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The Implementation of TPACK in Bosnian Classrooms

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Abstract

TPACK, an abbreviation for "Technological Pedagogical Content Knowledge," is a theoretical framework emphasizing teachers' skills to integrate technology into their classrooms effectively. According to Shulman (1986), these skills hold great value. This study explores technological, pedagogical, and content knowledge (TPACK) based on variables such as teachers' gender, experience, level of education, GPA (Grade Point Average), and type of education. A survey method was employed to collect data, and participants were selected via the snowball sampling technique. The research revealed no significant differences between genders within the TPACK model. However, differences were observed in teachers' experience concerning pedagogical knowledge, content knowledge, technological content knowledge, pedagogical content knowledge, and technological pedagogical knowledge. Participants with higher degrees demonstrated better performance in technological, pedagogical, and content knowledge areas. Additionally, those with a GPA in the range of 7.5 to 8.4 performed better in technology knowledge, content knowledge, and technological pedagogical knowledge. Finally, the study found the highest performance in technological pedagogical knowledge among teachers at both public and private universities. These findings suggest that resources should be allocated to organize workshops, enhance classroom technologies, and adapt the curriculum to meet teachers' needs effectively.

Keywords: TPACK, technology integration, GPA, gender, education.

1. Introduction

Teaching and learning processes have been notably evolving due to technological advancements. Teachers are increasingly required to transition from traditional teaching practices to more functional, unpredictable, and demanding technologies (Koehler, Mishra, 2009). One model used to better understand these processes and teachers' competencies is TPACK, which stands for the Technological Pedagogical Content Knowledge Framework (Koehler et al., 2014; Mishra, Koehler, 2006; Niess et al., 2018). Initially conceptualized by Mishra and Koehler (2006),

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TPACK builds on the foundational work of Shulman (1986). According to this model, the three key pillars of a teacher's knowledge are technological, pedagogical, and content knowledge (Koehler, Mishra, 2009). It is essential to consider the interactions between these components, such as PK (pedagogical knowledge), TCK (technological content knowledge), TPK (technological pedagogical knowledge), and TPACK (Koehler et al., 2014; Koehler, Mishra, 2009; Mishra, Koehler, 2006; Niess et al., 2018). The integrated blend of CK (content knowledge), PK (pedagogical knowledge), PCK (pedagogical content knowledge), TK (technological knowledge), TCK (technological content knowledge), TPK (technological pedagogical knowledge), and TPCK (technological, pedagogical, and content knowledge) forms the TPACK framework (Koehler, Mishra, 2009).

To understand its relevance, particularly in the context of teaching and learning in Bosnia and Herzegovina, it is crucial to highlight the digital transformation schools underwent during the COVID-19 pandemic (Nousopoulou et al., 2022). As stated by Canan Güngören and Isman (2014), it was teachers' responsibility to train "digital citizens," and many educators in the Western Balkans had to face the challenges of effectively using technologies with little experience (Bećirović, 2023; Nousopoulou et al., 2022). To achieve their educational goals, teachers relied on their initiative and active involvement in the teaching and learning processes. What this framework offers is both a way to identify the weak points and a wide array of resources and opportunities for educators to facilitate digitalization in the post-COVID period (Bećirović, 2023). Additionally, it recognizes the complex nature of teaching and fosters a relationship between digital competencies and TPACK elements (Çebi et al., 2022; Demeshkant et al., 2022).

Therefore, the purpose of this study is to provide insights into the factors affecting the integration of TPACK components within the Bosnian educational context. Since there are not many studies done in this area, and Bosnia is undergoing the process of modernization, the researchers found a research gap that can be filled with the current analysis. The research aims to understand trends based on specific variables like gender, age, experience, and GPA (Grade Point Average), providing valuable information on the challenges and opportunities that shape teachers' technological practices in a digital environment.

2. Literature Review

TPACK stands for "Technological Pedagogical Content Knowledge," a theory addressing teachers' capabilities to integrate technology into education and learning. It is important to define certain aspects of TPACK. One of them is pedagogical content knowledge (PCK) (Shulman, 1986). Pedagogical content knowledge (PCK) is based on the idea that teaching requires more than delivering subject content knowledge to students and that student learning is more than passively absorbing information. The second is content knowledge (CK). Content knowledge is a theoretical construct that describes the knowledge teachers need to carry out their work as teachers of a particular subject matter. This knowledge goes beyond merely understanding the subject itself. According to Shulman (1986), both PCK and CK are crucial for teacher effectiveness. CK relates to teachers' knowledge of the subject area (Shulman, 1986), while PCK, on the other hand, relates to teachers' "knowledge [of the subject] for teaching" (Shulman, 1986: 9).

Both Shulman (1986) and Mishra and Koehler (2006) concluded that the integration of ICT (Information and Communications Technology) has significant advantages and is effective for both teachers and students. TK (Technological Knowledge) relates to how teachers understand and operate the technologies used in education. PK (Pedagogical Knowledge) relates to their understanding of methods and conditions for applying these technologies, and lastly, CK (Content Knowledge) relates to the understanding of the subject matter (Shulman, 1986). Ghavifekr and Rosdy (2015) conducted quantitative research in Malaysia among 101 teachers from public secondary schools to investigate the effectiveness of ICT integration, professional development, and its role in ensuring quality student learning.

In addition, Gómez-Trigueros and Yáñez de Aldecoa (2021) conducted an exploratory and descriptive study on the differences between genders, focusing on the digital competencies of both pre-service and experienced teachers. Three different questionnaires were administered to analyze the perceptions of the groups mentioned above, and the third questionnaire was used to analyze self-perceptions of methodologies involving technology. Female participants showed low self-perception, including a lower predisposition toward technologies, indicating that tools should be inclusive for both males and females.

Similarly, Abubakir and Alshaboul (2023) examined TPACK among EFL teachers in Qatar. The study included 182 teachers and showed that teachers' knowledge across all TPACK constructs was high. Male teachers scored higher in technological knowledge than female teachers. Teachers with 1 to 5 years of experience showed the highest level of technological knowledge. Mohamad's (2021) research highlights that teachers with considerable teaching experience exhibit greater confidence in their CK (Content Knowledge), PK (Pedagogical Knowledge), and PCK (Pedagogical Content Knowledge). In contrast, novice teachers reported slightly higher confidence in their TK (Technological Knowledge).

Moreover, a study conducted by Castéra et al. (2020) empirically selected seven elements of TPACK and examined their effects based on national context, gender, age, and level of education. The validity of the TPACK seven-model framework was tested since there was no previous cross-national data. A total of 574 teachers participated in the online research. The relative stability of the model was proven, as well as the differences among university teachers across six countries in Asia and Europe. Age and TPACK factors were dependent, whereas academic level and TPACK factors were independent.

Likewise, Bozkurt (2014) carried out a study to investigate whether there was a significant relationship between academic achievement and TPACK levels among physics and science teachers and whether TPACK levels significantly predicted academic achievement. Significant results favored physics teachers regarding their academic achievements and TPACK attitudes. Shafie et al. (2023) found that the highest educational qualifications significantly influenced 21st-century Technological Pedagogical Content Knowledge (TPACK) levels, whereas teaching experience did not.

Furthermore, Katechaiyo (2021) conducted a study in a private school based on the TPACK model. The sample size included 431 private schools, and a questionnaire was used as the research method. Descriptive statistics, including frequency, mean, standard deviation, and percentage, were used to analyze the data. The results showed the desirable status and implementation of the TPACK model, especially in productive pedagogies and supportive classroom environments. The analysis of TPACK indicated the highest level of content knowledge, followed by technological knowledge.

Additionally, Mercado and Ibarra (2019) performed a study investigating the TPACK self-efficacy and ICT integration skills of 52 pre-service teachers. The participants perceived themselves as highly proficient in all areas of the TPACK model. The study also revealed a significant negative relationship between their GPA scores and the implementation of ICT-integrated instruction in the classroom environment.

Moreover, Adalar (2021) conducted research examining social studies teachers' self-efficacy beliefs regarding TPACK through a causal-comparative study using non-random sampling methods. Their knowledge of TPACK was found to be above average. There were no significant differences between their self-efficacy beliefs regarding TPACK and independent variables such as gender, GPA scores, computer ownership, and various courses.

Likewise, Alharbi (2020) aimed to explore EFL teaching knowledge according to the TPACK framework in Saudi Arabia. The study was descriptive and included 191 EFL teachers. The researcher found that the degree of teaching knowledge was high, as was the difference between male and female teachers, with results favoring female teachers.

To assess digital literacy (TPACK) and teaching performance, Muslimin et al. (2023) conducted a study among EFL lecturers from different universities in various cities in East Java Province, Indonesia. They found that participants were confident about their pedagogical and content knowledge. Additionally, Nazari et al. (2019) undertook a quantitative study applying the TPACK framework to evaluate novice and experienced EFL teachers' perceived TPACK for professional development. The participants were selected from various English language institutes in Tehran. The results showed that experienced teachers had significantly higher scores in pedagogical knowledge and pedagogical content knowledge. In contrast, novice teachers demonstrated significantly higher scores in technological knowledge, technological content knowledge, technological pedagogical knowledge, and overall TPACK.

When it comes to Bosnia and Herzegovina, no similar studies have been conducted; thus, this paper seeks to address this gap in the existing literature. The research hypotheses are:

1. There is no significant statistical difference in TPACK (technological knowledge, pedagogical knowledge, content knowledge, technological content knowledge, pedagogical content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge) based on the instructors' gender.

2. There will be significant differences in TPACK (technological knowledge, pedagogical knowledge, content knowledge, technological content knowledge, pedagogical content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge) based on instructors' experience.

3. There will be a significant difference in TPACK (technological knowledge, pedagogical knowledge, content knowledge, technological content knowledge, pedagogical content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge) based on the instructors' level of education.

4. There will be a statistical difference in TPACK (technological knowledge, pedagogical knowledge, content knowledge, technological content knowledge, pedagogical content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge) based on the instructors' GPA.

5. There will be significant differences in TPACK (technological knowledge, pedagogical knowledge, content knowledge, technological content knowledge, pedagogical content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge) based on the type of education.

3. Methodology

Participants

The research sample of the current study involved 152 participants, who were teachers or professors at the primary or secondary level, as well as university professors (Table 1). The snowball sampling method was used to select the participants through social networks such as Facebook, Instagram, and Gmail, and instant messaging applications like Viber and WhatsApp, in the quantitative research. The research sample consisted of 77 teachers (50.7 %) with bachelor's degrees, 72 teachers (47.3 %) with master's degrees, and 3 teachers (2 %) with PhD degrees. In addition, these participants, who teach in both private (N = 33; 21.7 %) and public (N = 119; 78.3 %) sectors, also work in different teaching contexts such as language courses (N = 34; 22.4 %), elementary schools (N = 102; 67.1 %), secondary schools (N = 43; 28.3 %), and universities (N = 8; 5.3%). The participants' ages ranged from 20 to 64. There were 114 female participants (75 %) and 38 male participants (25 %). The selected participants teach in Bosnia and Herzegovina. Table 1 represents a descriptive analysis of this selected group.

Table 1. Descriptive analysis of participants

Categories	Classification	N	Percent
Gender	Male	38	25
	Female	114	75
Level of Education	University	77	50.7
	Master	72	47.4
	PhD	3	2
University Type	Private	36	23.7
	State	114	75
	Both	2	1,4
Teaching Position	Language Courses	34	22.4
	Elementary school	102	67.1
	Secondary school	43	28.3
	University	8	5.3
Teaching in	Private sector	33	21.7
	Public sector	119	78.3
Total		152	100.0

Measures

The survey method was used to collect the data, which was divided into two parts. The first part provided information about the demographic characteristics of the respondents, such as gender, age, GPA, level of education, years of teaching, information about the diploma and university, current teaching position, and the average class size. The second part focuses on the TPACK elements validated by Schmidt et al. (2009), and the questionnaire items were based on a

4-point Likert scale ranging from 1 = strongly disagree to 4 = strongly agree. For example, "I feel confident learning new computer skills" and "I find it easier to teach by using ICT."

Cronbach's alpha was used to determine the data's reliability, indicating acceptable and high internal consistency levels for TPACK elements. The results indicated that technology knowledge exhibited a reliability coefficient of α = 0.935, closely followed by pedagogy knowledge with a reliability of α = 0.948. Content knowledge demonstrated a reliability of α = 0.938, while technological content knowledge had a reliability of α = 0.894. The reliability for pedagogical content knowledge was α = 0.890, and for technological pedagogical knowledge, it was α = 0.891. Lastly, the reliability for technological pedagogical, and content knowledge was α = 0.943.

Procedures

Informed consent was obtained from the participants, after which the researchers informed them about the research goals, anonymity, and confidentiality. The participants completed the online survey using Google Forms, which was distributed through various online networks. They were asked to read the questions carefully and provide the answers that best fit their opinions. The participants took 20 minutes to answer the questions. They were also encouraged to contact the researchers via email if they had any questions or recommendations.

Data analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS) version 23.0. The first step in this process was to check for missing values and outliers. Internal consistency was determined using Cronbach's alpha coefficient. A T-test was performed to test the first hypothesis. The second, third, fourth, and fifth hypotheses were tested using one-way ANOVA.

4. Results

Preliminary analysis

Skewness and kurtosis were assessed before hypothesis testing to ensure that all observed variables adhered to a normal distribution within the ranges of -2 to +2. The results in Table 2 indicate that teachers felt moderately confident about their technology knowledge, with a mean (M = 3.55, SD = 0.85), which was the lowest score recorded in the study. The findings also revealed that teachers expressed a high level of satisfaction with their pedagogical knowledge, with a mean of 4.06 and a standard deviation of 0.79. Teachers then scored similarly on content knowledge (M = 3.78, SD = 0.80). The situation was similar with technological content knowledge (M = 3.72, SD = 0.76). Teachers demonstrated a marginally higher score in pedagogical content knowledge (M = 3.81, SD = 0.78). They exhibited similar proficiency in technological pedagogical knowledge (M = 3.77, SD = 0.74). Furthermore, scores for technological pedagogical content knowledge were comparable (M = 3.78, SD = 0.75), showing no significant differences. Correlation analyses indicated a significant positive relationship among all dependent variables ($p < 0.001$). The relationships between dependent variables are presented in Table 2.

Table 2. Descriptive results and correlation

	N	M	SD	1	2	3	4	5	6	7	Sig. (2-tailed)	Skewness	Skewness	Kurtosis	Kurtosis
												Stat	SE	Stat	SE
1. TK	151	3.56	.86	1	.569	.569	.682	.567	.605	.650	.000	-.323	.197	-.312	.392
2. PK	151	4.06	.80	.569	1	.627	.544	.680	.659	.656	.000	-1.091	.197	1.347	.392
3. CK	151	3.78	.81	.569	.627	1	.689	.709	.505	.597	.000	-.619	.197	.097	.392
4. TCK	151	3.73	.76	.682	.544	.689	1	.697	.631	.652	.000	-.728	.197	.763	.392
5. PCK	151	3.81	.78	.567	.680	.709	.697	1	.722	.751	.000	-.930	.197	1.212	.392

6. TPK	151	3.77	.74	.605	.659	.505	.631	.722	1	.839	.000	-.710	.197	.845	.392
7. TPCK	151	3.78	.75	.650	.656	.597	.652	.751	.839	1	.000	-.745	.197	.726	.392
Total N	151														

Shapiro-Wilk tests

Shapiro-Wilk tests were conducted to assess normality within each group for each variable. The Shapiro-Wilk test results indicate that most knowledge domains are not normally distributed, particularly for Gender 2 (n = 114), where all p-values are below 0.05, such as Pedagogical knowledge (p = 0.000), Content knowledge (p = 0.000), and Technological pedagogical and content knowledge (p = 0.000), confirming significant deviation from normality. For Gender 1 (n = 37), normality is observed only in Technology knowledge (p = 0.270) and Content knowledge (p = 0.320), while other domains like Pedagogical knowledge (p = 0.021) and Technological content knowledge (p = 0.022) also show non-normality.

The Shapiro-Wilk normality test reveals that most knowledge domains are not normally distributed in several GPA subgroups, particularly GPA levels 3 and 4. Notable violations of normality include Pedagogical knowledge (GPA 3: p = 0.001; GPA 4: p = 0.000), Technological content knowledge (GPA 3: p = 0.000), and Technological pedagogical and content knowledge (GPA 2: p = .018; GPA 4: p = 0.006). Only GPA groups 0 and 5 consistently show normal distribution across most domains.

The Shapiro-Wilk normality test shows the same results for level of education and type of university.

The Levene's Test

The Levene's Test for homogeneity of variances across all knowledge domains yielded non-significant p-values (all Sig. > 0.05), such as Technology knowledge (p = 0.613), Content knowledge (p = 0.737), and Technological pedagogic knowledge (p = 0.965), indicating that the assumption of equal variances is met for all variables. Therefore, using one-way ANOVA for comparing group means across these knowledge domains is statistically appropriate in terms of variance homogeneity.

TPACK based on the instructors' gender

An independent T-test was performed to examine the TPACK model based on the instructors' gender.

The results of the T-test, namely t (149) = 0.507 and p = 0.613, show no significant differences. The findings indicated that there were no significant differences between males (M = 3.62; SD = 0.86) and females (M = 3.53; SD = 0.86) in technology knowledge.

Next, an independent sample t-test was carried out to check pedagogical knowledge between the genders. The findings showed that there were no significant differences between males (M = 4.00; SD = 0.68) and females (M = 4.08; SD = 0.82), t(149) = -.337, p = 0.614.

Similarly, there were no significant differences between males (M = 3.74; SD = 0.65) and females (M = 3.79; SD = 0.85) in terms of content knowledge. The results of the T-test indicate no significant findings, with t(149) = -0.337 and p = 0.737. A similar outcome was observed for the technological content variable. As such, there were no significant differences between males (M = 3.77; SD = 0.80) and females (M = 3.71; SD = 0.75). The results of the T-test indicated insignificance, as seen t(149) = 0.444, p = 0.658.

In addition, no significant difference was found in pedagogical content knowledge between males (M = 3.85; SD = 0.73) and females (M = 3.79; SD = 0.79), as indicated by the T-test results, t(149) = -.043, p = 0.676. A similar outcome was observed for technological pedagogical knowledge, with males (M = 3.76; SD = 0.66) and females (M = 3.77; SD = 0.76), where the T-test also showed no significant difference, namely, t(149) = 0.942p = 0.965.

Lastly, the independent T-test was also carried out for the technological pedagogical, and content knowledge variables and showed that there were no significant differences in usage between males (M = 3.88; SD = 0.66) and females (M = 3.74; SD = 0.77). The results of the T-test indicated insignificance, as shown by t(149) = 0.942, p = 0.348, as seen in Table 3.

Table 3. TPACK based on the instructors' gender

		F	Sig.	t	df	Sig. (2-tailed)	MD	SE
Technology knowledge	Equal variances assumed	.086	.770	.507	149	.613	.08277	.16312
	Equal variances not assumed			.506	60.919	.614	.08277	.16343
Pedagogical knowledge	Equal variances assumed	1.560	.214	-.506	149	.614	-.07624	.15079
	Equal variances not assumed			-.556	72.698	.580	-.07624	.13722
Content knowledge	Equal variances assumed	2.275	.134	-.337	149	.737	-.05149	.15296
	Equal variances not assumed			-.385	79.188	.701	-.05149	.13368
Technological content knowledge	Equal variances assumed	.123	.726	.444	149	.658	.06431	.14489
	Equal variances not assumed			.429	57.830	.670	.06431	.15000
Pedagogical content knowledge	Equal variances assumed	.265	.607	.419	149	.676	.06206	.14828
	Equal variances not assumed			.435	65.312	.665	.06206	.14269
Technological pedagogical knowledge	Equal variances assumed	.570	.452	-.043	149	.965	-.00612	.14064
	Equal variances not assumed			-.047	70.158	.963	-.00612	.13028
Technological pedagogical content knowledge	Equal variances assumed	2.067	.153	.942	149	.348	.13395	.14222

		F	Sig.	t	df	Sig. (2-tailed)	MD	SE
	Equal variances not assumed			1.020	70.537	.311	.13395	.13138

TPACK based on instructors' experience

A one-way ANOVA was performed to assess the TPACK model based on the instructors' experience. The results of the ANOVA between and within groups were not statistically significant and based on a total sample of 150 participants, as indicated by F(28,122) = 1.174, p == 0.271. The findings showed that there were no significant differences in technology knowledge between instructors with 15 years of experience (M = 3.76; SD = 0.95) and those with 2 years of teaching experience (M = 3.89; SD = 1.05).

Next, a one-way ANOVA was conducted to test the pedagogical knowledge between groups who had more or less than 15 years of teaching experience. The results of the ANOVA performed between and within groups indicated that there is no statistically significant difference based on the total sample size of 150, with F(28,122) = 1.303 and p = 0.165. The findings showed that instructors with more teaching experience (M = 4.45; SD = 0.43) performed better in pedagogical knowledge than those with fewer years of experience (M = 4.14; SD = 0.88).

Teachers with more years of teaching experience (M = 4.47; SD = 0.20) performed better in content knowledge than teachers with fewer years of teaching experience (M = 3.72; SD = 0.47). The ANOVA results indicated a statistically insignificant level of 0.567, based on a total of 150 observations, with F(28, 122) = 0.933 and p = 0.567. The situation is similar to technological content knowledge (M = 4.00; SD = 0.35) (M = 3.71; SD = 0.65). The analysis of variance (ANOVA) conducted between and within groups indicated no significant findings, based on a total sample size of 150 participants, with results showing F(28,122) = 1.333 and p = 0.145.

Following this, there was a difference in pedagogical content knowledge between participants with more years of teaching experience (M = 4.20; SD = 0.44) and those with less experience (M = 3.82; SD = 0.64). The results of the ANOVA conducted both between and within groups indicated no significant findings based on a total of 150 observations, as evidenced by F(28,122) = 1.440, p = 0.091. The situation is similar with technological pedagogical knowledge (M = 4.20; SD = 0.58) (M = 3.85; SD = 0.63).

The test conducted on technological pedagogical, and content knowledge indicated that there is no statistically significant difference between the two groups: those with more years of teaching experience and those with less. The data support this finding, with means and standard deviations recorded as (M = 4.29; SD = 0.61) for the more experienced group and (M = 4.12; SD = 0.35) for the less experienced group. Furthermore, the results of the ANOVA analysis, both between and within groups, revealed no significance based on the total of 150, as presented with F(28,122) = 1.348, p = 0.136, as shown in Table 4.

Table 4. TPACK based on instructors' experience

		Sum of squares	df	Mean Square	F	Sig.
Technology knowledge	Between groups	23.547	28	.841	1.174	.271
	Within groups	87.390	122	.716		
	Total	110.936	150			
Pedagogical knowledge	Between groups	21.826	28	.779	1.303	.165
	Within groups	72.980	122	.598		

		Sum of squares	df	Mean Square	F	Sig.
	Total	94.806	150			
Content knowledge	Between groups	17.191	28	.614	.933	.567
	Within groups	80.259	122	.658		
	Total	97.450	150			
Technological content knowledge	Between groups	20.502	28	.732	1.333	.145
	Within groups	66.990	122	.549		
	Total	87.493	150			
Pedagogical content knowledge	Between groups	22.754	28	.813	1.440	.091
	Within groups	68.867	122	.564		
	Total	91.621	150			
Technological pedagogical knowledge	Between groups	16.312	28	.583	1.077	.377
	Within groups	66.011	122	.541		
	Total	82.323	150			
Technological pedagogical content knowledge	Between groups	20.013	28	.715	1.348	.136
	Within groups	64.673	122	.530		
	Total	84.686	150			

TPACK based on the instructors’ level of education

A one-way ANOVA was performed to check the TPACK model based on the instructors’ level of education. There were two groups of teachers: 77 teachers (50.7 %) with bachelor’s degrees, and 72 teachers (47.3 %) with master's degrees. The findings showed similar results between teachers with master’s degrees ($M = 3.61$; $SD = 0.88$) and teachers with bachelor's degrees ($M = 3.49$; $SD = 0.85$). The results of the ANOVA conducted both between and within groups indicated no significant findings based on the total sample size of 150, with $F(2, 148) = 0.855$ and $p = 0.427$.

Next, a one-way ANOVA was carried out to check pedagogical knowledge across different levels of education. The findings indicated no significant difference between teachers with master’s degrees ($M = 4.08$; $SD = 0.77$) and teachers with bachelor's degrees ($M = 4.04$; $SD = 0.83$). The ANOVA results showed no significant difference between and within the groups as seen with $F (2.148) = 0.113$, and $p = .893$, based on a total of 150 participants.

Teachers with master's degrees demonstrate a comparable level of content knowledge to those with bachelor's degrees, as indicated by the means (M = 3.78, SD = 0.78 for master's degrees and M = 3.77, SD = 0.83 for bachelor's degrees). The ANOVA results, both between and within groups, indicated no significance based on the total of 150, as evidenced by F(2, 148) = 0.270 and p = 0.764. The situation is similar with technological content knowledge as well, master (M = 3.77; SD = 0.70), and bachelor (M = 3.67; SD = 0.82). The results of the ANOVA between and within groups show insignificance based on the total 150, as seen in F(2.148) = 0.507, p = 0.603.

Following this, there was a difference in pedagogical content knowledge between master's degrees (M = 3.83; SD = 0.73), and bachelor's degrees (M = 3.77; SD = 0.84). The results of the ANOVA between and within groups show insignificance based on the total 150, as seen in F(2.148) = 0.186, p = 0.830. The situation is similar with technological pedagogical knowledge between master's degree teachers (M = 3.85; SD = 0.73) and bachelor's degree teachers (M = 3.67; SD = 0.73). The results of the ANOVA conducted both between and within groups indicated no significant difference based on the total of 150, as demonstrated by F(2.148) = 1.885, p = 0.155.

Lastly, the assessment conducted on technological pedagogical, and content knowledge revealed comparable outcomes between teachers holding master's degrees (M = 3.84; SD = 0.75) and those with bachelor's degrees (M = 3.69; SD = 0.75). The results of the ANOVA between and within groups show insignificance based on the total 150, as seen in F(2.148) = 1.418, p = 0.245, as seen in Table 5.

Table 5. TPACK based on the instructor's level of education

		Sum of squares	df	Mean Square	F	Sig.
Technology knowledge	Between groups	1.267	2	.634	.855	.427
	Within groups	109.669	148	.741		
	Total	110.936	150			
Pedagogical knowledge	Between groups	.145	2	.073	.113	.893
	Within groups	94.660	148	.640		
	Total	94.806	150			
Content knowledge	Between groups	.354	2	.177	.270	.764
	Within groups	97.096	148	.656		
	Total	97.450	150			
Technological content knowledge	Between groups	.595	2	.298	.507	.603
	Within groups	86.897	148	.587		
	Total	87.493	150			
Pedagogical content knowledge	Between groups	.230	2	.115	.186	.830

		Sum of squares	df	Mean Square	F	Sig.
	Within groups	91.391	148	.618		
	Total	91.621	150			
Technological pedagogical knowledge	Between groups	2.045	2	1.023	1.885	.155
	Within groups	80.278	148	.542		
	Total	82.323	150			
Technological pedagogical content knowledge	Between groups	1.593	2	.796	1.418	.245
	Within groups	83.094	148	.561		
	Total	84.686	150			

TPACK based on instructors' GPA

One-way ANOVA was performed to check the TPACK model based on the instructors' GPA (Grade Point Average). There were 5 groups of teachers based on their GPA, ranging from 6 to 10. Next, there were 19 teachers in the range from 6 to 6.4. Next, 40 teachers are in the range from 6.5 to 7.4. There were 49 teachers in the range from 7.5 to 8.4, and 35 teachers in the range from 8.5 to 9.4. Lastly, there were 2 teachers in the GPA range of 9.5 to 10. Teachers with GPAs between 7.5 and 8.4 demonstrated higher performance in technology knowledge (M = 3.94; SD = 0.76) compared to those in other GPA groups. The subsequent group, consisting of teachers with GPAs from 9.5 to 10, had a mean of (M = 3.78; SD = 1.11). Conversely, the lowest performance was observed among teachers with GPAs ranging from 6 to 7.4 (M = 3.30; SD = 0.84) (M = 3.30; SD = 0.82). The results of the ANOVA conducted both between and within groups indicate statistical significance, as evidenced by the total of 150, with F(5.145) = 3.673 and p = 0.004.

Next, one-way ANOVA was done to check pedagogical knowledge between the different levels of education. The results of the ANOVA between and within groups showed significance based on the total 150, as seen in F(5.145) = 3.104, p = 0.011. The findings showed that the situation was similar to the previous one, where those with GPAs from 7.5 to 8.4 had the best results (M = 4.35; SD = 0.52), and those with (6 to 6.4) the lowest (M = 3.35; SD = 1.05).

Teachers with GPAs ranging from 7.5 to 8.4 exhibited better content knowledge (M = 4.06; SD = 0.69) compared to their peers. In contrast, those in the range (9.5 to 10) demonstrated the lowest content knowledge (M = 2.70; SD = 1.47). The results of the ANOVA between and within groups showed significance based on the total 150, as seen in F(5.145) = 3.200, p = 0.009. The situation is not similar with technological content knowledge because those in the range (9.5 to 10) (M = 4.37; SD = 0.88) had the best knowledge, then those in the range (7.5 to 8.4) (M = 3.90; SD = 0.64), and the group (6.5 to 7.4) had the lowest score (M = 3.50; SD = 0.84). The results of the ANOVA between and within groups show insignificance based on the total 150, as seen F(5.145) = 1.853, p = 0.106.

Following this, there was a difference in pedagogical content knowledge between those in the range (7.5 to 8.4) (M = 4.11; SD = 0.60), then those (6.5 to 7.4) (M = 3.72; SD = 0.82), and the lowest among those (9,5 to 10) (M = 3.12; SD = 1.23). The results of the ANOVA between and within groups show significance based on the total 150, as seen in F(5.145) = 2.722, p = 0.022. As for technological pedagogical knowledge, again, (7.5 to 8.4) (M = 4.07; SD = 0.56) showed better results than (8.5 to 9.4) (M = 3.86; SD = 0.86,) and the lowest were (6 to 6.4) (M = 3.36; SD

= 0.62). The results of the ANOVA between and within groups showed significance based on the total 150, as seen in $F(5.145) = 4.179$, $p < 0.001$.

Lastly, the test was done with technological pedagogical and content knowledge and showed that those with (7.5 to 8.4) had better results ($M = 4.12$; $SD = 0.62$), (8.5 to 9.4) ($M = 3.74$; $SD = 0.80$), and (6 to 6.4) ($M = 3.34$; $SD = 0.80$). The results of the ANOVA between and within groups show significance based on the total 150, as seen in $F(5.145) = 4.207$, $p < 0.001$, as seen in Table 6.

Table 6. TPACK based on instructors' GPA

		Sum of squares	df	Mean Square	F	Sig.
Technology knowledge	Between groups	12.471	5	2.494	3.673	.004
	Within groups	98.465	145	.679		
	Total	110.936	150			
Pedagogical knowledge	Between groups	9.165	5	1.833	3.104	.011
	Within groups	85.640	145	.591		
	Total	94.806	150			
Content knowledge	Between groups	9.685	5	1.937	3.200	.009
	Within groups	87.765	145	.605		
	Total	97.450	150			
Technological content knowledge	Between groups	5.255	5	1.051	1.853	.106
	Within groups	82.237	145	.567		
	Total	87.493	150			
Pedagogical content knowledge	Between groups	7.862	5	1.572	2.722	.022
	Within groups	83.759	145	.578		
	Total	91.621	150			
Technological pedagogical knowledge	Between groups	10.368	5	2.074	4.179	.001
	Within groups	71.955	145	.496		
	Total	82.323	150			

		Sum of squares	df	Mean Square	F	Sig.
Technological pedagogical content knowledge	Between groups	10.729	5	2.146	4.207	.001
	Within groups	73.957	145	.510		
	Total	84.686	150			

TPACK based on the type of education

One-way ANOVA was performed to check the TPACK model based on the instructors' type of education. The analysis included three groups instead of there were three groups: instructors who studied at public universities, those who studied at private universities, and both. The findings showed that those who studied at both universities had better results (M = 3.92; SD = 0.10) than the other two groups, public universities (M = 3.59; SD = 0.83) and private universities (M = 3.40; SD = 0.94) in technology knowledge. The results of the ANOVA conducted between and within groups indicate no significant findings, with a total sample size of 150, as demonstrated by $F(2.148) = 0.825$, $p = 0.440$.

Next, a one-way ANOVA was conducted to examine the differences in pedagogical knowledge across the various types of education. The findings showed that those who studied at public universities showed slightly better results (M = 4.09; SD = 0.79) than those who studied at private universities (M = 3.97; SD = 0.81). The results of the ANOVA between and within groups showed insignificance based on the total 150, as seen in $F(2.148) = .322$, $p = 0.725$.

Teachers who studied at public universities had better content knowledge (M = 3.86; SD = 0.79) than teachers who studied at private universities (M = 3.54; SD = 0.80). The results of the ANOVA between and within groups showed no significance based on the total 150, as seen in $F(2.148) = 2.379$, $p = 0.096$. The situation is similar with technological content knowledge as well, between public universities (M = 3.77; SD = 0.73) and private universities (M = 3.61; SD = 0.53). The results of the ANOVA between and within groups showed no significance based on the total 150, as seen in $F(2.148) = 1.239$, $p = 0.293$.

Following this, there was a difference in pedagogical content knowledge between teachers who studied at public universities (M = 3.86; SD = 0.75) and teachers who studied at private universities (M = 3.66; SD = 0.87). The results of the ANOVA between and within groups show no significance based on the total 150, as seen in $F(2.148) = 1.336$, $p = 0.266$. As for technological pedagogical knowledge, those who studied at both universities had the highest scores (M = 3.90; SD = 0.14). The results of the ANOVA between and within groups show no significance based on the total 150, as seen in $F(2.148) = 0.476$, $p = 0.622$.

Lastly, the test was done with technological, pedagogical, and content knowledge and showed that those who studied at public universities had better results (M = 3.80; SD = 0.72) than those who studied at private universities (M = 3.70; SD = 0.87). The results of the ANOVA between and within groups showed no significance based on the total 150, as seen in $F(2.148) = 0.242$, $p = 0.786$, as seen in Table 7.

Table 7. TPACK based on the type of education

		Sum of squares	df	Mean Square	F	Sig.
Technology knowledge	Between groups	1.223	2	.612	.825	.440
	Within groups	109.713	148	.741		

	Total	110.936	150			
Pedagogical knowledge	Between groups	.411	2	.205	.322	.725
	Within groups	94.395	148	.638		
	Total	94.806	150			
Content knowledge	Between groups	3.036	2	1.518	2.379	.096
	Within groups	94.414	148	.638		
	Total	97.450	150			
Technological content knowledge	Between groups	1.441	2	.720	1.239	.293
	Within groups	86.052	148	.581		
	Total	87.493	150			
Pedagogical content knowledge	Between groups	1.625	2	.813	1.336	.266
	Within groups	89.996	148	.608		
	Total	91.621	150			
Technological pedagogical knowledge	Between groups	.526	2	.263	.476	.622
	Within groups	81.797	148	.553		
	Total	82.323	150			
Technological pedagogical content knowledge	Between groups	.276	2	.138	.242	.786
	Within groups	84.411	148	.570		
	Total	84.686	150			

5. Discussion

The primary aim of this study was to examine Technological Pedagogical Content Knowledge (TPACK) among educators in Bosnia. Several significant aspects were addressed, including TPACK about the instructor's gender, professional experience, educational attainment, grade point average (GPA), and the nature of their academic background.

The study found no significant difference between genders in technology knowledge, pedagogical knowledge, content knowledge, pedagogical content knowledge, and technological pedagogical and content knowledge. These results contrast with Alharbi's (2020) study, which favored female teachers. However, the findings are in line with Gómez-Trigueros and Yáñez de Aldecoa (2021), where female participants showed a lower predisposition towards technology use. Additionally, the results differ from Abubakir and Alshaboul's (2023) study on TPACK among EFL teachers in Qatar, where male teachers scored higher in technological knowledge than their female counterparts.

The study also found no significant difference in technology knowledge with more or less than 15 years of teaching experience. However, those with over 15 years of teaching experience performed better than those with only two years of experience in pedagogical knowledge, content knowledge, technological content knowledge, pedagogical content knowledge, and technological pedagogical knowledge. No significant difference was observed between the groups in technological pedagogical, and content knowledge. These findings differ from Nazari et al. (2019) study, which showed different results, especially in technology knowledge, content knowledge, technological content knowledge, technological pedagogical knowledge, and TPACK. Abubakir and Alshaboul's (2023) study on TPACK among EFL teachers is in contrast to this because teachers with 1 to 5 years of experience scored at the highest level of technological knowledge. Additionally, it contrasts with Mohamad's (2021) research, which highlights that teachers with considerable teaching experience exhibit greater confidence in their CK, PK, and PCK. In contrast, novice teachers express slightly higher confidence in their TK.

The study also revealed comparable outcomes between individuals possessing master's degrees and those holding bachelor's degrees in the field of education. There was no significant disparity in pedagogical knowledge between the two groups. However, differences were observed between the groups in terms of content knowledge and pedagogical knowledge. Participants with advanced degrees demonstrated superior performance in technological pedagogical, and content knowledge. In comparison with the current study, the research conducted by Castéra et al. (2020) showed different results, namely that TPACK factors and academic level were independent. It contrasts with the study done by the scholars. This contrasts with the study conducted by the scholars. The study differs from Shafie et al. (2023) research, which indicates that the highest educational qualifications significantly influence the 21st-century Technological Pedagogical Content Knowledge (TPACK) level, whereas teaching experience does not.

The study found that teachers who had GPAs in the range of 7.5 to 8.4 performed better than other groups, and the lowest scores were from 6 to 7.4 in technology knowledge. Teachers with a GPA from 7.5 to 8.4 showed better results, and those with a GPA from 6 to 6.4 showed the worst results in pedagogical knowledge. Teachers with GPAs from 7.5 to 8.4 showed better results than other groups, and groups from 6.5 to 7.4 showed the lowest scores in content knowledge. Groups from 7.5 to 8.4 performed better, and those with the lowest scores were 6 to 6.4 in pedagogical content knowledge. Also, groups from 7.5 to 8.4 showed better results, and those with the lowest were 6 to 6.4 in technological pedagogical, and content knowledge. In contrast to this study, Bozkurt (2014) concluded that teachers with higher academic achievements showed better results on TPACK attitudes. Mercado and Ibarra (2019) found a negative correlation between pre-service teachers' GPAs and their ability to teach ICT-integrated content. Additionally, Adalar (2021) showed that there were no significant differences between participants' perceptions and beliefs related to TPACK and variables such as their gender, GPA, and computer ownership.

The study also demonstrated that participants who studied at both universities had better results in technology knowledge. Participants who studied at public universities showed slightly better results than other groups in pedagogical knowledge. Participants who attended public universities showed better results in content knowledge and technological content knowledge. Those who studied at public universities showed better results than those at private universities in pedagogical content knowledge. Participants who studied at both universities had the highest scores in technological pedagogical knowledge. Those who studied at public universities had better results than the group who studied at private universities in technological, pedagogical, and content knowledge. The study contrasts with Katechaiyo's (2021), where those from private schools showed the desirable status and implementation TPACK model, especially in productive pedagogies, and supportive classroom environments. Further, it showed the highest level of content knowledge, followed by technology knowledge.

While this study offers meaningful insights into teachers' Technological Pedagogical Content Knowledge (TPACK), several limitations should be considered. The sample was not evenly distributed across key groups since there were significantly more female than male participants, and imbalances were also present between public and private university graduates and across teaching positions. These factors may have limited the generalizability of the findings. The study also did not take into account specific contextual influences within the Bosnian and Herzegovinian education system, such as curriculum differences, access to technology, or opportunities for professional development. Additionally, since the data were self-reported, responses may reflect personal bias or overestimation. The use of quantitative methods further limits the depth of interpretation, as it leaves out the nuanced, personal experiences that qualitative data could provide. Lastly, factors like access to training or resources, which may impact TPACK, were not controlled and could have influenced the results.

6. Conclusion

In conclusion, the study focused on TPACK among Bosnian teachers, encompassing TK, PK, CK, TCK, PCK, TPK, and TPCK.

In contrast to previous studies, which favored females, this study showed no significant difference between males and females in technology knowledge, pedagogy knowledge, content knowledge, technological content knowledge, pedagogical content knowledge, technological pedagogical knowledge, or technological pedagogical and content knowledge.

Compared to earlier studies, this study showed better performance among experienced teachers in pedagogical knowledge, content knowledge, technological content knowledge, pedagogical content knowledge, and technological pedagogical knowledge.

The study also showed that groups with higher degrees performed better in technological pedagogical, and content knowledge.

Additionally, it showed that participants with GPAs in the range from 7.5 to 8.4 performed better in technology knowledge, content knowledge, and technological pedagogical and content knowledge.

Moreover, the study indicated that teachers who graduated from public universities typically achieved stronger results compared to their counterparts from private institutions, particularly in the area of pedagogical content knowledge. Notably, both groups excelled in technological pedagogical knowledge.

To conclude, the study revealed no meaningful differences across gender, education level, or teaching experience, with all related effect sizes in the small or negligible range. However, differences based on GPA showed moderate practical significance, particularly in components such as Technological Pedagogical Content Knowledge ($\eta^2 = 0.127$), Technological Pedagogical Knowledge ($\eta^2 = 0.126$), and Technology Knowledge ($\eta^2 = 0.112$), suggesting GPA may play a relevant role in shaping teachers' self-perceived TPACK. Levene's Test for homogeneity of variances indicated no significant differences across groups in any of the knowledge domains (all $p > 0.05$), confirming that the assumption of equal variances was met and justifying the use of ANOVA and t-tests from the perspective of variance equality. Although the study employed t-tests and ANOVA for group comparisons, the Shapiro-Wilk tests revealed violations of normality across several key subgroups, particularly among gender and GPA levels. As a result, the findings from parametric analyses should be interpreted cautiously, and future research is encouraged to apply non-parametric methods for more robust inferences.

This research has the potential to raise awareness among administrators and education ministers regarding the importance of allocating funds, organizing workshops, and providing support for teachers as they adapt to new classroom environments. Further studies should include a larger number of participants to either support or challenge the hypothesis of this research. Additionally, more research should be conducted across different educational courses to check whether it affects the results.

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Informed Consent

The authors have obtained informed consent from all participants.

8. Conflict of Interest

The authors declare that there is no conflict of interest.

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