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Demographic and Contextual Factors Associated with Teachers' Perceived TPACK: Evidence from the Maldives

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Abstract

The use of digital technologies in education has increased the importance of teachers' Technological Pedagogical Content Knowledge (TPACK). However, existing research on the effect of demographic variables on teachers' TPACK has produced inconsistent findings, and empirical evidence from Small Island Developing States (SIDS) remains limited. This study investigated the demographic and contextual factors affecting Maldivian in-service secondary teachers' perceived TPACK competency. A validated 29-item questionnaire was administered to 485 teachers, and the data were analyzed using descriptive statistics and multivariate analysis of variance (MANOVA). The results revealed a generally high level of perceived TPACK across all dimensions. Significant differences were found based on frequency of technology use, teaching subject, and teacher nationality, whereas gender, age, and teaching experience showed no significant differences. Maldivian teachers teaching local subjects reported relatively lower perceptions of technological knowledge, likely due to the limited availability of subject-specific digital resources. This study contributes to the TPACK literature by providing empirical evidence from a SIDS and demonstrating that contextual factors, rather than demographic factors, have a greater influence on teachers' perceived TPACK. The findings highlight the importance of contextualized professional development and subject-specific digital resources to support effective technology integration.

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INTRODUCTION

Rapid technological advancement has transformed education systems, increasing the need to integrate digital technologies to meet the evolving needs of learners and society. Teachers, therefore, play a central role in ensuring that technology is meaningfully integrated into teaching and learning (Ministry of Education, 2025; UNESCO, 2023). The Maldives, a Small Island Developing State (SIDS), has similarly prioritized digital transformation in education through national ICT initiatives (Maldives Monetary Authority, 2026; UNICEF, 2025). Since the late 1990s, the Maldivian government has continuously invested in ICT infrastructure, teacher professional development, and curriculum digitization initiatives to strengthen digital education nationwide. These efforts accelerated during the COVID-19 pandemic, enabling online learning across geographically dispersed islands and reinforcing the country's long-term commitment to educational digital transformation (Ministry of Education, 2022; United Nations, 2007).

The advancements in the field of education using Digital Technologies demonstrated the vital role that technology has to play as a vehicle to enhance the quality and effectiveness of teaching, increase student involvement, and develop the digital capabilities necessary for all students to participate meaningfully in today's society (Nirmala et al., 2025; Relmasira & Donaldson, 2025).

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However, while we continue to invest heavily in these technologies and, thus far, have been able to provide them to our students, there are still barriers preventing us from realizing ideal, equitable, and effective technology integration nationwide. Despite these investments, equitable technology integration remains challenging due to the Maldives' geographically dispersed islands, unequal digital infrastructure, and varying levels of institutional support and teacher preparedness (Ministry of Education, 2022; UNICEF, 2025). In addition, varying degrees of teacher preparedness and confidence in technology integration pose a challenge to the provision of technology-driven education. Previous studies consistently emphasize that technology alone does not improve learning; rather, effective technology integration depends on teachers' pedagogical and technological competence(Chandra & Briskey, 2012; Chandra et al., 2014; Choudhury et al., 2025; Gulbahar & Guven 2008; Waseela 2022) Thus, the success of such initiatives depends on two areas: first, the availability of technology infrastructure; and second, the ability of the teacher to harness technology for educational value through verbal, visual, and non-verbal communication.

According to Mishra & Koehler (2006), for effective technology integration, teachers need to have an understanding of three interconnected knowledge domains: technology, pedagogy, and subject content knowledge, which they conceptualized as the TPACK framework. There is ample research examining the role of TPACK in supporting teachers' technology integration across various teaching contexts (Altun & Akyıldız, 2017; Archambault & Crippen, 2009; Barac et al., 2017; Castéra et al., 2020; Chaipidech et al., 2022; Jang et al., 2013; Ortiz Colón et al., 2023; Owusu et al., 2015; Rahman et al., 2017; Redmond & Peled, 2019; Sahin, 2011; Tokmak et al., 2013; Yanış & Yürük, 2021). Evidence suggests that teachers with well-developed TPACK are more capable of assessing technology with respect to its application as a technical tool and as a pedagogically valuable resource aligned with curriculum and learning goals (Guntara et al., 2021; Kurniawati et al., 2023; Nurulsari et al., 2023). However, TPACK research has been numerous; they often yield contradictory findings about the factors influencing teachers' TPACK, with most studies oversimplifying the complex, context-dependent nature of technology integration.

One persisting area of contradiction relates to the effect teacher demographics have on their use of technology. While some studies report significant demographic differences in teachers' TPACK and digital competence, others find minimal or no meaningful differences. As an example, Erdogan & Sahin (2010) compared math teacher candidates' TPACK and found male teachers demonstrating higher TPACK perceptions than female teachers. Contrarily, recent studies by Nguyen et al. (2026) on pre-service teachers in Vietnam and Weinstein & Riegel (2025) in K-12 Classrooms found no consistent gender differences in teachers' overall digital competence. Similarly, conflicting interpretations have been produced from studies examining teaching experience and age-related factors. Luik et al. (2018) and Abundo & Palillo (2025) found experienced teachers having stronger pedagogical and content knowledge, while comparatively weaker technological knowledge, whereas less experienced teachers seemed more pliable to digital technologies. Analogous patterns were identified by (Nguyen et al., 2026; Weinstein & Riegel, 2025; Yang et al., 2026). In their study on contextual factors, Redmond & Peled (2019) identified significant differences in TK and CK between pre-service teachers in Australia and Israel, while Castéra et al. (2020) noted substantial cross-national differences in TPACK among teacher educators in six countries. Correspondingly, Alqurashi et al. (2017) in their study on TPCK between teachers from Saudi Arabia and the US found significant differences in TK, TCK, and TPK, with the former having higher perceptions across all four technology knowledge domains.

Taken together, these inconsistencies suggest that teachers' TPACK is shaped not only by demographic characteristics but also by contextual factors such as infrastructure, institutional support, professional learning opportunities, subject discipline, and professional background. Nevertheless, these contextual dimensions remain underexplored, particularly in Small Island Developing States, where technology integration is constrained by geographical dispersion and limited educational resources. Furthermore, little attention has been given to differences associated with teacher nationality and subject discipline despite their potential influence on technology integration practices.

This study addresses two important gaps in the TPACK literature by examining teachers' TPACK within the context of a Small Island Developing State and by investigating how teacher nationality and subject discipline relate to TPACK in the Maldivian education system, both of which

remain underexplored. Accordingly, this study investigates Maldivian in-service secondary teachers' TPACK perceptions and examines variations across demographic factors (gender, age, and teaching experience) and contextual factors (frequency of technology use, subject discipline, and nationality). The following research questions guide the study:

1. Do teachers' TPACK perceptions vary based on demographic characteristics such as gender, age, and years of teaching experience?
2. Do teachers' TPACK perceptions vary based on contextual characteristics such as frequency of technology use, subject discipline, and nationality?

METHOD

This study is an example of the topic being researched and is referred to as Phase 1 of the larger mixed-method explanatory case study about teachers' technology integration practices in the Maldivian education system (Yin, 2014). The methodology is designed as two sequential phases. The first one is a quantitative survey to determine if there are patterns in the way the teachers perceive TPACK. The second part of the methodology is the qualitative data collection to help (1) explain and (2) elaborate on the TPACK perceptions found in Phase 1. The results of Phase 1 of the data collection will be reported in this paper as they relate to the teachers' self- reported TPACK perceptions (quantitative data), without qualitative data from the second phase.

Context and Timing of the Study

The data collected for this quantitative study occurred in 2019 during a time of significant investment in educational technology throughout the Maldives. There were several national projects, including but not limited to the Curriculum Digitization Project and the Digital School Project, to provide all schools access to digital devices and online learning platforms via the implementation of nationwide policies. As such, this dataset represents an important baseline for understanding teachers' TPACK perceptions at a pivotal time for digital transformation in Maldivian educational institutions. However, given that data has been collected, reported, and published long after the point of collection, the reported results reflect teachers' perceptions related to educational reform during this time and do not reflect current conditions.

Instrument and validation

The items for the TPACK survey questionnaire were adapted from Koh et al. (2013), and validated for this phase (Waseela, 2022). The instrument underwent a multi-stage validation process. Face validity was established through consultation with four practicing teachers to identify ambiguities and improve item clarity. Content validity was assessed by two experts in educational technology. The instrument was then piloted with 30 teachers to ensure reliability and suitability for the Maldivian context. The questionnaire used a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Target population, sampling, and data collection

The target population consisted of in-service teachers (N = 2,984) teaching grades 9 and 10 (lower secondary) in government schools in the Maldives. Based on sampling guidelines proposed by Cohen et al. (2007), Research showed that a minimum of 341 teachers (out of 2,984) was required to satisfy the level of confidence and margin of error for the population of teachers nationally. In order to obtain the necessary sample size, all eligible teachers were invited to complete an online survey through a method called voluntary response sampling. The result was an increase in the number of teachers who participated in the survey, along with responses from teachers located throughout the Maldives. The survey was sent to all eligible teachers to complete, with only teachers completing the entire survey being included in the total sample size. The final sample size for this study consisted of 485 teachers (the minimum sample size was 341 teachers). Only completed responses were included in the final analyses. Therefore, while this sampling method increased the number of participants in the study, it did create the possible presence of self-selection bias, as those who chose to participate may have characteristics that are different from those who did not reply.

Participants

Among the 485 participants, 266 (54.8%) were male teachers, while 219 (45.2%) females. More than half the population, 277 (57.1%), were at least 35 years old, with most teachers, 389 (80.2%), having at least five or more years of teaching experience. Trained teachers comprised 432 (89%), which the remaining had not done any teacher training 43 (8.9%) or did not provide the data 10 (2.1%). The largest subject group comprised of Mathematics teachers, 96 (19.8%), followed by English, 90 (18.6%), while a few teachers taught Dhivehi, 36 (7.4%), and Islamic studies, 28 (5.8%). Many teachers (71.5%) taught more than one subject and both grade levels. A substantial proportion of the sample consisted of expatriate teachers (62.1% Indian (n=301); 1.2% Sri Lankan (n=6)), while 36.7% were Maldivian nationals (n=178). Teachers were distributed across all regions of the country, with the majority working in island schools (87.4%, n=424) rather than the capital region (12.6%, n=61). These characteristics reflect the diverse and geographically dispersed nature of the Maldivian teaching workforce.

Data analysis

To examine the significant differences in TPACK constructs based on teacher demographics, MANOVA (Multivariate Analysis of Variance) was utilized as the study involved multiple dependent variables (Pallant, 2013; Tabachnick et al., 2013). Preliminary assumptions were checked before the analysis. This included the tests for normality, linearity, multicollinearity, univariate and multivariate outliers, and homogeneity of variance-covariance matrices, which were all satisfied (refer to Appendix, Tables 2 to 4). Mahalanobis distance scores were examined to detect multivariate outliers, resulting in the removal of 15 cases and leaving 470 valid responses for the final analysis (refer to Appendix, Table 5). Due to unequal group sizes across the demographic variables, Pillai's Trace was used as the preferred multivariate test statistic (Tabachnick et al., 2013). To minimize the risk of Type I error arising from multiple comparisons, Bonferroni adjustments were applied to the alpha level (Pallant, 2013). Scheffé's post hoc multiple comparison procedure was conducted to determine specific group differences (Pallant, 2013).

Analytical Scope and Limitations

In assessing characteristics of the TPACK construct, this report will look at each of the study's demographic and contextual variables independently, providing a straightforward understanding of differences among groups. However, this does not allow for a complete consideration of possible relationships between the demographic and contextual variables (e.g., the relationship between a teacher's nationality and the subject area taught). In discussing TPACK characteristics, the limitations of this approach will be discussed as an important aspect of the analyses. Finally, self-report measures of TPACK are used to gather the teacher's perceived confidence when using technology. Therefore, this study represents only the perceptions of TPACK and not the actual practices of teachers using TPACK in their daily instructional practices. As such, findings should be interpreted as indicative of perceived capability rather than actual technology integration competence.

RESULTS AND DISCUSSION

Results

Descriptive statistics for the individual scale items and TPACK subscales are presented in Table 1 (refer to Appendix). The mean scores for all subscales exceeded 3.4, which was based on a Likert scale from 1 to 5, indicating generally high to very high levels of teachers' TPACK perceptions. In particular, the domains related to technology - TK, TCK, TPK, and overall TPACK- had relatively similar mean scores of 4.11, 4.23, 4.17, and 4.26, respectively, suggesting strong teacher confidence in technology integration-related competencies. Consistent with previous TPACK research, the highest scores were found in teachers' content knowledge (CK), followed by pedagogical knowledge (PK) (Archambault & Crippen, 2009; Barac et al., 2017; Koh et al., 2014; Redmond & Peled, 2019). This might be due to the prominence given to developing subject expertise and pedagogy while undergoing teacher education training, especially in secondary teacher education programs, where it is compulsory for pre-service teachers to possess highly advanced level results in their specialized subjects before entering teacher training. Such requirements, combined with focused training of

various pedagogical strategies, could likely influence teachers' confidence in subject content and instructional practices over technology-related domains.

Although slightly lower than CK and PK, teachers in this study also had relatively high scores in technology-related areas (TK, TPK, TCK, and TPACK). This finding aligns with earlier studies, which demonstrated that teachers usually held higher perceptions of their subject and teaching abilities than of their skills in using digital technologies for educational purposes (Barac et al., 2017). The results on teachers' PCK showed the lowest average score with the highest variation. This contrasted with earlier studies, where PCK was often one of the stronger TPACK areas (Barac et al., 2017; Koh et al., 2014; Liu et al., 2015; Owusu et al., 2015). Lower and more variable results for PCK may reflect persistent struggles in the integration of pedagogy and content knowledge—or continuing curricular reform efforts. Recent shifts towards competency-based curricula and digital learning initiatives in the Maldivian context may have compounded this complexity for teachers as they adapt their instructional practices (NIE, 2014). Besides, the limited number of questions used to measure PCK in the survey might also have affected the results. Lastly, though PCK scores were lower than those in other areas, it is important to note that they were generally high according to Ersoy & Aktay (2007) classification.

Multivariate Analysis of Demographic and Contextual Factors

As stated earlier, Multivariate Analysis of Variance (MANOVA) was employed to examine differences in teachers' TPACK perceptions across demographic and contextual characteristics, as the study involved multiple dependent variables (Hair et al., 2019; Pallant, 2013; Tabachnick et al., 2013). MANOVA was considered appropriate as it analyses multiple correlated dependent variables simultaneously, while reducing the risk of Type I error, which is likely to occur when conducting multiple separate analyses (Pallant, 2013; Tabachnick et al., 2013). In addition, the technique provides a more comprehensive understanding of group differences and may identify multivariate effects that might not emerge through individual ANOVAs (Tabachnick et al., 2013). The analysis, therefore, examined teachers' TPACK perceptions across selected demographic characteristics, which included teachers' gender, age, years of teaching experience, and contextual factors such as frequency of technology use, nationality, and teaching subject.

Gender

The Multivariate Analysis comparing the mean scores, standard deviations, and effect sizes of all seven TPACK constructs across gender is presented in Table 6 (refer to Appendix). Results showed a statistically significant effect for gender, $F(7, 462) = 4.12$, $p < 0.001$, Pillai's Trace = 0.059. However, follow-up univariate analysis (with a Bonferroni-adjusted alpha value of 0.007) indicated that the difference was primarily limited to technological knowledge (TK), with male teachers showing slightly higher perception than female teachers. The effect was statistically significant yet small, suggesting minimal practical differences between the two groups. No notable differences in gender were found in the other TPACK domains. This finding was consistent with the literature available at the time of the study, which indicated that the male teachers self-perceived higher levels of technological knowledge than female teachers (Jang et al., 2013; Koh et al., 2014; Long et al., 2020).

Age

Statistically significant differences were also identified across age groups, $F(14, 924) = 2.506$, $p = 0.002$, Pillai's Trace = 0.073. The differences were mainly observed in content knowledge (CK) and pedagogical knowledge (PK), where older teachers reported higher perception levels than younger teachers. Although technology-related domains did not show statistically significant variation, the descriptive trends suggested that younger teachers had comparatively higher perceptions in technology-oriented domains, whereas older teachers reported higher perceptions in pedagogy and content-related domains. These results align with prior research implying that as teachers age, they will have more experience, which could strengthen their content and pedagogical expertise, while more junior teachers may be lacking in these two domains but exhibit greater familiarity with digital technologies (Jang et al., 2013; Koh et al., 2014; Long et al., 2020). The mean scores, standard deviation and effect sizes for all seven TPACK constructs across different age categories are shown in Table 7 (refer to Appendix).

Years of teaching experience

The multivariate analysis of TPACK perception against teachers' years of teaching experience, shown in Table 8 (refer to Appendix), produced statistically significant multivariate differences as well, $F (14, 924) = 1.847$, $p = 0.029$, Pillai's Trace = 0.054. However, follow-up analyses showed that the differences were relatively limited, with statistically significant variation identified only for CK. More experienced teachers generally reported higher confidence in CK and PK domains, while differences in technology-related domains were comparatively smaller and not statistically significant. Overall, the findings suggest that teaching experience contributes more strongly to pedagogy- and content-oriented knowledge than to technology integration confidence.

Frequency of using technology

The results of multivariate analysis on TPACK perception as a function of teachers' frequency of technology use are shown in Table 9 (refer to Appendix). This analysis showed the highest and most consistent variation among all demographic variables with teachers' TPACK perceptions, $F (14, 908) = 5.929$, $p < 0.001$, Pillai's Trace = 0.168. Except for PCK, significant differences were found across all TPACK domains. Teachers who frequently and consistently adopt technology reported substantially stronger TPACK perceptions in technology-related domains, particularly TK, TCK, TPK, and overall TPACK, compared to teachers who rarely used technology in their teaching. Medium to large effect sizes were produced, signifying meaningful and practical differences between groups. This is an anticipated result as more technology integration is expected to yield stronger confidence in one's abilities to effectively adopt them. Thus, unlike static demographic characteristics such as age or gender, regular engagement with digital technologies may play a major role in shaping stronger TPACK perceptions among teachers.

Subject discipline

The comparison of mean scores of teachers' TPACK and corresponding effect sizes across subject disciplines is shown in Tables 10 and 11 (refer to Appendix). This analysis used the four compulsory subjects in the Maldivian curriculum for secondary grade students, which include English language, Mathematics, Dhivehi, and Islamic Studies, as students are required to get a pass grade in these subjects to progress to the next grade level. Thus, the sample for this analysis comprised 170 teachers in total. This included English language (N=71), Mathematics (N=52), Dhivehi teachers (N=22), and Islamic Studies (N=25) teachers.

Statistically significant multivariate differences were observed across subject disciplines, $F (21, 4867) = 2.743$, $p < 0.001$, Pillai's Trace = 0.318, with differences identified across all TPACK domains except PCK. English language teachers consistently reported the highest confidence across most TPACK domains, followed by mathematics teachers, while Dhivehi language teachers reported the lowest confidence levels. The most significant differences were detected between English and Dhivehi language teachers, predominantly in the technology domains, while no significant differences were observed between Islamic Studies teachers and mathematics or Dhivehi language teachers in most domains. These findings indicate that teachers' readiness to integrate digital technologies is significantly influenced by their subject discipline, possibly because of the way various disciplines define their curriculum requirements and access to subject-related digital content and pedagogical traditions.

Nationality

The multivariate results for teachers' TPACK perceptions based on their nationality are shown in Table 12 (refer to Appendix). For this analysis, responses from Maldivian (N=166), and Indian (N=299) nationalities were used, and Sri Lankan (N=5) nationality was excluded to minimize errors arising from a small sample size that might distort the results.

The multivariate analysis on nationality produced the largest variation compared to all previous factors, with $F (7, 457) = 20.33$, $p < 0.001$, Pillai's Trace = 0.237. Significantly higher TPACK perception was observed among teachers from Indian nationality across most TPACK domains, predominantly in TK, TCK, TPK, and overall TPACK. The effect sizes also ranged from medium to large, indicative of considerable variations between the two groups. CK and PK represented the strongest domains for both nationalities. However, comparatively lower perception was observed

among Maldivian teachers in TK, while for Indian teachers, lower confidence was seen in their PCK compared to other domains. Given the considerably high proportion of expatriate teachers employed in the Maldivian education system, these findings are crucial as teachers' nationality can be an important contextual factor influencing technology integration practices in Maldivian schools. These results suggest that teachers' TPACK may be shaped by differences in teachers' professional preparation, prior technological exposure, and access to professional learning opportunities, rather than by individual demographic characteristics such as their age or gender. Taken together, the results indicate that contextual factors played a more substantial role than demographic characteristics in shaping teachers' TPACK perceptions. In sum,

1. The frequency of technology use, subject discipline, and nationality showed the strongest associations with TPACK.
2. In contrast, gender, age, and teaching experience demonstrated relatively limited or domain-specific effects.
3. Across all groups, teachers consistently reported stronger confidence in content and pedagogy than in technology integration.

These findings suggest that teachers' self-reported TPACK is more closely linked to their exposure to technology and contextual teaching conditions than to static demographic characteristics.

Discussion

This study investigated the TPACK perceptions of in-service teachers teaching in grades 9 and 10 of Maldivian government schools and compared their TPACK across demographic factors such as gender, age, years of teaching experience, and contextual factors, which included the frequency of technology use, nationality, and teaching subject. Survey data from 485 respondents resulted in high TPACK perception for all the constructs, suggesting that they understand and agree to being able to accomplish most of the tasks that were described in the items of the TPACK survey. Consistent with previous TPACK studies, the highest perception was on their CK and PK, followed by TK and other technology-related domains (TK, TCK, TPK, and TPACK), which were all relatively high, while the lowest was for PCK (Koh et al., 2014; Owusu et al., 2015). As denoted by Waseela (2022), the nationwide technology training (Google Classroom) that teachers underwent in preparation for the 'Digital School Project' might have positively impacted teachers' perceptions, inflating these results (Ministry of Education, 2019).

A notably contrasting result was found in teachers' pedagogical content knowledge (PCK), which was also the lowest in this study. A likely explanation for this discrepancy might be linked to the new curriculum introduced in 2015. As highlighted in the Education Sector Analysis report, teachers were still getting familiarized with this curriculum (Ministry of Education, 2019). The report identified issues in conceptualizing and effectively applying the competency-based curriculum in teaching and lesson planning, especially in schools with a higher number of untrained, temporary/contract teachers, and in the timely provision of supervisory support from the Leading Teachers (Ministry of Education, 2019). However, readers are cautioned when interpreting these PCK results, as the proposed connection to the 2015 curriculum reform represents only a plausible explanation drawn from contextual factors rather than a direct finding established by this study. Furthermore, this study revealed that teachers' TPACK was statistically significantly different according to teachers' gender, age, years of teaching experience, frequency of technology use, nationality, and the subject they taught. These findings highlight a number of key issues that warrant further discussion.

First, the findings align with previous studies showing differences in teachers' TPACK based on gender, where male teachers had a significantly higher TK perception compared to female teachers (Altun & Akyıldız, 2017; Erdogan & Sahin, 2010; Jang et al., 2013; Koh et al., 2014). This might be due to male teachers' greater willingness to actively use technical knowledge in teaching, while female teachers may face problems, including a lack of confidence and fewer opportunities for technical training, resulting in their lower perceptions of TK. Hence, the finding signifies the importance of addressing potential gender disparities when designing training programs aimed at enhancing teachers' capacity to integrate technology, particularly by providing greater support for female teachers in technology-related domains.

Second, in line with existing literature, this study found statistically significant differences in TPACK between senior, more experienced teachers and junior, less experienced teachers, particularly in their CK and PK, with more experienced teachers having higher perceptions in both knowledge domains (Castéra et al., 2020; Jang et al., 2013; Koh et al., 2014; Liu et al., 2015). However, the effect size indicated that this difference was negligible. This might be due to contextual differences between the present study and prior research, as the current study focused on in-service secondary grade teachers' TPACK, while previous studies largely examined pre-service teachers, who may still be in the process of developing the professional experience required to enhance their content knowledge and pedagogical skills.

Third, a perspective rarely investigated in the literature is the influence of teachers' frequency of technology use on their TPACK perceptions. This study revealed significant differences among the three user categories ('always', 'frequent', and 'rare'). In-service teachers who reported daily or near-daily use of digital technologies showed significantly higher scores across all technology-related TPACK domains compared to those who used technology infrequently. Similar results were reported by Loi (2021), who assessed in-service English language teachers' perceptions of TPACK in Vietnamese high schools using a six-factor TPACK scale. They found that teachers who used technology more often reported higher TPACK levels in TK, TCK, and TPCK compared to teachers who used it less often. The evidence that teachers' frequency of technology use positively influences their TPACK perceptions is not unexpected (Loi, 2021). Research evidence indicates that the more experience one gains in using technology in teaching, the more confident and skilled they become in their technology integration practices, resulting in higher TPACK perceptions (Loi, 2021; Rouf & Mohamed, 2018). This can have a ripple effect, with acquiring more knowledge and skills leading to higher confidence and a morale boost, allowing them to find innovative ways to adopt technology in their lessons. Thus, as Loi (2021) and Rouf & Mohamed (2018) noted, this underscores the importance of creating avenues for teachers to frequently practice and enhance their TPACK self-efficacy to integrate technologies effectively into their teaching.

Fourth, this study demonstrated that teachers' subject discipline plays an important role in their adoption of technology, with English language teachers having the highest TPACK, followed by Mathematics teachers, which contrasts previous studies, where higher perception was found among Mathematics and Science teachers (Tokmak et al., 2013). Likewise, those teaching the two subjects in the local language, Dhivehi, and Islamic studies exhibited the lowest perceptions across all knowledge domains, predominantly in technology-related areas. However, these findings should be interpreted with some caution, as the sample sizes for Dhivehi and Islamic Studies teachers were comparatively smaller than those of English and Mathematics teachers, which may have contributed to greater variability in the results. Further, the comparatively lower scores for these two subjects may reflect contextual challenges related to technology integration within these disciplines. For instance, one possible explanation may be the relatively limited availability of subject-specific digital resources and technology-supported teaching materials in areas such as Dhivehi and Islamic Studies (Ministry of Education, 2022). Many of the existing digital resources are designed in developed countries to teach their curricula and thus do not apply to local subjects, thereby limiting the opportunities available for teachers to integrate technology in these disciplines (Waseela, 2022). Accordingly, teachers teaching these subject disciplines might perceive less value in the limited technology tools at their disposal, resulting in possibly lower TPACK (Ottenbreit-Leftwich, 2012). However, as this factor was not directly measured in the present study, this interpretation remains speculative. Consequently, to address this pressing issue and create opportunities for those teaching the local subjects to explore and implement technologies in their classrooms, urgent measures are called for by sourcing funds and resources to develop subject and context-specific digital resources (Ottenbreit-Leftwich, 2012; Waseela, 2022).

Lastly, the significant differences found in teachers' TPACK based on their nationality provided important insights into how their professional backgrounds may shape TPACK perceptions within the Maldivian education system. The findings in this study revealed statistically significant differences in TPACK, with expatriate Indian teachers showing higher perceptions in all the constructs except PCK compared to locals. For both groups, no significant difference was observed for PCK, indicative of relatively similar perceptions in combining pedagogy and content knowledge. Given the limited research comparing TPACK through the lens of teacher nationality, this finding

indicates that TPACK is not a universally fixed construct, but is shaped by broader socio-cultural, institutional, and technological contexts. For instance, in their study comparing TPACK among pre-service teachers in Australia and Israel, Redmond & Peled (2019) reported significant differences in TK and CK, while Castéra et al. (2020) also found substantial variations in teacher educators' TPACK across six countries in Asia and Europe. Likewise, similar findings were reported by Alqurashi et al. (2017), who found notable differences in technology integration knowledge amongst teachers from Saudi Arabia and the United States. Taken together, these studies inform that teachers' TPACK can be affected by the unique characteristics found in their education systems, such as access to digital infrastructure, institutional cultures, and professional learning prospects. The current study's findings extend this literature by demonstrating that differences in TPACK may occur in both countries, as well as among teachers from different nationalities working in the same national education system (Rathnabai, 2024; Waseela, 2022).

These differences, however, warrant further examination, particularly given that expatriate teachers constitute a substantial proportion of the secondary grade teaching workforce within the Maldivian context. This was also reflected in the survey response rate, where participation from expatriate teachers was considerably higher than that of local teachers, which might have contributed to a degree of response imbalance and potentially influenced the observed results. Another plausible explanation for the comparatively higher TPACK perceptions reported by Indian teachers may be their prior exposure to educational technologies and the professional experiences acquired before entering the Maldivian school system (Rathnabai, 2024). Moreover, the more technologically integrated educational environments in India may have afforded teachers greater exposure to digital pedagogies and ICT-focused teacher education initiatives in India (Rathnabai, 2024). In contrast, local in-service teachers might have been constrained by contextual challenges such as uneven ICT infrastructure, geographic spread of island schooling, and limited access to continuous professional development opportunities, among other factors (Ministry of Education, 2019). Yet, these nationality-based differences should be interpreted with caution, as the results are derived from self-reported data that reflect teachers' perceived confidence in their TPACK competencies and not a direct measure of the actual classroom practice or technology integration effectiveness. Hence, the high TPACK among expatriate teachers may not necessarily be indicative of more pedagogically effective technology integration in actual teaching. Besides, the insignificant results for PCK for both groups suggest that pedagogical understanding related to subject teaching may be related to classroom experiences and curriculum demands, and not necessarily related to nationality. This result lends even more weight to the criticisms regarding the use of demography in understanding TPACK because it tends to underestimate the complexity of the context that is at play with regard to teachers' technology integration efforts. However, regardless of this, the results from comparing nationality are a step towards filling a critical void in the TPACK literature, especially that which relates to SIDS. Therefore, through comparison of TPACK among nationalities within the Maldives environment, the present study contributes to TPACK literature by moving beyond the technologically developed and well-resourced environments to emphasize the relevance of context, professional backgrounds, and power structures when studying technology integration within the educational setting.

LIMITATIONS

There are some limitations of this study that need to be taken into account while interpreting the results of the research. First, the level of teachers' TPACK was estimated through the data obtained via self-reporting surveys, which are prone to possible biases, such as the response bias and social desirability bias, as well as to inaccuracy in the self-perceptions of teachers. This means that the results presented in this paper show the perception of the level of TPACK by the teachers and not the true level of technology integration. Therefore, further research needs to include classroom observations, interviews, lesson artefact analysis, or other performance-based evaluations. Third, even though this study considered some important variables, including demographic and contextual variables, it did not consider any institutional or sociocultural factors like ICT infrastructure, internet availability, leadership support, professional development, and technological readiness at the school level that might affect the TPACK of teachers in the Maldives. Fourth, while there were many

significant differences in terms of demographics and contexts, most of the effect sizes observed were small or medium, implying that the TPACK of teachers is a context-based construct.

CONCLUSION

Implications of this study include various significant issues for research and practice. Even though the perceptions of TPACK in-service Maldivian secondary school teachers were mostly high, the findings suggest that contextual factors appear to play a more prominent role than demographic characteristics in shaping teachers' perceived TPACK. This study makes an additional contribution to the TPACK body of knowledge through presenting national-level data from a Small Island Developing State and proving distinctions in TPACK between disciplines of teaching, including local subjects like Dhivehi and Islamic Studies, and among teachers of various nationalities within the same education system. The results imply that TPACK should be considered contextually dependent and not only an attribute of the teacher individually. Consequently, future studies need to consider the effects of the contextual aspects such as school infrastructure, leadership support, and policy implementation, among others. Practically, the findings highlight the need for targeted professional development that strengthens teachers' technological pedagogical competencies, particularly in TK, TPK, TCK, and PCK, while providing additional support for teachers of locally taught subjects to promote more effective and meaningful technology integration.

AUTHOR CONTRIBUTIONS

Idea conceptualization, methodology, data collection, analysis, writing, and visualization were done by the corresponding author, AW. VC and CF were the supervisor and co-supervisor, respectively, for this work. Both supervisors provided project-level guidance and helped edit this work. All authors have read and agreed to the published version of the manuscript.

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Appendix

Table 1. Teachers perceptions on the TPACK construct (M and SD)

TPACK scales	Mean	SD
TK1 I have the technical skills to use computers effectively	4.39	0.63
TK2 I can learn technology easily	4.47	0.59
TK3 I know how to solve my own technical problems when using technology	3.94	0.83
TK4 I keep up with important new technologies	4.11	0.73
TK5 I am able to create web pages	3.24	1.08
TK6 I am able to use social media (e.g., Blog, Wiki, Facebook)	4.51	0.63
Technological Knowledge subscale (TK)	**4.11**	**0.56**
CK1 I have sufficient knowledge about my teaching subject	4.77	0.42
CK2 I can think about the content of my teaching subject like an expert in the subject area	4.55	0.58
CK3 I am able to develop in-depth understanding about the content of my teaching subject	4.62	0.52
Content Knowledge subscale (CK)	**4.65**	**0.44**
PK1 I am able to stretch my students' thinking by creating challenging tasks for them	4.48	0.55
PK2 I am able to guide my students to adopt appropriate learning strategies	4.52	0.55
PK3 I am able to help my students to monitor their own learning	4.55	0.54
PK4 I am able to help my students to reflect on their learning strategies	4.47	0.56
PK5 I am able to guide my students to discuss effectively during group work	4.57	0.55
Pedagogical Knowledge subscale (PK)	**4.52**	**0.45**
PCK2 Without using technology, I know how to select effective teaching approaches to guide student thinking and learning in my teaching subject	3.92	0.94
PCK3 Without using technology, I can help my students to understand the content knowledge of my teaching subject using various teaching methods	3.94	0.99
Pedagogical Content Knowledge subscale (PCK)	**3.93**	**0.89**
TCK1 I can use the software that are created specifically for my teaching subject	4.03	0.84
TCK2 I know about technologies that I can use to research for content on my teaching subject	4.25	0.67
TCK3 I can use appropriate technologies (e.g., multimedia resources, simulation) to represent the content of my teaching subject	4.40	0.61
Technological Content Knowledge subscale (TCK)	**4.23**	**0.57**
TPK2 I am able to facilitate my students to use technology to find more information on their own	4.36	0.63
TPK3 I am able to facilitate my students to use technology to plan and monitor their own learning	4.16	0.72
TPK4 I am able to facilitate my students to use technology to construct different forms of knowledge representation	4.10	0.72
TPK5 I am able to facilitate my students to collaborate with each other using technology	4.07	0.77
Technological Pedagogical Knowledge subscale (TPK)	**4.17**	**0.60**
TPACK1 I can teach lessons that appropriately combine my subject, technologies, and teaching approaches	4.34	0.62
TPACK2 I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn	4.32	0.65
TPACK3 I can use strategies that combine content, technologies, and teaching approaches that I learnt about in my coursework in my classrooms	4.25	0.64
TPACK4 I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school	4.11	0.77
Technological Pedagogical and Content Knowledge subscale (TPACK)	**4.26**	**0.55**

N=485

Table 2 Skewness and Kurtosis tests for normality

Dependent variables	Min	Max	Mean	St. Dev.	Skewness		Kurtosis	
					Statistic	Std. Error	Statistic	Std. Error
TK	2.00	5.00	4.11	0.56	-0.583	0.111	0.480	0.221
CK	2.67	5.00	4.65	0.44	-0.977	0.111	0.182	0.221
PK	2.80	5.00	4.52	0.45	-0.521	0.111	0.672	0.221
PCK	1.00	5.00	3.93	0.89	-0.748	0.111	0.110	0.221
TCK	2.00	5.00	4.23	0.57	-0.511	0.111	0.263	0.221
TPK	2.00	5.00	4.17	0.60	-0.558	0.111	0.397	0.221
TPACK	1.75	5.00	4.26	0.55	-0.534	0.111	0.590	0.221

Note: N=470, after removing 15 outliers

Table 3 Linearity and multicolleniarity diagnostics (N=470)

	TK	CK	PK	PCK	TCK	TPK	TPACK
TK	1						
CK	.507**	1					
PK	.433**	.594**	1				
PCK	.188**	.223**	.240**	1			
TCK	.624**	.494**	.516**	.257**	1		
TPK	.515**	.462**	.569**	.298**	.639**	1	
TPACK	.563**	.539**	.587**	.242**	.680**	.705**	1

Note: N=470, after removing 15 outliers

Table 4 Box's M values

Dependent variables	Box's M	Sig.	Pillai sig
Gender	40.218	0.072	0.000
Age	124.474	0.006	0.006
Years of teaching experience	89.314	0.006	0.048
Nationality	99.704	0.000	0.000
Teaching subject (compulsory)	120.001	0.041	0.001
Frequency of technology use	83.303	0.017	0.001

Note: N=470, after removing 15 outliers

Table 5 Residuals statistics - Mahalanobis distance score

	Minimum	Maximum	Mean	Std. Deviation
Predicted Value	2.3710	3.8241	3.1918	.21994
Std. Predicted Value	-3.732	2.875	.000	1.000
Standard Error of Predicted Value	.053	.333	.110	.034
Adjusted Predicted Value	2.2954	3.8001	3.1924	.22053
Residual	-1.75861	2.01942	.00000	.89044
Std. Residual	-1.961	2.251	.000	.993
Stud. Residual	-1.984	2.270	.000	1.001
Deleted Residual	-1.80010	2.05227	-.00065	.90530
Stud. Deleted Residual	-1.990	2.280	.000	1.002
Mahal. Distance	.713	65.567	6.986	5.796
Cook's Distance	.000	.035	.002	.003
Cantered Leverage Value	.001	.135	.014	.012

Note: N=470, after removing 15 outliers

Table 6 Comparison of males and females (M±SD) for TPACK subscales (N=470)

TPACK scales	Male (263)	Female (207)	F	Effect size
TK	4.22±0.51	4.03±0.53	14.68*	0.36
CK	4.69±0.41	4.62±0.44	2.64	0.15
PK	4.55±0.43	4.51±0.46	0.76	0.08
PCK	3.94±0.84	3.97±0.92	0.17	0.04
TCK	4.29±0.53	4.21±0.53	2.32	0.14
TPK	4.22±0.57	4.21±0.56	0.05	0.02
TPACK	4.27±0.55	4.29±0.50	0.18	0.04

Note: p < 0.007 (Bonferroni adjustment alpha to reduce Type I error)
Effect size interpretation: small (0.2), medium (0.5), or large (0.8) (Cohen, 1988)

Table 7 Comparison of age categories (M±SD) for TPACK subscales (N=470)

TPACK scales	<35 years	35 to 44	above 44	F	Effect size <35 & 35-44yrs	Effect size 35-44 & >44yrs	Effect size <35 & >44yrs
TK	4.12±0.54	4.16±0.54	4.12±0.49	0.33	-0.08	0.07	-0.01
CK	4.60±0.44	4.66±0.43	4.75±0.38	4.10*	-0.13	-0.22	-0.35*
PK	4.44±0.47	4.58±0.44	4.63±0.38	8.11*	-0.31*	-0.13	-0.45*
PCK	4.01±0.78	3.97±0.92	3.82±0.97	1.67	0.06	0.15	0.22
TCK	4.22±0.54	4.31±0.53	4.24±0.50	1.35	-0.17	0.14	-0.04
TPK	4.15±0.57	4.27±0.57	4.24±0.53	2.31	-0.22	0.07	-0.16
TPACK	4.22±0.50	4.30±0.57	4.34±0.50	2.14	-0.15	-0.08	-0.24

Note: p < 0.007 (Bonferroni adjustment alpha to reduce Type I error)
Effect size interpretation: small (0.2), medium (0.5), or large (0.8) (Cohen, 1988)

Table 8 Comparison of years of teaching experience (M±SD) for TPACK subscales (N=470)

TPACK scales	<5 years	5-10years	>10 years	F	Effect size <5 & 5-10yrs	Effect size 5-10 & >10yrs	Effect size <5 & >10yrs
TK	4.04±0.55	4.21±0.51	4.11±0.52	3.41	-0.33	0.19	-0.15
CK	4.56±0.46	4.65±0.42	4.71±0.41	3.41*	-0.22	-0.14	-0.35*
PK	4.46±0.47	4.52±0.45	4.58±0.43	0.57	-0.13	-0.13	-0.26
PCK	4.04±0.76	3.88±0.91	3.98±0.89	0.66	0.20	-0.12	0.07
TCK	4.21±0.53	4.27±0.52	4.26±0.54	0.47	-0.12	0.02	-0.20
TPK	4.17±0.59	4.22±0.56	4.22±0.56	1.76	-0.09	0.01	-0.09
TPACK	4.16±0.56	4.30±0.49	4.31±0.54	3.41	-0.26	-0.01	-0.26

Note: p < 0.007 (Bonferroni adjustment alpha to reduce Type I error)
Effect size interpretation: small (0.2), medium (0.5), or large (0.8) (Cohen, 1988) (Cohen, 1988)

Table 9 Comparison of frequency of technology use (M±SD) for TPACK subscales (N=470)

TPACK scales	Rare	Frequent	Always	F	Effect size Rare & Frequent	Effect size Rare & Always	Effect size Frequent & Always
TK	3.82±0.53	4.15±0.50	4.37±0.48	26.91*	-0.63*	-1.09*	-0.46*
CK	4.49±0.47	4.68±0.41	4.76±0.40	10.12*	-0.44*	-0.62*	-0.19
PK	4.36±0.50	4.52±0.42	4.70±0.41	13.25*	-0.35*	-0.73*	-0.42*
PCK	4.02±0.67	3.92±0.88	3.96±1.02	0.51	0.14	0.08	-0.05
TCK	3.99±0.53	4.24±0.50	4.51±0.49	24.00*	-0.48*	-1.02*	-0.55*
TPK	3.94±0.60	4.20±0.52	4.47±0.54	21.34*	-0.47*	-0.93*	-0.50*
TPACK	3.98±0.54	4.27±0.49	4.55±0.49	28.99*	-0.57*	-1.10*	-0.56*

Note: p < 0.007 (Bonferroni adjustment alpha to reduce Type I error)
Effect size interpretation: small (0.2), medium (0.5), or large (0.8) (Cohen, 1988)

Table 10 Comparison of teaching subject (M±SD) for TPACK subscales (N=170)

TPACK scales	Dhivehi	English	Math	Islam	F
TK	3.71±0.35	4.13±0.52	4.09±0.53	3.85±0.53	5.171*
CK	4.18±0.41	4.66±0.41	4.58±0.45	4.40±0.47	7.819*
PK	4.17±0.36	4.57±0.43	4.46±0.47	4.42±0.46	4.661*
PCK	3.91±0.48	3.82±0.98	4.12±0.68	4.24±0.61	2.389
TCK	3.76±0.50	4.34±0.48	4.13±0.46	3.99±0.52	9.444*
TPK	3.74±0.49	4.26±0.55	4.07±0.56	3.99±0.37	6.154*
TPACK	3.77±0.44	4.38±0.52	4.09±0.46	4.01±0.49	10.691*

Note: p < 0.007 (Bonferroni adjustment alpha to reduce Type I error)
Sample size for compulsory subjects only

Table 11 Comparison of the Effect sizes for TPACK subscales (N=170)

TPACK scales	Effect size Dhivehi & English	Effect size Dhivehi & Math	Effect size Dhivehi & Islam	Effect size English & Math	Effect size English & Islam	Effect size Math & Islam
TK	-0.97*	-0.85*	-0.30	0.09	0.54	0.45
CK	-1.16*	-0.94*	-0.50	0.17	0.58	0.40
PK	-1.01*	-0.70	-0.61	0.24	0.33	0.08
PCK	0.12	-0.36	-0.61	-0.35	-0.52	-0.19
TCK	-1.19*	-0.79*	-0.45	0.43	0.70*	0.30
TPK	-1.01*	-0.63	-0.58	0.34	0.59	0.18
TPACK	-1.26*	-0.70	-0.51	0.60*	0.74*	0.16

Note: Effect size interpretation: small (0.2), medium (0.5), or large (0.8) (Cohen, 1988)
Sample size for compulsory subjects only

Table 12 Comparison of nationalities (M±SD) for TPACK subscales (N=465)

TPACK scales	Maldivian (166)	Indian (299)	F	Effect size
TK	3.87±0.52	4.28±0.47	73.98*	-0.82
CK	4.42±0.47	4.79±0.34	92.66*	-0.90
PK	4.31±0.47	4.66±0.38	75.45*	-0.82
PCK	3.93±0.76	3.97±0.94	0.29	-0.05
TCK	4.02±0.52	4.39±0.49	57.95*	-0.73
TPK	3.94±0.54	4.37±0.52	67.77*	-0.79
TPACK	4.01±0.49	4.43±0.49	79.50*	-0.86

Note: p < 0.007 (Bonferroni adjustment alpha to reduce Type I error)
Effect size interpretation: small (0.2), medium (0.5), or large (0.8) (Cohen, 1988)
Sri Lankan nationality group excluded due to its small sample size (n = 6)