for a research project (Creswell & Plano-Clark, 2011). In this study, a correlational design with a cross-sectional approach was employed.

## Sampling techniques

The sample consists of ($n$ = 245) teacher educators, consisting of 196 (80%) males and 49 (20%) females who are teaching in higher education institutions and were selected by using a stratified sampling method. Then, the teacher educators were drawn from the college of natural, social and pedagogical sciences. For this purpose, a structured questionnaire was distributed to 265 participants, and 245 (92.4%) correctly completed it.

## Data collection

A structured questionnaire, adapted from Schmidt et al. (2009), Koh et al. (2013) and Valtonen et al. (2017), was used to assess TPACK competence. The study received ethical approval from the institute ethics committee of the participating universities, ensuring informed consent and confidentiality of participants' responses. The questionnaire relied on self-reported data, which may introduce biases such as social desirability or overestimation of competencies, a limitation acknowledged in the study's design. The questionnaire was piloted with 37 teacher educators outside the sampled institutions. Face and content validity were ensured through expert reviews by educational technology specialists, who provided feedback on item clarity and relevance. Construct validity was further established by aligning questionnaire items with the TPACK framework's theoretical constructs, using factor analysis during the pilot phase to confirm that items accurately measured CK, PK, TK, PCK, TCK, TPK and TPACK. Reliability was assessed using Cronbach's alpha (Table 1).

The Cronbach's alpha value of 0.956 for the teacher educators' TPACK scale indicates very high internal consistency. This means that the 45 items within this scale are highly correlated with each other, suggesting they effectively measure the construct.

Table 1. Reliability of the questionnaire.

| Themes | Items | Cronbach's alpha |
|---|---|---|
| Teacher educators' TPACK competence | 45 | 0.956 |


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This implies that the TPACK Competence Scale is a reliable and valid measure for assessing teacher educators' TPACK competence.

## Data Analysis

In order to analyse the data gathered though the questionnaire; both the descriptive and inferential statistics were used. The descriptive statistics such as mean and standard deviation were employed to describe teacher educators' TPACK competence. On the other hand, the inferential statistics such as independent sample *t*-test and one way Analysis of Variance (ANOVA) were used to determine teacher educators' TPACK competence based on their demographic characteristics and these include gender, qualifications, experience and fields of study.

## Results

This section presents sets of results relating to the profile of respondents on teacher educators' perceived TPACK competence based on demographics. Profile of respondents: Table 2 displays a summary of the characteristics of the total sample of teacher educators who participated in the study. As result, a total of 245 teacher educators' participated in this study comprising their gender, qualifications, experiences and fields of study.

The data obtained revealed that 196 (80%) and 49 (20%) participants were male and female teacher educators respectively. This showed that female teacher educators are fewer when compared to their male counterparts. On the other hand, Table 2 indicated that 165 (67.3%) teachers were MA/MSC holders, and the remaining 80 (32.7%) of participants had PhD degrees. This showed that the participants were highly dominated by MA/MSC holders.

Regarding work experience, 19.2% had 0–5 years of experience, 21.2% had 6–10 years of experience, 35.9% had 11–15 years of experience, 19.6% had 16–20 years of experience and the remaining, 4.1% of teacher educators had 21 and above years of work experience in teaching. Further, 22.4%, 32.7% and 44.9% of teacher educators were drawn from natural, social and pedagogical sciences respectively.

Table 2. Demographic characteristics of the participants.

| Variables | Categories | Frequency | Percentage | Total |
|---|---|---|---|---|
| Gender | Male | 196 | 80 | 245 |
| | Female | 49 | 20 | |
| Qualification | MA/MSC | 165 | 67.3 | 245 |
| | PhD | 80 | 32.7 | |
| Experience | 0–5 years | 47 | 19.2 | 245 |
| | 6–10 years | 52 | 21.2 | |
| | 11–15 years | 88 | 35.9 | |
| | 16–20 years | 48 | 19.6 | |
| | 21 & above | 10 | 4.1 | |
| Field of Study | Natural | 55 | 22.4 | 245 |
| | Social | 80 | 32.7 | |
| | Pedagogical | 110 | 44.9 | |

### Teacher educators' levels of TPACK competence

The data show the average scores and standard deviations for dimensions of TPACK competence among 245 participants. Understanding these dimensions helps to identify the teacher educators' TPACK competence levels and areas that need improvement, ultimately leading to enhanced technology integration in the teaching and learning process.

Table 3 provides the mean and standard deviations for teacher educators' TPACK competence, with a sample size of 245 teacher educators. Accordingly, CK had the highest mean score (3.19), while TK had the lowest (2.66). This shows that teacher educators' technology level of competence is the lowest when compared with the other TPACK subscales. This suggests a need for training and support in using technology effectively in teaching.

### Differences in teacher educators' TPACK competences

The subsequent tables depict teacher educators' TPACK competence in relation to their demographic characteristics such as gender, qualifications, experiences and fields of study. Tables 4–7 comprised the results.

Table 3. Teacher educators' TPACK competence.

| Dimensions | *N* | Mean | SD |
|---|---|---|---|
| Content Knowledge (CK) | 245 | 3.19 | 0.59 |
| Pedagogical Knowledge (PK) | 245 | 2.84 | 0.46 |
| Technological Knowledge (TK) | 245 | 2.66 | 0.41 |
| Pedagogical Content Knowledge (PCK) | 245 | 2.72 | 0.43 |
| Technological Pedagogical Knowledge (TPK) | 245 | 2.73 | 0.41 |
| Technological Content Knowledge (TCK) | 245 | 2.90 | 0.59 |
| Technological Pedagogical Content Knowledge (TPACK) | 245 | 2.84 | 0.29 |

Table 4. Teacher educators' TPACK competence and gender.

| Dimensions | Gender | *N* | Mean | SD | *t* | *Df* | *Sig.* |
|---|---|---|---|---|---|---|---|
| CK | Male | 196 | 3.21 | 0.58 | 0.697 | 243 | 0.487 |
| | Female | 49 | 3.15 | 0.62 | | | |
| PK | Male | 196 | 2.85 | 0.45 | 0.589 | 243 | 0.556 |
| | Female | 49 | 2.81 | 0.50 | | | |
| TK | Male | 196 | 2.67 | 0.39 | 0.367 | 243 | 0.714 |
| | Female | 49 | 2.65 | 0.48 | | | |
| PCK | Male | 196 | 2.74 | 0.43 | 0.700 | 243 | 0.485 |
| | Female | 49 | 2.69 | 0.46 | | | |
| TPK | Male | 196 | 2.76 | 0.41 | 1.646 | 243 | 0.101 |
| | Female | 49 | 2.65 | 0.42 | | | |
| TCK | Male | 196 | 2.91 | 0.58 | −0.202 | 243 | 0.840 |
| | Female | 49 | 2.92 | 0.62 | | | |
| TPACK | Male | 196 | 2.86 | 0.29 | −0.979 | 243 | 0.329 |
| | Female | 49 | 2.81 | 0.30 | | | |


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Table 5. Teacher educators' TPACK competence and qualifications.

| Dimensions | Qualification | *N* | Mean | SD | *t* | *Df* | *Sig.* |
|---|---|---|---|---|---|---|---|
| CK | MA/MSC | 165 | 3.17 | 0.65 | −3.163 | 243 | 0.002 |
| | PhD | 80 | 3.37 | 0.40 | | | |
| PK | MA/MSC | 165 | 2.81 | 0.46 | −1.521 | 243 | 0.129 |
| | PhD | 80 | 2.91 | 0.46 | | | |
| TK | MA/MSC | 165 | 2.58 | 0.42 | −5.194 | 243 | 0.001 |
| | PhD | 80 | 2.85 | 0.33 | | | |
| PCK | MA/MSC | 165 | 2.70 | 0.44 | −1.422 | 243 | 0.156 |
| | PhD | 80 | 2.78 | 0.43 | | | |
| TPK | MA/MSC | 165 | 2.73 | 0.46 | −0.464 | 243 | 0.643 |
| | PhD | 80 | 2.75 | 0.316 | | | |
| TCK | MA/MSC | 165 | 2.96 | 0.62 | 1.807 | 243 | 0.072 |
| | PhD | 80 | 2.81 | 0.50 | | | |
| TPACK | MA/MSC | 165 | 2.81 | 0.30 | −2.506 | 243 | 0.013 |
| | PhD | 80 | 2.91 | 0.25 | | | |

Table 6. Teacher educators' TPACK competence and experiences.

| Dimensions | Source | Sum of squares | *Df* | Mean square | *F* | *Sig.* |
|---|---|---|---|---|---|---|
| CK | Between Groups | 3.366 | 4 | 0.841 | | |
| | Within Groups | 81.250 | 240 | 0.339 | 2.485 | 0.044 |
| | Total | 84.616 | 244 | | | |
| PK | Between Groups | 0.372 | 4 | 0.093 | | |
| | Within Groups | 52.127 | 240 | 0.217 | 0.428 | 0.788 |
| | Total | 52.499 | 244 | | | |
| TK | Between Groups | 2.211 | 4 | 0.553 | | |
| | Within Groups | 38.617 | 240 | 0.161 | 3.435 | 0.009 |
| | Total | 40.828 | 244 | | | |
| PCK | Between Groups | 0.292 | 4 | 0.073 | | |
| | Within Groups | 46.158 | 240 | 0.192 | 0.379 | 0.824 |
| | Total | 46.449 | 244 | | | |
| TPK | Between Groups | 0.371 | 4 | 0.093 | | |
| | Within Groups | 41.574 | 240 | 0.173 | 0.535 | 0.710 |
| | Total | 41.945 | 244 | | | |
| TCK | Between Groups | 9.698 | 4 | 2.424 | | |
| | Within Groups | 73.826 | 240 | 0.308 | 7.881 | 0.000*** |
| | Total | 83.524 | 244 | | | |
| Overall | Between Groups | 0.289 | 4 | 0.072 | | |
| TPCK | Within Groups | 20.216 | 240 | 0.084 | 0.857 | 0.491 |
| | Total | 20.505 | 244 | | | |

In order to compare the competence of teacher educators TPACK based on their gender, an independent sample *t*-test was employed. The findings revealed that there were no statistically significant differences between male and female teacher educators across the TPACK components.

Table 5 reveals significant differences in performance between lectures and PhD holders on the three out the seven components: CK ($p < 0.002$), TK ($p < 0.001$) and

Table 7. Teacher educators' TPACK competence and fields of study.

| Dimensions | Source | Sum of squares | *Df* | Mean square | *F* | *Sig.* |
|---|---|---|---|---|---|---|
| CK | Between Groups | 2.146 | 2 | 1.073 | 3.149 | 0.045 |
| | Within Groups | 82.469 | 242 | 0.341 | | |
| | Total | 84.616 | 244 | | | |
| PK | Between Groups | 0.719 | 2 | 0.359 | 1.680 | 0.189 |
| | Within Groups | 51.780 | 242 | 0.214 | | |
| | Total | 52.499 | 244 | | | |
| TK | Between Groups | 2.539 | 2 | 1.269 | 8.023 | 0.000*** |
| | Within Groups | 38.289 | 242 | 0.158 | | |
| | Total | 40.828 | 244 | | | |
| PCK | Between Groups | 0.395 | 2 | 0.197 | 1.037 | 0.356 |
| | Within Groups | 46.055 | 242 | 0.190 | | |
| | Total | 46.449 | 244 | | | |
| TPK | Between Groups | 0.832 | 2 | 0.416 | 2.448 | 0.089 |
| | Within Groups | 41.113 | 242 | 0.170 | | |
| | Total | 41.945 | 244 | | | |
| TCK | Between Groups | 6.769 | 2 | 3.385 | 10.672 | 0.000*** |
| | Within Groups | 76.754 | 242 | 0.317 | | |
| | Total | 83.524 | 244 | | | |
| TPACK | Between Groups | 0.115 | 2 | 0.058 | 0.685 | 0.505 |
| | Within Groups | 20.390 | 242 | 0.084 | | |
| | Total | 20.505 | 244 | | | |

TPACK ($p < 0.013$). In these instances, PhD holders demonstrated significantly higher mean scores compared to the lectures.

For the PK component, no significant difference in performance was observed between the two groups ($p = 0.129$). This suggests that both lectures and PhD teacher educators demonstrate similar competences on this TPACK subscale.

The findings suggest that PhD teacher educators, on average, outperformed lectures on a majority of the assessed TPACK components. This showed that additional study is required to investigate the factors contributing to these observed differences and their implications for TPACK practices.

Table 6 provides the results of one-way ANOVA analyses to investigate differences in teacher educators' TPACK competence across the five levels of teaching experiences for seven different TPACK components (CK, PK, TK, PCK, TPK, TCK and TPACK).

Statistically significant differences in TPACK competence across teaching experiences were found for three dimensions: CK ($p = 0.044$), TK ($p = 0.009$) and TCK ($p < 0.000$). This indicates that the mean score TPACK competence on these components varies significantly among the five teaching experiences.

For the other subscales (PK, PCK, TPK and TPACK), the ANOVA results did not reveal significant differences in TPACK competence across teacher educators' the teaching experiences. This suggests that, for these subscales, the mean competence seems to be relatively consistent across the teaching experiences.

These findings suggest that teacher educators' teaching experience have a significant impact on TPACK competences in three TPACK subscales, that is, CK, TK and TCK, while its influence seem to be less in other components. Post-hoc tests


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showed less experienced teachers (0–5 years) had significantly higher scores in TK and TCK, suggesting they may be more competent with integrating technology into their teaching practices. In contrast, no significant differences were observed in PK, PCK, TPK and Overall TPACK, indicating that teaching experience may not have a strong impact on these competencies. These findings suggest that while CK tends to grow with teaching experience, newer teachers display stronger TK competencies. This highlights a potential gap in technological adaptation among more experienced educators, underscoring the need for targeted professional development to enhance technology integration for experienced teachers. Conversely, newer teachers might benefit from mentorship to strengthen their PK and CK.

Data in the table showed the results of one-way ANOVA analysis that was conducted to investigate possible significant differences in teacher educators' TPACK competences for seven components (CK, PK, TK, PCK, TPK, TCK and TPACK with regard to their fields of study).

Three sub-dimensions showed statistically significant differences in performance: TK ($p < 0.000$), TCK ($p < 0.000$) and CK ($p = 0.045$). This shows that the TPACK capacity of teacher educators means score across these subscales are significantly varied.

For the remaining four subcomponents (PK, PCK, TPK and TPACK), the ANOVA results did not reveal significant differences in competence of teacher educators. This suggests that, for these subscales, the mean teacher educators' TPACK competence appears to be relatively consistent.

These findings suggest that teacher educators' TPACK competency may differ significantly across the components. Further analysis using a post-hoc test was used to determine which specific field of study differs significantly from each other in terms of their TPACK competence. The result revealed that significant difference was found between the natural and social sciences ($p = 0.049$), indicating that teacher educators from the social sciences scored higher in CK. Also, significant differences are found between 'natural' and 'pedagogical' ($p = 0.005$), and between 'social' and 'pedagogical' ($p = 0.002$), indicating that teacher educators from the pedagogical science scored significantly lower in TK. Moreover, significant differences were found between 'social' and 'pedagogical' fields ($p < 0.001$), where teachers from pedagogical sciences scored significantly higher in TCK. However, no significant differences were observed in PK, PCK, TPK and Overall TPACK across fields of study ($p > 0.05$). Therefore, the findings can have implications for technology integration in the higher learning institutions.

## Discussion

The findings indicate that teacher educators in Ethiopian higher education institutions exhibit the lowest competence in TK compared to the other TPACK subscale, consistent with prior studies compared with the other TPACK subscales, consistent with prior studies (Akturk & Saka, 2019; Almithqal & John, 2025; Astuti et al., 2019; Castéra et al., 2020; Chee et al., 2017; Mansour et al., 2024; Naaz & Khan, 2018; Thinzarkyaw, 2019; Yusuf, 2021). This suggests a critical gap in technology integration, necessitating targeted professional development. Contrary to this, significant differences of teacher competence based on their gender were established (Akram et al., 2021; Bas & Senturk, 2018; Marange & Tatira, 2024; Ozudogru & Ozudogru, 2019).

This discrepancy may reflect contextual factors, such as uniform access to technology training across genders in Ethiopia, unlike settings where gender-based disparities in technology access persist. The absence of gender differences challenges assumptions about male dominance in technology-related competencies and suggests that professional development should focus on universal skill enhancement rather than gender-specific interventions.

Significant differences in CK, TK and overall TPACK by qualifications (PhD vs. MA/MSc) highlight the fact that higher academic qualifications correlate with stronger competencies, supporting Bingimlas (2018), Akturk and Saka (2019) and Antony et al. (2019) but contradicting Thinzarkyaw (2019), Jang & Chang, (2016), Ozudogru and Ozudogru (2019) and Mansour et al. (2024). This unexpected finding may be attributed to PhD programs' emphasis on research and exposure to advanced technological tools, which MA/MSc programs may lack. This suggests that professional development for MA/MSc holders should prioritize TK to bridge this gap.

Similarly, teaching experience significantly influenced CK, TK and TCK, with less experienced educators (0–5 years) scoring higher in TK and TCK, consistent with Akturk and Ozturk (2019). This counterintuitive result may reflect younger educators' familiarity with digital tools, while experienced educators rely on traditional methods. Targeted training for experienced educators could address this technological lag, while novice educators may benefit from mentorship to enhance CK and PK.

Field of study also revealed significant differences in CK, TK and TCK, with pedagogical science educators scoring lower in TK compared to natural and social sciences. This finding contrasts with expectations that pedagogical science educators, trained in teaching methodologies, would excel in technology integration. It suggests that their training may prioritize pedagogy over technology, necessitating specialized TK-focused professional development for this group. The lack of differences in PK, PCK, TPK and overall TPACK across fields aligns with Mansour et al. (2024), indicating that these competencies may be less discipline-specific.

Recent research highlights the importance of teacher educators' TPACK competency in teacher education programs for effective teaching (Cuhadar, 2018). Yet, many teacher educators still lack the necessary PK and TK to integrate technology into their teaching and learning process effectively (Agustini et al., 2019). Consequently, future teachers are often not adequately prepared to teach with technology, as the focus tends to be on subject matter alone.

These findings underscore the need for tailored professional development to enhance TK across all teacher educators, particularly for those with higher qualifications, more experience and pedagogical science backgrounds. Integrating TPACK-focused training into teacher education curricula could better prepare future teachers to use technology effectively, aligning with global trends in educational technology (Tondeur et al., 2019).

## Conclusion

The study highlights the fact that teacher educators' TK is notably weaker than other TPACK subscales, indicating a need for enhanced technology training. While no gender differences were found, qualifications, experience and field of study significantly influence TPACK competencies. These findings have broader implications for policy, suggesting that Ethiopian higher education institutions should prioritize


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TK-focused professional development and integrate TPACK into teacher training curricula to align with global standards. Future research should explore qualitative insights and classroom observations to deepen understanding of TPACK implementation.

## Recommendations

Teacher education programs should incorporate TPACK-based strategies, emphasizing technology integration through professional development. Pre-service teachers should engage in TPACK-focused training to prepare for technology-integrated classrooms. Policymakers should develop targeted interventions for experienced educators and those in pedagogical sciences to enhance TK, ensuring equitable technology integration across all disciplines.

## Limitations

The study focused on selected Ethiopian universities, limiting generalizability. Reliance on self-reported data may introduce biases, and the absence of classroom observations limits insights into actual TPACK practices. Future studies should incorporate qualitative methods and observations for a comprehensive understanding.

## Disclosure statement

The authors report that there are no competing interests to declare.

## Data availability

The data that support the findings of this study are available from the corresponding author upon request.

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