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Technological Pedagogical and Content Knowledge as a Predictor of Metacognitive Skills among Secondary School Teachers in India

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Abstract: This study examines the influence of technological pedagogical and content knowledge (TPACK) on the metacognitive skills of secondary school teachers in Odisha and explores differences in TPACK and metacognitive skills by gender and teaching experience. The study employed a descriptive survey design. The sample consisted of 606 government secondary school teachers in Odisha, selected through a multistage sampling technique. To examine the impact of TPACK on metacognitive skills and the significant differences in metacognitive skills and TPACK by gender and teaching experience, two standardized tools, namely a TPACK questionnaire and a metacognitive skills scale, were used. The reliability coefficients of the TPACK instrument and the metacognitive skills scale were 0.869 and 0.928, respectively. The statistical techniques used in this study were the t-test, correlation, and regression analysis. The findings revealed significant differences in TPACK and metacognitive skills based on gender and teaching experience. Male teachers outperformed female teachers in both TPACK and metacognitive skills, while less experienced teachers had higher TPACK scores and more experienced teachers demonstrated stronger metacognitive skills. Regression analysis showed that TPACK is a significant predictor of metacognitive skills, suggesting a positive relationship between teachers' ability to integrate technology into pedagogy and their metacognitive skills. This study examined the influence of TPACK on the metacognitive skills of secondary school teachers in the Indian context, and the development and standardization of two tools, namely a TPACK questionnaire and a metacognitive skills scale, constitute the unique contribution of this study.

Keywords: Technological Pedagogical and Content Knowledge (TPACK), Metacognitive Skills, Pedagogical Practices, Professional Development, Higher-order Thinking Skills, Secondary School Teachers

1. Introduction

The demands of the 21st century require individuals to possess a range of essential skills needed to succeed in their personal and professional lives, particularly in education and future careers. These skills include critical thinking, creativity, communication, and collaboration (Maoulida *et al.*, 2023; Rahman, 2019). Among these, metacognitive skills are also recognized as essential elements of the cognitive processes categorized under 21st-century competencies and are often defined as thinking about one's own cognitive processes. In the field of education, metacognition plays a pivotal role in promoting higher-order thinking skills and self-regulated learning (Flavell, 1979). It involves the systematic management of cognitive processes to guide future learning experiences, as well as higher-order thinking skills such as decision-making, critical thinking, and creative thinking (Flavell, 1979; Gaile & Adams, 2018; Lidor, 2004). Metacognitive skills are crucial for effective teaching. Teachers who are aware of their metacognitive processes can employ different ways of thinking in their teaching (Kim & Lee, 2018; Demir & Doganay, 2019). Metacognition guides teachers in examining and assessing their own skills, competencies, needs, and strategies for enhancing awareness and applying pedagogical practices (Jaleel, 2016).

In parallel, the integration of technology into educational practices has become fundamental to effective teaching in a rapidly changing educational environment. The Technological Pedagogical and Content Knowledge (TPACK) framework, proposed by Mishra and Koehler (2006), provides a comprehensive approach for teachers to integrate content, pedagogy, and technology effectively. This framework emphasizes the interplay among three types of knowledge for a teacher content knowledge, pedagogical knowledge, and technological knowledge enabling teachers to design resources and techniques for integrating technology into instruction, select suitable technological tools, and choose relevant topics to teach using technology (Tseng *et al.,* 2022). The process of integrating these knowledge domains and selecting appropriate technologies that align pedagogical strategies with relevant content requires complex decision-making and higher-order thinking from teachers (Aldemir Engin *et al.,* 2023; Zohar & Schwartzer, 2005).

The relationship between TPACK and metacognitive skills can be conceptually understood through the lens of self-regulated learning and reflective practice. The effective implementation of TPACK requires teachers to actively engage in metacognitive processes such as planning instructional strategies, monitoring the effectiveness of teaching approaches, and evaluating learning outcomes (Yeh *et al.,* 2021). These higher-order thinking skills are fundamental elements of metacognition, as defined by Flavell (1979) and later elaborated by Schraw (1998). While integrating TPACK into instruction, teachers consciously plan how to use appropriate technology with pedagogical approaches and content, drawing on their metacognitive processes (Taopan *et al.,* 2022). Teachers also monitor the effectiveness of their teaching by assessing student learning outcomes and engagement (Sujianti, 2025; Schraw & Dennison, 1994). By integrating technology into instruction to foster metacognitive development, teachers can increase student engagement and enable students to become self-directed and lifelong learners (Ajani, 2023). Moreover, the integration of technology into pedagogy requires adaptive academic proficiency and reflective thinking (Ertmer & Ottenbreit-Leftwich, 2010). Studies have found that teachers with higher levels of TPACK tend to exhibit greater reflective practice and more adaptive teaching methods, which are indicators of strong metacognitive skills (Koh *et al.,* 2015; Chai *et al.,* 2013).

Although extensive research has examined technological pedagogical and content knowledge in relation to the integration of technology in teaching practices, and separate studies have explored metacognitive skills in relation to self-regulated learning, there is a lack of integrated research examining the association between these two constructs. Most studies focus on integrating the TPACK framework into the teaching and learning process (Jibril & Adedokun-Shittu, 2023; Wang, 2022; Chai *et al.,* 2013), whereas studies on metacognitive skills have primarily focused on students rather than teachers (Fitriana *et al.,* 2025; Wider & Wider, 2023; Abedini, 2022). However, only a limited number of studies have investigated the influence of TPACK on metacognitive skills, highlighting a significant gap in the literature (Huang *et al.,* 2021; Ertmer & Ottenbreit-Leftwich, 2010). Therefore, the present study seeks to address this gap by examining the influence of TPACK on the metacognitive skills of secondary school teachers. This study contributes to the existing literature by adding empirical data from the Indian educational context and analyzing differences related to gender and teaching experience. The findings are expected to provide insights for teacher education programs and policy initiatives focused on improving technological integration and reflective approaches to instruction. The study highlights the role of metacognitive skills in enhancing teachers' ability to rethink, plan, monitor, and evaluate their instructional practices. These skills are essential for fostering self-regulated and reflective teaching, which supports teachers' professional development. Integrating teacher metacognitive training into teacher education programs can improve overall teaching effectiveness.

1.1 Technological Pedagogical and Content Knowledge (TPACK)

Technological Pedagogical and Content Knowledge (TPACK) is an important framework for educators because it brings together three domains of knowledge technology, pedagogy, and content to support the effective integration of technology into teaching (Aldemir Engin *et al.,* 2023; Mishra *et al.,* 2023; Mishra & Koehler, 2006). In light of this framework, teachers must have a thorough understanding of the interplay among these areas in order to design successful lessons. Teachers can improve student engagement and academic achievement by using TPACK to create lessons that are rich in content, pedagogically sound, and technologically enhanced (Kasapoglu, 2021; Kim *et al.,* 2021). The fundamental concept of this framework is that instructors need an in-depth understanding of the interplay among three knowledge domains content knowledge (CK), pedagogical knowledge (PK), and technological

knowledge (TK) to effectively navigate the dynamic environment of technology integration in the classroom. All of these domains work together to provide a complete picture of the knowledge and skills that educators need to effectively incorporate technology into their lessons (Zhang & Tang, 2021).

The TPACK framework is based on the idea of pedagogical content knowledge (PCK), which was first proposed by Shulman in 1986. Pedagogical content knowledge (PCK) was originally limited to teachers' content knowledge and pedagogical knowledge, focusing on how teachers integrate content knowledge with pedagogy to teach students effectively. However, the TPACK framework extends PCK by including one more knowledge component, namely technological knowledge. According to Mishra and Koehler (2006), teaching effectively with technology requires a balance among all three domains content, pedagogy, and technology and the ability to integrate technology in ways that meaningfully support instructional practice is one of the most important aspects of modern education. The TPACK framework consists of seven knowledge types, of which the three primary types are pedagogical knowledge, content knowledge, and technological knowledge. The remaining knowledge types are pedagogical content knowledge, technological pedagogical knowledge, technological content knowledge, and technological pedagogical and content knowledge, which are combinations of the three primary constructs (Mishra & Koehler, 2006).

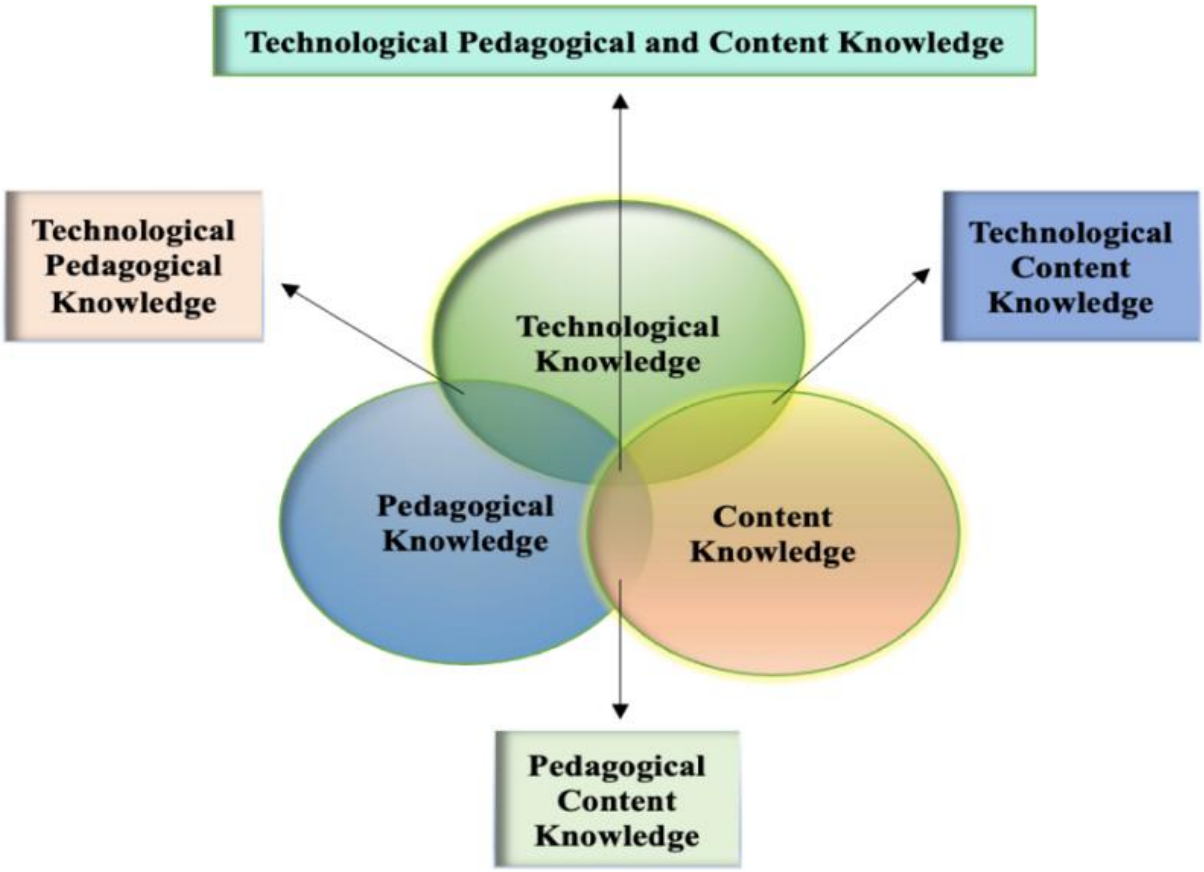

Figure 1. TPACK Framework

(**Source:** http://tpack.org)

Figure 1 explains the seven components of the TPACK framework as described by Koehler and Mishra (2009), which include: 1) Technology Knowledge (TK), related to knowledge of the application of technological tools and techniques; 2) Content Knowledge (CK), related to the teacher's knowledge of the subject matter to be taught; 3) Pedagogical Knowledge (PK), including approaches to teaching and learning such as classroom management, lesson-plan development, student learning, and assessment; 4) Pedagogical Content Knowledge (PCK), involving the integration of pedagogy and content to enhance instructional methods within specific subject areas; 5) Technological

Content Knowledge (TCK), which includes knowledge of how technology can be used to present specific content; 6) Technological Pedagogical Knowledge (TPK), relating to knowledge of instructional strategies and the integration of various technologies to enhance teaching; and 7) Technological Pedagogical Content Knowledge (TPACK), which is the knowledge teachers require to integrate technology into any content area using suitable pedagogies.

1.2 Metacognitive Skills

Metacognition can be defined as "thinking about thinking," which refers to the knowledge and awareness of one's own cognitive processes (Nelson, 1990; Flavell, 1979). The idea of metacognition was first introduced by Flavell in 1979. For an individual, "metacognition" involves monitoring one's own understanding, being aware of one's thinking processes, and being capable of controlling them (Flavell, 1979). Brown (1978) defined metacognition as individuals' self-awareness and systematic organization of thought processes in the context of purposeful learning and problem-solving. Similarly, Forrest Pressley and Waller (1984) defined it as the framework that reflects an individual's understanding of their own mental functions and their ability to regulate them. Metacognitive skills include the ability to understand one's own learning style, thinking patterns, and working methods (Slavin, 2006). Learners who possess metacognitive skills are expected to be aware of themselves and their learning styles, plan, monitor, and control their own learning, respond consciously, evaluate themselves, and manage their own learning process (Duman & Semerci, 2019).

Metacognition, a high-level thinking process that involves active control over the cognitive functions involved in learning, consists of two components: knowledge of cognition and regulation of cognition (Schraw, 1998; Wenden, 1998). Knowledge of cognition encompasses all the concepts individuals possess regarding their cognitive performance, including strategies and potential influencing factors. Declarative, procedural, and conditional knowledge are all components of knowledge of cognition (Pintrich *et al.,* 2000; Schneider & Pressley, 1997; Flavell, 1979). Similarly, regulation of cognition refers to how effectively individuals manage their learning, including planning, awareness of how tasks are performed, and the use of strategies to maintain control over ongoing activities. Planning, monitoring, and evaluating are all components of the regulation of cognition (Schraw & Dennison, 1994).

1.3 TPACK and Metacognitive Skills: Literature Review

Teachers' ability to create successful technology-enhanced learning experiences is greatly influenced by their metacognitive skills and technological pedagogical and content knowledge (TPACK), as shown in Figure 2. TPACK integrates three knowledge components technology, pedagogy, and content knowledge and is essential for encouraging students' creativity and critical thinking. It is a dynamic framework for expressing the knowledge teachers require for the development, implementation, and assessment of technology-assisted instruction (Durdu & Dag, 2017; Koştur, 2018). Teachers are required to have TPACK to effectively integrate multiple technologies into their lessons, regardless of the subject matter or activity being taught (Guzey & Roehrig, 2009; Harris & Hofer, 2011).

Figure 2. Impact of TPACK on Metacognitive Skill

Teachers who possess a high level of TPACK can effectively incorporate technology into their instruction, shifting away from teacher-centered approaches toward learner-centered approaches, thereby enhancing student engagement and interaction (Kafyulilo *et al.,* 2015). Sonsupap *et al.* (2024) found that teachers' critical thinking and problem-solving skills are significantly influenced by their TPACK proficiency levels, emphasizing the need for TPACK-related professional development for teachers. A teacher who efficiently applies metacognitive awareness strategies in the classroom will be able to set appropriate objectives for improving teaching (Spruce & Bol, 2015; Ghasempour

et al., 2013). According to Abuan *et al.* (2024), teachers can enhance their teaching practices by using metacognitive approaches such as self-monitoring and reflection to manage their TPACK effectively.

1.4 Significance of the Study

When it comes to education, teachers play a crucial role in shaping students' academic success and personal development. Competent teachers not only foster academic achievement but also contribute to the development of responsible citizens and productive members of society (Darling-Hammond, 2000). The use of technology in the classroom continues to grow in importance in the modern era as a means of improving both the effectiveness of teaching and student learning outcomes. The technological pedagogical and content knowledge framework provides an extensive basis for understanding how teachers can effectively incorporate technology into their teaching while ensuring subject accuracy (Aldemir Engin *et al.,* 2023; Chaidam *et al.,* 2022). Like TPACK, metacognitive skills are crucial for teachers' reflective practice and professional growth. Teachers with strong metacognitive skills are more successful in planning, monitoring, and assessing their teaching strategies, adapting to diverse learner needs, and continuously improving their practices (Veenman *et al.,* 2006). As technology transforms the learning environment and demands extensive instructional planning, the need for teachers to engage in metacognitive processes becomes more apparent.

Although technology integration affects pedagogical practices and student performance, its potential impact on teachers' cognitive and metacognitive development remains underexplored (Huang *et al.,* 2021; Ertmer & Ottenbreit-Leftwich, 2010). In the Indian context, a number of studies have investigated metacognitive awareness in relation to students' academic achievement and learning (Roy & Guha, 2024; Sonowal & Kalita, 2017; Sawhney & Bansal, 2015; Jain *et al.,* 2017). Similarly, research on TPACK in India has largely focused on technology integration, teachers' professional development, and technology self-efficacy (Rani & Kaur, 2025; Charania *et al.,* 2024; Joshi, 2023), without examining teachers' cognitive and metacognitive aspects. The existing literature reveals that only a limited number of empirical studies have examined the relationship between TPACK and metacognitive skills. Therefore, this study aims to investigate the impact of TPACK on the metacognitive skills of secondary school teachers, thereby addressing a significant gap in the literature. For this purpose, the investigators randomly selected the state of Odisha as the sample state in India for data collection. The investigators could not find research evidence on TPACK and the metacognitive skills of secondary school teachers in the Indian context, which represents a major gap addressed by the present study. Therefore, the objectives of the present study are as follows:

1. To compare the technological pedagogical and content knowledge of secondary school teachers with reference to gender and teaching experience.
2. To compare the metacognitive skills of secondary school teachers with reference to gender and teaching experience.
3. To examine the impact of technological pedagogical and content knowledge on the metacognitive skills of secondary school teachers.

Based on the objectives of the study, the following hypotheses were formulated:

1. There is a significant difference in the technological pedagogical content knowledge of male and female secondary school teachers.
2. There is a significant difference in the technological pedagogical content knowledge of more experienced and less experienced secondary school teachers.
3. There is a significant difference in the metacognitive skills of male and female secondary school teachers.
4. There is a significant difference in the metacognitive skills of more experienced and less experienced secondary school teachers.
5. Technological pedagogical and content knowledge will have a significant impact on the metacognitive skills of secondary school teachers.

2. Methods and Procedure

2.1 Research Design

The present study aims to examine the influence of TPACK on metacognitive skills and to explain the differences in TPACK and metacognitive skills with respect to gender and teaching experience among government secondary school teachers in India. TPACK is considered the independent variable in this study, and metacognitive skills are the dependent variable. The study involves comprehensive data collection through the survey method and thus employs quantitative analysis techniques. In this context, it follows a descriptive survey design in which the influence of the independent variable, TPACK, is examined on the metacognitive skills of secondary school teachers in India.

2.2 Population and Sample

The population in the present study comprised secondary school teachers in Odisha. According to the UDISE+ Report (2023–24), Odisha has 9,415 secondary schools and 97,993 secondary school teachers. Based on Raosoft's sample size calculator, the required sample size was estimated to be 383. In the first stage, Bhadrak district was randomly selected from the 30 districts of Odisha. In the second stage, the seven blocks of Bhadrak district Basudevpur, Tihidi, Bhadrak, Bhandaripokhari, Bonth, Dhamnagar, and Chandabali were considered. These blocks collectively comprise 218 gram panchayats. In the third stage, 19 gram panchayats were randomly selected from the 218 gram panchayats, and in the final stage, four secondary schools were randomly selected from each gram panchayat. As a result, 76 schools were selected, and data were collected from teachers who voluntarily participated in the survey. Accordingly, the investigator collected data from 606 secondary school teachers in Bhadrak district, Odisha, using a multistage sampling technique.

2.3 Tools for Data Collection

Data were collected using a Technological Pedagogical and Content Knowledge (TPACK) questionnaire adapted from Schmidt *et al.* (2009) and Jibril & Adedokun-Shittu (2023), as well as a teacher metacognition scale adapted from Jiang *et al.* (2016). The instruments were adapted to suit the study context, and their reliability and validity were established. The reliability coefficient of the TPACK questionnaire is 0.869, and that of the metacognitive scale is 0.928. The content validity of the tools was established through feedback from experts in the respective fields.

1. Technological pedagogical and content knowledge (TPACK): The TPACK questionnaire consisted of 40 items divided into seven dimensions (technological knowledge, pedagogical knowledge, content knowledge, technological pedagogical knowledge, pedagogical content knowledge, technological content knowledge, and technological pedagogical and content knowledge). These 40 items were evaluated using a 3-point Likert scale: 1 = No, 2 = Can't say, and 3 = Yes.
2. Metacognitive skills: The metacognitive skills scale consisted of 38 items divided into seven dimensions (declarative knowledge, procedural knowledge, conditional knowledge, planning, monitoring, implementing, and evaluating). These 38 items were evaluated using a 5-point Likert scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree.

2.4 Reliability of the tools

The reliability of the tools used in the present study was established using Cronbach's alpha coefficient, which assesses the internal consistency of the scale items. The overall reliability coefficient of the TPACK questionnaire is 0.869, and that of the metacognitive scale is 0.928. The dimension-wise reliability coefficients for the TPACK questionnaire were found to be as follows: Technological Knowledge (TK) (α = .712), Pedagogical Knowledge (PK) (α = .578), Content Knowledge (CK) (α = .538), Pedagogical Content Knowledge (PCK) (α = .605), Technological Pedagogical Knowledge (TPK) (α = .688), Technological Content Knowledge (TCK) (α = .478), and TPACK (α = .520), indicating that some individual dimensions of TPACK demonstrate low internal consistency.

Similarly, for the metacognitive skills scale, the dimension-wise reliability coefficients were Planning (α = .803), Monitoring (α = .801), Implementation (α = .805), and Evaluation (α = .810), indicating good internal consistency.

2.5 Techniques of Analysis and Interpretation

The data collected using the tools, namely a TPACK questionnaire and a metacognitive skills scale administered to government secondary school teachers, were analyzed using the t-test, correlation, and simple regression analysis.

3. Results

Data were collected from secondary school teachers in Odisha and analyzed using descriptive and inferential statistics such as the t-test, correlation, and simple regression. These analyses were performed using SPSS version 27.

3.1 Technological Pedagogical and Content Knowledge and Metacognitive Skills: Profiles of Secondary School Teachers

The data on the different components of technological pedagogical and content knowledge and metacognitive skills, both separately and overall, for male and female teachers as well as more experienced and less experienced teachers, are presented in Tables 1, 2, 3, and 4.

Table 1. Technological Pedagogical and Content Knowledge Profiles of Male and Female Secondary School Teachers

Mean Score of Teachers	N	TK	PK	CK	TPK	TCK	PCK	TPACK	Total TPACK
Mean score of male teachers	323	14.93	18.25	15.16	15.15	12.75	12.39	13.00	101.66
Mean score of female teachers	283	14.23	17.59	14.94	14.55	12.26	12.26	12.56	98.42
Total mean score	606	14.61	17.94	15.06	14.87	12.52	12.33	12.80	100.15

Note. N = number of teachers; TK = technological knowledge; PK = pedagogical knowledge, CK = content knowledge; TPK =technological pedagogical knowledge; TCK =technological content knowledge; PCK = pedagogical content knowledge; TPACK= technological pedagogical and content knowledge

Table 1 presents the mean scores of teachers by gender across seven components of the technological pedagogical and content knowledge (TPACK) framework, namely Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), and overall TPACK. Male teachers (N = 323) demonstrated higher scores than female teachers (N = 283) in overall TPACK (101.66 > 98.42). The most notable differences were found in Technological Knowledge (TK) (14.93 > 14.23), Pedagogical Knowledge (18.25 > 17.59), Content Knowledge (CK) (15.16 > 14.94), Technological Pedagogical Knowledge (TPK) (15.15 > 14.55), Technological Content Knowledge (TCK) (12.75 > 12.26), and TPACK (13.00 > 12.56). However, the difference in the mean score for Pedagogical Content Knowledge (PCK) was relatively small between male and female teachers.

Table 2. Technological Pedagogical and Content Knowledge Profiles of More Experienced and Less Experienced Secondary School Teachers

Mean Score of Teachers	N	TK	PK	CK	TPK	TCK	PCK	TPACK	Total TPACK
Mean score of more experienced teachers	310	13.76	18.02	15.03	14.25	12.13	12.41	12.66	98.29
Mean score of less experienced teachers	296	15.49	17.85	15.08	15.52	12.93	12.25	12.94	102.10
Total mean score	606	14.61	17.94	15.06	14.87	12.52	12.33	12.80	100.15

Note. N = number of teachers; TK = technological knowledge; PK = pedagogical knowledge, CK = content knowledge; TPK =technological pedagogical knowledge; TCK =technological content knowledge; PCK = pedagogical content knowledge; TPACK= technological pedagogical and content knowledge

Table 2 presents the mean scores of teachers by teaching experience across seven components of the technological pedagogical and content knowledge (TPACK) framework, namely Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), and overall TPACK. Less experienced teachers (N = 296) demonstrated higher scores than more experienced teachers (N = 310) in overall TPACK (102.10 > 98.29). Less experienced teachers performed better across most components of TPACK, particularly in Technological Knowledge (TK) (15.49 > 13.76), Technological Pedagogical Knowledge (TPK) (15.52 > 14.25), Technological Content Knowledge (TCK) (12.93 > 12.13), and TPACK (12.94 > 12.66). However, the differences in the mean scores for Pedagogical Knowledge (PK), Content Knowledge (CK), and Pedagogical Content Knowledge (PCK) were minimal between more experienced and less experienced teachers.

Table 3. Metacognitive Skills Profiles of Male and Female Secondary School Teachers

Mean Score of Teachers	N	Planning	Monitoring	Implementing	Evaluating	Total MCS
Mean score of male teachers	323	34.44	27.70	30.98	37.98	131.08
Mean score of female teachers	283	33.74	27.40	30.07	37.29	128.44
Total mean score	606	34.11	27.56	30.55	37.66	129.90

Note. N = number of teachers; MCS = metacognitive skills

Table 3 presents the mean scores of teachers by gender across the four components of metacognitive skills, namely planning, monitoring, implementing, and evaluating. Male teachers (N = 323) demonstrated higher scores than female teachers (N = 283) in overall metacognitive skills (131.08 > 128.44). The most notable difference was found in planning (34.44 > 33.74). However, only slight differences in favor of male teachers were found in the other components, namely monitoring, implementing, and evaluating.

Table 4. Metacognitive Skills Profiles of More Experienced and Less Experienced Secondary School Teachers

Mean Score of Teachers	N	Planning	Monitoring	Implementing	Evaluating	Total MCS
Mean score of more experienced teachers	323	34.63	27.95	31.04	38.07	131.70
Mean score of less experienced teachers	283	33.57	27.16	30.04	37.22	127.91
Total mean score	606	34.11	27.56	30.55	37.66	129.90

Note. N = number of teachers; MCS = metacognitive skills

Table 4 presents the mean scores of teachers by teaching experience across the four components of metacognitive skills, namely planning, monitoring, implementing, and evaluating. More experienced teachers (N = 310) demonstrated higher scores than less experienced teachers (N = 296) in overall metacognitive skills (131.70 > 127.91). A notable difference was found in the mean scores for planning (34.63 > 33.57), implementing (31.04 > 30.04), and evaluating (38.07 > 37.22), all in favor of more experienced teachers. However, the mean scores for monitoring were almost similar between more experienced and less experienced teachers.

3.2 Hypothesis 1: There exists a significant difference in the technological pedagogical content knowledge of male and female secondary school teachers

The first objective of the present study was to compare the significance of the mean differences in the technological pedagogical and content knowledge of male and female secondary school teachers. Before conducting

the t-test, it was necessary to determine the normality of the data. A one-sample Kolmogorov–Smirnov test was used for this purpose, and the data were found to be normally distributed.

The analysis of Table 5 reveals that the mean scores for technological pedagogical and content knowledge among male and female teachers are 101.66 and 98.42, respectively, and the corresponding standard deviations are 12.37 and 14.03. When the mean scores of male and female secondary school teachers on technological pedagogical and content knowledge were tested for significance, the calculated t-ratio was found to be 3.021.

Table 5. Significance of the Difference in the Mean Scores for the Technological Pedagogical and Content Knowledge of Male and Female Teachers

Teachers	N	Mean	SD	SED	df	t	Remarks
Male teachers	323	101.66	12.37	1.07	604	3.021	Significant at 0.01
Female teachers	283	98.42	14.03				

Note. N = number of teachers; SD = standard deviation; SED = standard error of difference; df = degrees of freedom; t = t-ratio.

The analysis of Table 5 reveals that the mean scores for technological pedagogical and content knowledge among male and female teachers are 101.66 and 98.42, respectively, and the corresponding standard deviations are 12.37 and 14.03. When the mean scores of male and female secondary school teachers on technological pedagogical and content knowledge were tested for significance, the calculated t-ratio was found to be 3.021.

The analysis of the data revealed that the calculated t-value (3.021) is greater than the critical t-value for 604 degrees of freedom, which is 2.58 at the 0.01 level of significance. Therefore, it can be concluded that a significant difference exists in the technological pedagogical and content knowledge of male and female secondary school teachers. Accordingly, the research hypothesis stating that there is a significant difference in the technological pedagogical and content knowledge of male and female secondary school teachers is accepted. It may therefore be inferred that male and female secondary school teachers differ in technological pedagogical and content knowledge, with male teachers obtaining higher mean scores than their female counterparts.

3.3 Hypothesis 2: There Exists a Significant Difference in the Technological Pedagogical Content Knowledge of More Experienced and Less Experienced Secondary School Teachers

The study also aimed to determine the significance of the mean differences in the technological pedagogical and content knowledge of more experienced and less experienced secondary school teachers. The data were examined for normality using the one-sample Kolmogorov–Smirnov test, and they were found to be normally distributed.

Table 6. Significance of the Difference in the Mean Scores for the Technological Pedagogical and Content Knowledge of More Experienced and Less Experienced Teachers

Teachers	N	Mean	SD	SED	df	t	Remarks
More experienced teachers	310	98.29	13.95				
Less experienced teachers	296	102.10	12.22	1.07	604	3.564	Significant at 0.01

Note. N = number of teachers; SD = standard deviation; SED = standard error of difference; df = degrees of freedom; t = t-ratio.

The analysis of Table 6 reveals that the mean scores for technological pedagogical and content knowledge among more experienced and less experienced teachers are 98.29 and 102.10, respectively, and the corresponding standard deviations are 13.95 and 12.22. When the mean scores of more experienced and less experienced secondary school teachers on technological pedagogical and content knowledge were tested for significance, the calculated t-ratio was found to be 3.564.

The analysis of the data revealed that the calculated t-value (3.564) is greater than the critical t-value for 604 degrees of freedom, which is 2.58 at the 0.01 level of significance. Therefore, it can be concluded that a significant difference exists in the technological pedagogical and content knowledge of more experienced and less experienced secondary school teachers. Accordingly, the research hypothesis stating that there is a significant difference in the technological pedagogical and content knowledge of more experienced and less experienced secondary school teachers is accepted. It may therefore be inferred that these two groups differ in technological pedagogical and content knowledge, with less experienced teachers obtaining higher mean scores than their more experienced counterparts.

3.4 Hypothesis 3: There exists a Significant Difference in the Metacognitive Skills of Male and Female Secondary School Teachers

The study also sought to determine the significance of the mean differences in the metacognitive skills of male and female secondary school teachers. In the present study, the data were tested for normality using the one-sample Kolmogorov–Smirnov test, and they were found to be normally distributed.

Table 7. Significance of the Difference in the Mean Scores for the Metacognitive Skills of Male and Female Teachers

Teachers	N	Mean	SD	SED	df	t	Remarks
Male teachers	323	131.08	14.07	1.18	604	2.240	Significant at 0.05
Female teachers	283	128.44	14.82				

Note. N = number of teachers; SD = standard deviation; SED = standard error of difference; df = degrees of freedom; t = t-ratio.

The analysis of Table 7 reveals that the mean scores for metacognitive skills among male and female teachers are 131.08 and 128.44, respectively, and the corresponding standard deviations are 14.07 and 14.82. When the mean scores of male and female secondary school teachers on metacognitive skills were tested for significance, the calculated t-ratio was found to be 2.240.

The analysis of the data revealed that the calculated t-value (2.240) is greater than the critical t-value for 604 degrees of freedom, which is 1.96 at the 0.05 level of significance. Therefore, it can be concluded that a significant difference exists in the metacognitive skills of male and female secondary school teachers. Accordingly, the research hypothesis stating that there is a significant difference in the metacognitive skills of male and female secondary school teachers is accepted. It may therefore be inferred that male and female secondary school teachers differ in metacognitive skills, with male teachers obtaining higher mean scores than their female counterparts.

3.5 Hypothesis 4: There exists a Significant Difference in the Metacognitive Skills of More Experienced and Less Experienced Secondary School Teachers

One major objective of the study was to determine the significance of the mean differences in the metacognitive skills of more experienced and less experienced secondary school teachers. The data were examined for normality using the one-sample Kolmogorov–Smirnov test, and they were found to be normally distributed.

Table 8. Significance of the Difference in the Mean Scores for the Metacognitive Skills of More Experienced and Less Experienced Teachers

Teachers	N	Mean	SD	SED	df	t	Remarks
More experienced teachers	310	131.70	13.98				
Less experienced teachers	296	127.91	14.75	1.17	604	3.247	Significant at 0.01

Note. N = number of teachers; SD = standard deviation; SED = standard error of difference; df = degrees of freedom; t = t-ratio.

The analysis of Table 8 reveals that the mean scores for metacognitive skills among more experienced and less experienced teachers are 131.70 and 127.91, respectively, and the corresponding standard deviations are 13.98 and 14.75. When the mean scores of more experienced and less experienced secondary school teachers on metacognitive skills were tested for significance, the calculated t-ratio was found to be 3.247.

The analysis of the data revealed that the calculated t-value (3.247) is greater than the critical t-value for 604 degrees of freedom, which is 2.58 at the 0.01 level of significance. Therefore, it can be concluded that a significant difference exists in the metacognitive skills of more experienced and less experienced secondary school teachers. Accordingly, the research hypothesis stating that there is a significant difference in the metacognitive skills of more experienced and less experienced secondary school teachers is accepted. It may therefore be inferred that these two groups differ in metacognitive skills, with more experienced teachers obtaining higher mean scores than their less experienced counterparts.

3.6 Hypothesis 5: Technological pedagogical and content knowledge (TPACK) will have a significant impact on the metacognitive skills of secondary school teachers

Another major objective of the study was to examine the impact of technological pedagogical and content knowledge on the metacognitive skills of secondary school teachers. To test the hypothesis, the normality of the data was first confirmed. It was essential to examine data normality before applying statistical methods to analyze the collected data. The data were tested for normality using the one-sample Kolmogorov–Smirnov test, and they were found to be normally distributed.

Table 9. Influence of Technological Pedagogical and Content Knowledge on the Metacognitive Skills of Secondary School Teachers

Variable	B	SE	β	t	p	F	r	R^2	Adjusted R^2	Durbin-Watson
TPACK	*80.292*	*4.000*	*.453*	20.071	< .001	156.16	.453	*.205*	*.205*	1.398
MCS	*.495*	0.040		12.497	< .001	*df (1,604)*				

Note. Independent variable (Technological pedagogical and content knowledge (TPACK)) and dependent variable (Metacognitive skills).

Table 9 presents the results of the correlation and regression analyses performed on the technological pedagogical and content knowledge and metacognitive skills of secondary school teachers. The assumptions of regression were assessed before conducting the regression analysis. A Pearson correlation analysis was performed to examine the relationship between the two variables. The correlation coefficient between technological pedagogical and content knowledge and metacognitive skills among secondary school teachers was .453, indicating a moderate positive correlation between the two variables. In general, a correlation coefficient (r) below 0.4 is considered weak, between 0.4 and 0.8 is considered moderate, and above 0.8 is considered strong (Shi & Conrad, 2009). The Durbin–Watson statistic (d) was 1.398, which suggests that autocorrelation is not a serious concern because the value is relatively close to 2.

The regression analysis examined the relationship between technological pedagogical and content knowledge and metacognitive skills among secondary school teachers. The coefficient for technological pedagogical and content knowledge was 0.495 ($\beta = .453$, $p < .001$), indicating that for each one-unit increase in technological pedagogical and content knowledge, metacognitive skills are expected to increase by approximately 0.495 units. When technological pedagogical and content knowledge is zero, the estimated value of metacognitive skills is 80.292. The t-value for technological pedagogical and content knowledge is 20.071, indicating that the coefficient is significantly different from zero. This suggests that technological pedagogical and content knowledge is a significant predictor of metacognitive skills among secondary school teachers. The model fit was significant [$F(1, 604) = 156.16$, $p < .001$], indicating that technological pedagogical and content knowledge makes a significant contribution to predicting metacognitive skills among secondary school teachers. Furthermore, the R2 value of .205 indicates that approximately 20.5% of the variance in metacognitive skills can be explained by its linear relationship with technological pedagogical and content knowledge.

4. Discussion

The purpose of the present study was to examine the impact of technological pedagogical and content knowledge (TPACK) on metacognitive skills and to investigate significant differences in TPACK and metacognitive skills with respect to the gender and teaching experience of secondary school teachers in India. The above analysis was conducted in accordance with the objectives of the study. Overall, Tables 1 and 2 provide a comparative picture of teachers by gender and teaching experience with respect to technological pedagogical and content knowledge, both component-wise and overall. The data show that male teachers (N = 323) outscored female teachers (N = 283) in overall technological pedagogical and content knowledge (101.66 > 98.42), and less experienced teachers (N = 296) demonstrated higher scores than more experienced teachers (N = 310) in overall technological pedagogical and content knowledge (102.10 > 98.29). Similarly, Tables 3 and 4 provide a comparative picture of teachers by gender and teaching experience with respect to metacognitive skills, both component-wise and overall. Male teachers (N = 323) also outscored female teachers (N = 283) in the overall metacognitive skills score (131.08 > 128.44), and more experienced teachers (N = 310) demonstrated higher scores than less experienced teachers (N = 296) in overall metacognitive skills (131.70 > 127.91).

The findings revealed a significant difference in the technological pedagogical and content knowledge of male and female secondary school teachers. This result is consistent with the studies of Masry-Herzallah (2025), Orakova *et al.* (2024), Abubakir and Alshaboul (2023), Beri and Sharma (2019), Ozudogru and Ozudogru (2019), Cetin-Berber and Erdem (2015), Karaca (2015), and Chang, Tsai, and Jang (2014), which reported significant differences in the technological pedagogical and content knowledge of male and female school teachers. However, some studies found no significant differences in teachers' TPACK (Momenanzadeh *et al.,* 2023; Irwanto *et al.,* 2022). Similarly, the present study found a significant difference in the technological pedagogical and content knowledge of more experienced and less experienced secondary school teachers. This finding corroborates the results of Orakova *et al.* (2024), Demirok and Baglama (2018), Cetin-Berber and Erdem (2015), and Chang, Tsai, and Jang (2014).

The difference in technological pedagogical and content knowledge depends on teachers' self-efficacy and their exposure to technology. Previous studies indicate that the technology integration self-efficacy of male teachers is higher than that of their female counterparts (Ifinedo *et al.,* 2020). Some studies also found that the technological knowledge (TK) of male teachers is higher than that of female teachers (Lin *et al.,* 2013; Ekrem & Recep, 2014), which positively influences their ability to integrate technology into teaching practices. Since TPACK depends on the effective use of technological, pedagogical, and content knowledge, greater technological exposure and higher technological self-efficacy may lead to better performance among male teachers. Similarly, with regard to teaching experience, less experienced teachers tend to have a more favorable view of technological knowledge (Liu *et al.,* 2015), whereas more experienced teachers, especially older teachers, may feel less confident about using technology (Kazu & Erten, 2014). A study by Sabic et al. (2022) also found that male and younger teachers possess higher levels of self-efficacy for using technology than female and older teachers.

Further, the study observed a significant difference in the metacognitive skills of male and female secondary school teachers. This finding corresponds with the results reported by Ahmed (2023), Mendoza *et al.* (2023), Asy'ari and da Rosa (2022), Karadan and Hameed (2016), Koc and Kuvac (2016), and Tali and Dar (2014). Similarly, a significant difference in the metacognitive skills of more experienced and less experienced secondary school teachers was found, which aligns with earlier studies conducted by Daher and Hashash (2022), Çakici (2018), Karadan and Hameed (2016), and Koc and Kuvac (2016). However, some studies found no significant difference in the metacognitive skills of male and female teachers (Mehrabian *et al.,* 2022). Differences in metacognitive skills are linked to variations in self-efficacy, cognitive styles, and problem-solving approaches. Gender has been found to have a strong moderating effect on individuals' metacognitive skills, with females tending to be underconfident and males tending to be overconfident in their performance assessments (Gutierrez & Price, 2017; Gutierrez & Schraw, 2015). According to self-efficacy theory, individuals who possess greater confidence in their abilities are more likely to actively engage in metacognitive processes, including planning, monitoring, and evaluating their actions (Bandura, 1997). It has also been found that personality traits positively associated with self-efficacy and emotional responses may contribute to better metacognitive awareness among male teachers than among female teachers (Derakhshan *et al.,* 2023).

The last objective of the study was to examine the impact of technological pedagogical and content knowledge on the metacognitive skills of secondary school teachers. The findings revealed that technological pedagogical and content knowledge is a significant predictor of the metacognitive skills of secondary school teachers. However, R2 = 0.205 indicates that TPACK explains only 20.5% of the variance in metacognitive skills, suggesting that it is not the sole determinant of metacognitive skills. The modest explanatory power of TPACK suggests that other factors may also play a substantial role in shaping teachers' metacognitive skills. These factors may include teaching experience, which influences teachers' decision-making and reflective practices; professional development training, which enhances teachers' competence and skills; and self-efficacy in using technology (Desiriani et al., 2023; Chen & Chen, 2022; García-Lázaro *et al.,* 2022). Previous studies have also found that different components of technological pedagogical and content knowledge, such as technological knowledge, pedagogical knowledge, and content knowledge as a whole, affect the metacognitive skills of school teachers (Joshpine & Albina, 2023), which supports the findings of the present study.

5. Limitations and Implications for Future Study

The study investigated the extent to which secondary school teachers' metacognitive skills are predicted by their technological pedagogical and content knowledge. However, there are some limitations. Although TPACK was found to be a statistically significant predictor of metacognitive skills, its impact was modest (R2 = 0.205). This suggests that the development of teachers' metacognitive skills may be influenced more strongly by other factors. The study did not investigate the influence of teachers' TPACK and metacognitive skills on student learning outcomes, which is essential for understanding their actual impact in the classroom. The study included only teachers from government secondary schools. Private institutions were not included, and they may have yielded different results because of differences in access to technology and training opportunities. The study was also limited to secondary school teachers from a single district (Bhadrak) in Odisha.

After completing the research, the investigators identified areas that required further study. To investigate the influence of technological pedagogical and content knowledge on metacognitive skills in school teachers, a mixed-method study could be conducted. Integrating qualitative methods such as interviews and focus groups may provide in-depth knowledge and understanding of the use of TPACK and metacognitive skills in real classroom settings. Future research may also use experimental methods to assess the effectiveness of specific instructional approaches based on teachers' TPACK and metacognitive skills. Due to the limited time span of the study, the results cannot shed light on the developmental aspects of the relationship between technological pedagogical and content knowledge and metacognitive skills. Therefore, longitudinal research could be undertaken to explore the development of technological pedagogical and content knowledge and metacognitive skills among both pre-service and in-service teachers at different levels, such as primary, secondary, and higher education, over time. Further studies may also examine the impact of teachers' TPACK and metacognitive skills on students' academic performance and higher-order thinking skills.

6. Conclusion

The present study investigated the impact of technological pedagogical and content knowledge (TPACK) on the metacognitive skills of secondary school teachers, as well as the significant differences in technological pedagogical and content knowledge (TPACK) and metacognitive skills with respect to gender and teaching experience. The results revealed that male teachers performed significantly better than their female counterparts in both TPACK and metacognitive skills. Likewise, teachers with less experience demonstrated higher levels of TPACK, whereas teachers with more experience demonstrated higher levels of metacognitive skills. Regression analysis further showed a moderate positive correlation between teachers' technological pedagogical and content knowledge (TPACK) and metacognitive skills, and TPACK was found to be a significant predictor of metacognitive skills (R2 = 0.205).

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Amiya Ranjan Panigrahi: Conceptualization, Methodology, Writing - Original Draft. Sesadeba Pany: Supervision, Writing- Reviewing and Editing. Sankar Prasad Mohanty: Visualization, Investigation. Shamshir Singh Dhillon: Software, Validation. Man Singh: Formal Analysis, Writing review and editing. All the authors read and approved the final version of the manuscript.

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Yes

Conflict of Interest

The authors have no conflicts of interest to declare. There is also no financial interest to report. The author certifies that the submission is original work and is not under review at any other publication.

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