Research Article

Smart Minds in Math: The TPACK Advantage of Educators' Cognitive Abilities

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Abstract

With the advent of the 21st century, as in the entire teaching-learning process, the subject mathematics plays a dominant role. It becomes important for mathematics teachers to ensure the optimum learning of students by upgrading their abilities especially in the field of technology. This paper attempts to unlock the impact of cognitive abilities of mathematics educators on their Technological Pedagogical and Content Knowledge (TPACK). The cognitive abilities namely, analytical, evaluative and creative abilities of mathematics educators are explored in the present study in context to mathematics subject. The TPACK test for mathematics teachers and the cognitive factors test are validated instruments used in the study to collect information from 189 elementary mathematics educators of Punjab (India) through a survey method. The data were analysed through percentage analysis, product moment correlation and s-estimation approach of Robust Least Square Regression. In the present study, the cognitive abilities of the mathematics educators are explored extensively. The study unveils the significant impact of cognitive abilities of mathematics educators on their TPACK. It is suggested to take concrete initiatives in the direction of development of cognitive abilities and TPACK among the mathematics educators.

Keywords: TPACK, cognitive abilities, mathematics educators, analytical ability, evaluative ability, creative ability

Introduction

Mathematics is one of the greatest intellectual achievements of human endeavour that epitomises the power of deductive reasoning. Moreover, the student's experience as a learner needs to adopt a composite and comprehensive view to learn mathematics successfully. Not surprisingly, much of the research on mathematics teaching and learning portrays mathematical proficiency which synthesises cognitive as well as intellectual ability. In particular, mathematics embraces an imperative place in the education of an individual as the knowledge of mathematics is vital in almost every sphere of life. Yet, many students believe the subject to be challenging (Akhter and Akhter, 2018) which leads to their low grades in the subject. While tracing the probable reasons for students' mediocre performance, it is widely acknowledged that mathematics teachers employ inefficient teaching strategies in their classrooms (Marbán and Sintema, 2021).

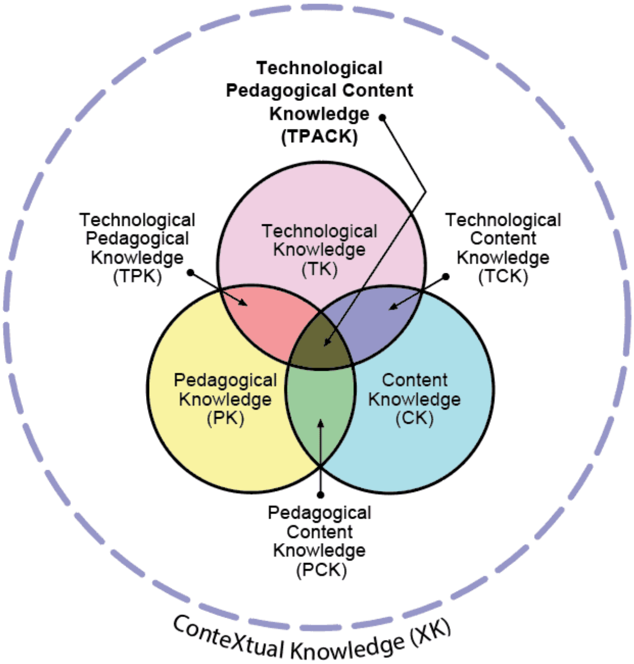
Due to the repeated shutdowns of Indian schools during the Covid-19 pandemic situation, nowadays the delivery of mathematics instruction is mostly done online, and educators have to improvise their teaching by incorporating cutting-edge pedagogies and technologies (Juanda et al., 2021). Mere use of technological tools into the mathematics classroom does not solve the purpose, it is the appropriate selection and integration of technology with the pedagogy and content, which will serve to benefit quality education (Bakar et al., 2020; Ozudogru, and Ozudogru, 2019). Thus, mathematics educators must be able to design their learning environment by optimum utilisation of their technological pedagogical and content knowledge (TPACK). Further, the cognitive abilities of mathematics educators can interplay their role in the process of acquisition of knowledge and skills. The purpose of the present study is to explore the cognitive abilities i.e., analytical, evaluative, and creative abilities of mathematics educators and unveiling their composite impact on TPACK. In this paper, the higher cognitive abilities, i.e., analytical, evaluative, and creative abilities, of elementary mathematics educators are discussed in detail along with its influence on their TPACK.

Theoretical Foundation via Review Synthesis

TPACK Framework for Integrating Technology in Classroom

For integration of technology in the classroom, a teacher needs to also consider other factors like pedagogy and content. A widely accepted framework, namely TPACK framework, is the best suited theoretical foundation for successful integration of technology. The TPACK framework was articulated by Mishra and Koehler in 2006 and it is an extended work of Shulman (1986) on Pedagogical Content Knowledge (PCK). Shulman posited that teachers should know general pedagogical methods for teaching a particular content. They should be able to develop the pedagogical strategies according to the content to be taught. In the era of technology, the PCK framework was extended to TPACK, interlocking the technology with content and pedagogy (Anjeli and Valanides, 2008). Mishra and Koehler (2006) conceived the third primary form of knowledge, i.e. TK, as the teachers' know-how for integrating technology in the classroom. Further, the constructs TPK, TCK and PCK are considered the foundation of TPACK. In TPACK framework, there is equal application of three areas of knowledge, i.e. TK, PK and CK, in the process of teaching and learning. In addition to these elementary forms of knowledge, TK, PK and CK, there are three secondary forms of knowledge, i.e. TCK (Technological Content Knowledge), PCK (Pedagogical Content Knowledge) and TPK (Technological Pedagogical Knowledge), which are prepared from the intersection of these elementary forms of knowledge. The intersection of primary forms of knowledge resulting in the secondary forms is displayed through the Venn diagram in Figure 1.

Figure-1: Revised version of the TPACK image. © Punya Mishra, 2018. Reproduced with permission



In this Venn diagram, Content is associated with 'What' i.e. what the teachers know? It may be any subject content e.g. science, mathematics etc. Pedagogy is linked with 'How' i.e. how the teachers teach? There are various methods of teaching like dialogue, play-way method, experiential learning, differentiated instruction etc. Technology deals with 'Which' i.e. which technology is used e.g. smart board, mobile etc. TPK means how technology is applied in education without referring to specific content, for example, computer-supported collaborative learning. TCK refers to how the technology is used in a subject for effective learning, for example, Geometer's sketchpad. PCK involves how to effectively engage the students in learning concepts, for example, a deductive method for solving mathematical problems. The recent update in TPACK framework, includes another element of knowledge i.e. the Contextual knowledge (XK). This XK is derived from the outer dotted circle i.e. an enclosed space showing the contexts. These contexts are the organisational or situational constraints that the teachers have to deal with while performing their tasks (Mishra, 2006).

In the present scenario where the classrooms are turning out to be virtual, the teachers need to update their knowledge in all three areas, i.e. technology, pedagogy and content, according to the contexts involved while teaching. Notably, recent advancements in teacher education and instructional design have emphasised the integration of innovative frameworks and methodologies to enhance teaching practices and learning outcomes. One prominent theme is the necessity of experiential learning for pre-service educators. Jia and Yang (2024) emphasised the importance of off-campus internships led by experts, enabling pre-service mathematics educators at Shandong Normal University to refine their teaching evaluation skills in real-world middle school settings. Similarly, Elim (2024) explored the use of generative AI within Bloom's taxonomy to enhance cognitive thinking. The study found "creating" and "evaluating" as critical domains for fostering reflection and questioning among primary school students, though it noted challenges in applying these skills to broader contexts. The findings offer valuable insights for integrating AI to improve critical thinking and learning outcomes. Addressing the Affective dimension in teaching, McLay and Reyes (2024) extended the TPACK model to TAPACK, incorporating affective elements such as emotions, attitudes and values. Thereby promoting meaningful technology integration among preservice teachers (PSTs) in teaching and learning. Their findings showed that explicitly engaging with these dimensions fosters positive attitude and orientations toward technology integration among pre-service teachers, enhancing teacher education programs. Meanwhile, Ning et al. (2024) introduced the AI-TPACK framework to integrate Artificial Intelligence technology with pedagogical methods and subject-specific content, which aims to better understand the intricate interrelations and synergistic effects of AI technology. This comprehensive model offers insights for assessing and advancing teachers' competencies in AI integration, supporting sustainable professional development in the AI-driven educational landscape.

Mansour et al. (2024) sought to investigate competencies and self-efficacy within the domain of technological pedagogical content knowledge. The main emphasis was on Project-Based Learning (PBL) and Science, Technology, Engineering, and Mathematics (STEM) curriculum. The findings showed that there were no notable disparities observed among science and mathematics teachers in terms of teaching experience and school level. Nevertheless, there were still gender differences, since male teachers demonstrate superior performance in technology integration. Li and Li (2024) conducted a study on the TPACK framework in mathematics education, specifically focusing on the role of Contextual Knowledge (XK) among middle school mathematics teachers in Chongqing, China. They used structural equation modelling (SEM) to examine the connections between different components of TPACK. The results suggest that XK, when combined with Pedagogical Knowledge (PK), Pedagogical Content Knowledge (PCK), and Technological Content Knowledge (TCK), has a significant influence on the total TPACK framework.

Utari et al. (2024) conducted a descriptive study on fourteen students with the objective of developing instructional sequences for teaching and learning that would enhance students' collaborative abilities by utilising the Technological Pedagogical Content Knowledge (TPACK) framework. The results showed that using the TPACK framework like TK (computer and Android software), PK (a project-based learning model), and CK (introduction to statistics through project-based learning) can help students work together better. Importantly, Kartal and Çınar (2022) aimed to probe the TPACK development of preservice elementary mathematics instructors, conducted a study on thirty-three preservice teachers (PSTs) who received the TPACK survey. The six pre-service teachers (PSTs) carried out a total of four lessons that were focused on technology. These lessons included two microteaching sessions as part of the mathematics teaching method course, and two lessons during their student teaching. The findings indicated that the participants did not demonstrate effective and efficient utilisation of technology during their microteaching sessions. Upon assessing their initial instructional sessions in schools, pre-service teachers significantly enhanced their teaching. In this context, the content knowledge of middle school mathematics pre-service teachers in an Australian school of education, is found to be weak (Norton, 2019). The steady development of TPACK among the pre-service and in-service teachers can result in better learning of students. The teachers' knowledge of how to use ICT is found to have a positive impact on the academic achievement of students (Akturk and Saka Ozturk, 2019). Evidently, the traditional classroom is continuously converting into smart classrooms, as the students take more interest in gadgets and other latest technologies. In India, National Education Policy (NEP) 2020 also holds the view of integration of technology in the classroom for ensuring quality education. CIET-NCERT is promoting the vision by providing various resources to the teachers for integrating technology in their teaching. In recent times, the Government of India has taken various initiatives to promote digital learning under the mission, namely 'National Mission on Education through Information and Communication Technology (NMEICT). A variety of learning materials in the form of e-resources, i.e. audios and videos, have been developed and shared through web portals like e-Pathshala, Study Webs of Active-Learning for Young minds (SWAYAM), National Repository of Open Educational Resources (NROER) and mobile applications (ePathshala).

Remarkably, NEP 2020 mentions that the teachers will be provided with opportunities for their continuous professional development (CPD). For every teacher, it will be compulsory to attend 50 CPD courses which will focus on the latest pedagogies like arts-integrated pedagogy, story-telling and experiential learning etc. The NEP 2020 has also emphasised on the concrete steps to be taken by NCERT and SCERT for doing the required modifications in the curriculum and pedagogy for reducing the burden of students.

Cognitive Abilities

The psychological constructs, cognitive ability and intelligence, are used interchangeably according to the context involved. It describes the differences among the individuals on the basis of their mental abilities. Cognitive abilities relate to the cognitive domain of learning. According to the original version of Bloom's taxonomy given by Benjamin Bloom in 1956, the cognitive domain is divided into six levels, i.e. Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. In 2001, Bloom's taxonomy was revised with slight changes in the above-mentioned six levels. According to the revised Bloom's taxonomy, the levels are Remember, Understand, Apply, Analyse, Evaluate and Create. The first three levels, i.e. remember, understand and apply, correspond to the lower order of abilities in cognitive domain. The above three levels, i.e. analyse, evaluate and create, refer to the higher-order of abilities of an individual.

Considering the present study, cognitive abilities are confined to the higher-order thinking skills, i.e. analyse, evaluate and create. Analytical ability refers to the ability to analyse, i.e. to breakdown something into its constituent parts. With reference to the teachers, the analytical ability refers to the ability of analysing the classroom situations, students' behaviour and performance which leads towards an appropriate solution or action to be taken by the teachers. Evaluative ability of teachers refers to their ability to evaluate their students and give judgement. Thus, the evaluative ability of teachers is not only confined to checking the responses or performance of students; rather, it also includes the feedback given by the teachers for the improvement of students' learning.

The creative ability of teachers refers to their ability to create something new or novel. In several countries, the employer always strives to assess the intellectual level of teachers before hiring them. Thus, the cognitive abilities are the integral component involved in the procedure of teachers' selection (Klassen and Kim, 2019). It is also found that the mathematics teachers' knowledge about higher-order thinking skills is very low and they are unable to solve the higher-order thinking skills (HOTS) based problems (Retnawati et al., 2018). The instances of relationship between technology and cognitive abilities are witnessed in various other fields like business, agriculture etc. HR professionals use technology in their business for handling data, metrics and statistics. It is revealed that HR professionals having a high level of analytical ability perform better in their job in comparison to their counterparts (Kryscynski et al., 2017). Similarly, IT managers, having a combination of decision styles i.e. intuitive and analytical, can better evaluate information technology (Selart et al., 2008). Research has also been conducted on the farmers of the United States to study the interrelationship between their cognitive ability and technology adoption. It is found that the farmers who adopted the technology at an early stage are having high cognitive ability (Barham et al., 2018). Such study clearly indicates that the teachers with high cognitive ability may also be able to adopt technology in their daily practice.

Methodology

The study involves a survey method of descriptive type of research conducted on 189 mathematics educators teaching mathematics to 8th standard students of government schools of Punjab (India). For obtaining information about their TPACK and cognitive abilities, instruments were prepared with reference to the subject mathematics only. The TPACK test for mathematics teachers (TPACK-MT) was a multiple-choice test covering the three broad dimensions TK, PK and CK. Items of TK were further based on the sub-dimensions namely, awareness of technology, appropriate use of technology and integration of technology in content. Similarly, the items under PK were framed according to the sub-dimensions namely, awareness of pedagogy, appropriate use of pedagogy, integration of pedagogy in content. After applying the procedure of standardisation of instruments, 17 items of the TPACK test were finalised. The reliability of TPACK test for mathematics teachers i.e. Cronbach's Alpha came out to be 0.70.

Similarly, for assessing the cognitive abilities of mathematics educators, a cognitive factors test for mathematics teachers was constructed and validated. The cognitive factors test involved three dimensions namely, analytical, evaluative and creative ability. All the items were based on the content of mathematics. The items under analytical and creative ability were multiple-choice items and the items under creative ability were open ended questions for the creative expression of mathematics educators. There were 16 items in the cognitive factors test for mathematics teachers. The instrument was reliable as the Spearman-Brown Prophecy Coefficient came out to be 0.75. Thus, both the instruments used in the present study were valid and reliable for investigating the TPACK and cognitive abilities of mathematics educators.

The scoring of the TPACK test for mathematics teachers was done using the answer key of the test. For the cognitive factors test, the scoring of analytical and evaluative ability was done with the answer key. For the analytical ability, items were based on deconstruction of mathematical figures or mathematical numbers e.g. 'deconstruction of the number 1527593.75' or 'breaking down the figure'. The evaluative ability of mathematics educators was assessed through the items in which the educators had to judge the hypothetical responses or calculations done by the students. The score of 1 or 0 was given based on their right or wrong judgement.

For the third part, i.e. creative ability, the Non-verbal Test of Creative Thinking (NVTCT) by Baqer Mehdi (2005) was referred to. The items under the creative ability were scored on three components i.e. Fluency, Elaboration and Originality. Fluency deals with the number of relevant responses given by the respondents and one score is given for each relevant response of mathematics educators. Elaboration deals with the depth of an explanation. For the minimum primary response, one score is given and for each additional idea given in the response, the respondents are given one score. Originality deals with the ability of giving uncommon responses relative to their peers. If the response is uncommon to any of the relative peers (i.e. given by one respondent only), then that response gets an originality score of 5; if a response is given by 1 or 2 percent of subjects (i.e. 2 respondents) then the originality score becomes 4; if a response is given by 2 to 3 percent of respondents (i.e. 3 respondents) then score is given as 3; if a response is given by 3 to 4 percent of respondents (i.e. 4 respondents) then originality score becomes 2; if the response is given by 4 to 5 percent of respondents (i.e. 5 respondents) then the score of 1 is given and if the response is given by more than 5 percent of respondents (i.e. more than 5 subjects) then originality score is given as 0. After administering the instruments to the mathematics educators, their scores of TPACK and cognitive abilities were subjected towards analysis for obtaining the results.

Results and Discussion

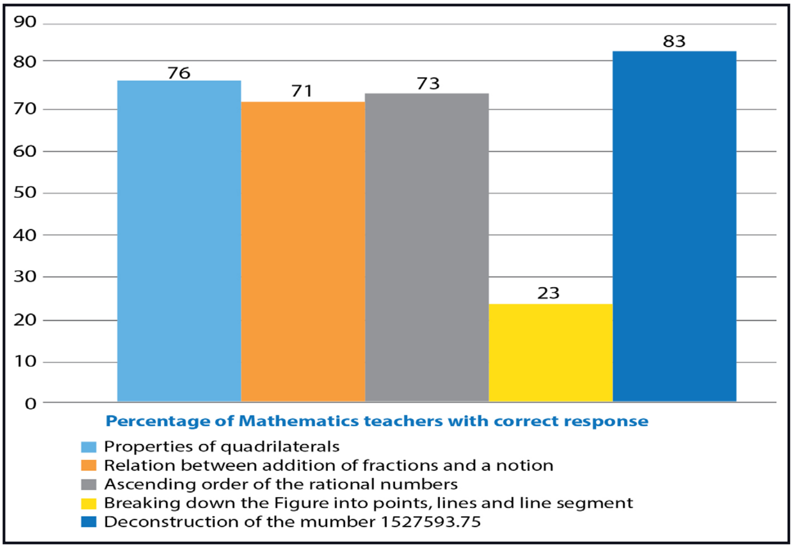
Cognitive Abilities of Mathematics Educators

The cognitive abilities i.e. analytical, evaluative and creative abilities of elementary mathematics educators were investigated through the cognitive factors test for mathematics teachers.

Analytical Ability

For assessing the analytical ability of mathematics educators, items based on elementary level mathematics were formulated where the teachers had to analyse the statement for giving the correct response. The percentage of teachers who showcased their analytical ability by giving correct responses to the items is shown in Figure 2. below;

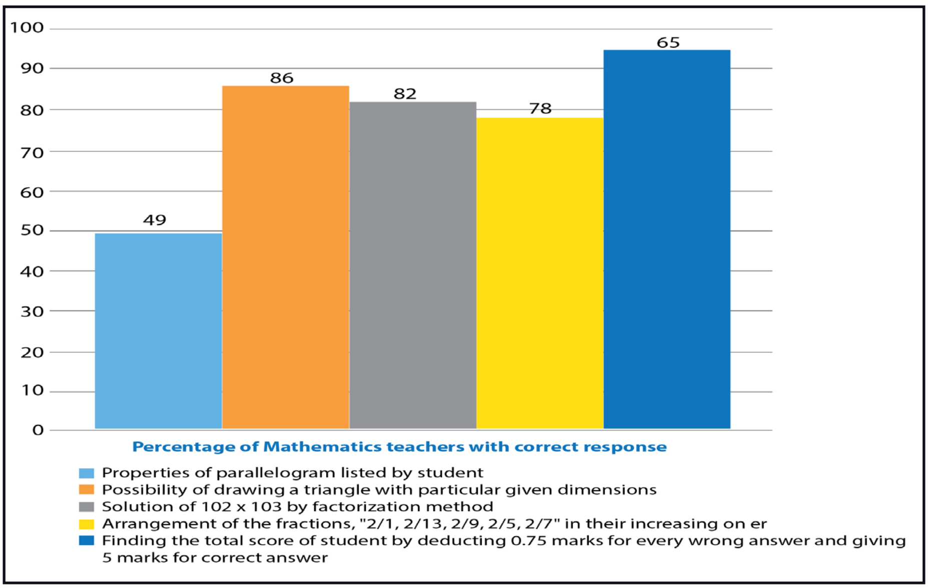
Figure-2: Analytical Ability of Mathematics Educators



Evaluative Ability

The evaluative ability of mathematics educators was determined by asking situation-based items from them. In these items, their ability to evaluate their students in mathematics was effectively shown through their responses as evident in Figure 3. Below;

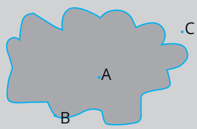
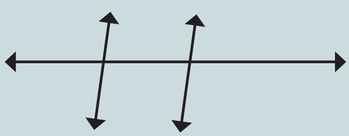
Figure-3: Evaluative Ability of Mathematics Educators



Creative Ability

While responding to the following questions mentioned in Figure 4. The mathematics educators were requested to think as creatively as they could by taking sufficient time for creative expression.

Figure-4: Creative Ability of Mathematics Educators

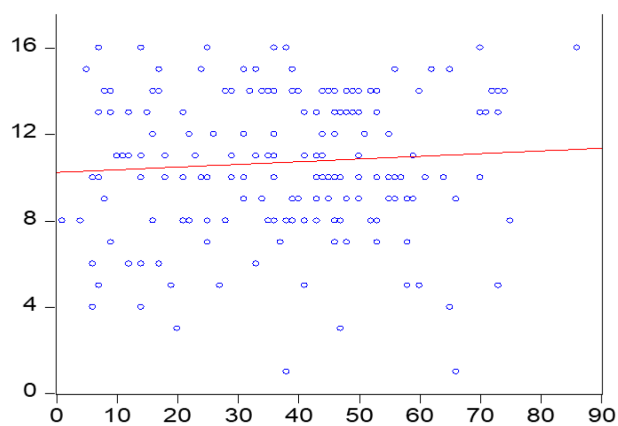
Items	Pattern of Responses given by Mathematics Educators
Iteml. To make the students better understand the concept of **'Interior, exterior and boundary of the closed curve'** as shown below in figure, what **examples from real life** will you give?  	For this item, the mathematics educators gave several interesting and unique examples like • Tennis court • Circle drawn on table and chalks placed on it • Agriculture field of farmer • Badminton ground and shuttle • Map of Punjab • Piece of cloth • Dartboard • Leaf of a plant
Item2. Frame **one question** on the topic 'Profit Percentage' **beyond the text book**.	The mathematics educators framed questions related to purchase of various things like laptop, chocolates, cricket ball, eggs, mobile, bananas and refrigerator.
Item 3. If you get an opportunity to talk about **values** with the students, which values will you try to develop in the students while discussing about the topic **'Fraction'** Also give a brief description about the way of developing them	The mathematics educators exhibited their creativity by listing out various values while discussing about the topic fraction. The unique values were • Positive and negative thoughts as numerator and denominator • Unity is strength • Eating by sharing • Equal division of work • Concept of big and small for teaching the values like respect for elders and taking care of young ones
Item 4. To teach the concept of **'transversal lines**', which examples can be given to the students **from their daily life** which relate the position of lines as shown below in the figure; 	The mathematics educators showcased their creativity with various examples like • Grills of window • Rods in the wheel • Railway lines • Bridge on the nver • Knitting needles in the roll of yarm • Folding the paper and putting the pencils • Luddo game • Electricity poles
Item 5. While teaching the topic **'Profit & Loss',** which story you will narrate for stimulating the interest of the students in the concept	Most of the stories narrated by the mathematics educators were unique relative to other respondents. All the mathematics educators got an originality score as 3 or more than 3 for this item. These stories were generally related to purchase of items. One story was related to an employer and employees which was a unique one among other stories of profit and loss.
Item 6. Formulate a **novel situation** for (7 5)x6 (One such situation for (5+8) × 6 is: Soham and Reetika work for 6 days, Soham works 5 hours a day and Reetika 8 hours a day. How many hours do both of them work in a week?	This item was responded similar to the example as stated above by many of the mathematics educators. They changed the names and figures and less input was there from their side.

The findings related to cognitive abilities show that the majority of mathematics educators were adequately able to analyse, evaluate and create something novel in their classroom teaching. The question lies in the implementation of these abilities while teaching the subject mathematics to their students.

Impact of Cognitive Abilities on TPACK

The study also aimed to study the influence of cognitive abilities of mathematics educators on their TPACK. For this, a composite score of cognitive abilities was calculated by adding the scores of analytical, evaluative and creative abilities for each sampled mathematics educator. Similarly, the scores of TPACK of corresponding mathematics educators was calculated using the scoring key of the TPACK test for mathematics teachers. For finding the relationship of cognitive abilities with TPACK, Pearson product-moment correlation was applied. Although the relationship of cognitive abilities with TPACK came out to be positive i.e. 0.073, yet it was not statistically significant. The reason behind the non-significant relationship of cognitive abilities with the TPACK lies in the outliers in the datasets and Pearson's product moment correlation is very sensitive to the extremities in the data under study as it is defined in terms of standard deviation (Kennedy, 2015; Schober et al., 2018). However, it is not always legitimate and logical to exclude the outliers before performing the correlation analysis (Kwak and Kim, 2017) as it may undermine the interpretive powers of outcomes. Further, the non-significance of such a relationship between variables does not preclude the possibility of the impact of cognitive abilities on TPACK as correlation does not imply causation (Bewick et al. 2003) because one variable may cause another variable to change. It is generally found in case of extreme values in data that two variables might not be significantly related to each other but may show strong association in regression. Thus, it was decided to apply Robust Least square regression which is suitable for such datasets with extreme values (Rousseeuw and Yohai, 1984) for further investigation of impact of cognitive abilities on TPACK. The Robust Least Square (RLS) regression is less sensitive to outliers as it cuts down their influence with weighted and reweighted least square regression. Thus, between the two ways of 'excluding outliers from the data' and 'including all the data points equally', RLS regression helps in finding the middle ground.

Figure 5: Leverage Plots of TPACK vs Cognitive Abilities



The properties of datasets of TPACK and cognitive abilities were studied by creating leverage plots which demonstrates in Figure 5. significant outliers in the data. It was revealed that cognitive abilities have significant outliers because of the creative ability scores included in the data as shown in Table 1.

Table-1: Example of creative ability scores of respondents for item no.1

Respondents	Responses	Fluency	Originality	Elaboration	Total Creative ability score
R_1	Example of pool, by closing the pool with ribbon. Standing the students at points A, B and C. and asking the students	1	0	4	5
R_2	Students can be given examples from daily life. For this, examples of tyre of scooter, bus, motor cycle can be given. Also, the example of trunk, tiffin box, ring can be given	6	20	6	32

From above examples of creative ability scores of respondents in Table 1, it is apparent that the scores include the extreme values which contribute to the significant outliers in the scores of cognitive ability of mathematics educators.

Thus, s-estimation approach of Robust Least Square Regression was applied through SPSS to study the impact of cognitive abilities on TPACK of mathematics educators. The results are presented in Table 2.

Table-2: Impact of Cognitive abilities on TPACK of Teachers

Regressor	Coefficient	Std. Error	z-Stat.	p-val.
Cognitive abilities	0.226*	0.013	16.85	0.000
R_N^2 **-Stat.**	284.19*			

Dependent Variable: TPACK of teachers *p < 0.01

Null Hypothesis under RN-sq.: All the coefficients are equal to zero

From the above Table 2, it is evident that the coefficient of cognitive abilities is found to be positive and statistically significant at 0.01 level of significance.

This indicates that the cognitive abilities of mathematics educators' positively influence their TPACK. Furthermore, one unit increase in the cognitive abilities of mathematics educators increases their TPACK by 0.226 units. These results are statistically robust as the R.N. – The squared statistic is relatively high and significant at 0.01 levels.

To conclude, it can be stated that there is a significant relationship between the cognitive factors and TPACK of mathematics educators. The present findings are concordant with the previous researches (Barham et al., 2018; Hiebert et al., 2017; Jia and Yang, 2024; Retnawati et al., 2018; Selart et al., 2008; Van Es and Sherin, 2002).

Conclusion

The outbreak of COVID-19 has again pushed the idea of technology-integration to the forefront with more momentum and the TPACK framework is still relevant in this context. Among the various factors affecting the TPACK of mathematics teachers, cognitive abilities i.e. analytical, evaluative and creative abilities are the 21st century skills which are having significant impact on TPACK of mathematics teachers. Thus, the findings of the present study indicate the need of developing cognitive abilities of teachers for the regular development of TPACK in the contemporary virtual learning environments. Although, this study is confined to the application of TPACK in mathematics; however, science and other subjects represent other avenues for further exploration about technology integration. Integrating Affective (attitudinal) dimensions into the TPACK framework, as proposed by McLay and Reyes (2024), can be investigated to enhance the significance of technological integration among educators, which is crucial for an effective classroom. Similarly, with the rise of generative AI, frameworks such as AI-TPACK, which was familiarised by Ning et al. in 2024, emphasise how important it is for teachers to comprehend how AI technology, teaching strategies, and subject-matter expertise interact. As AI becomes more prevalent in educational applications, there is room for research on teachers' use of AI-TPACK to enhance student learning with new educational technologies.

Thus, while preparing the pre-service teachers for their profession of teaching, the importance of cognitive abilities and TPACK may be borne in mind. The professional development programs may be organised for the in-service teachers where they can update their knowledge and skills to keep up with the increasing needs of technology-mediated learning.

Limitations

The limitation of the present study lies in its small sample of 189 mathematics educators. The respondents were reluctant to spare time for responding to the items of creative ability. Despite this limitation, the present study highlights the higher cognitive abilities of mathematics educators and its significant impact on their TPACK.

References

Akhter, N., & Akhter, N. (2018). Learning in mathematics: Difficulties and perception of students. *Journal of Educational Research, 21*(1), 147-163.

Akturk, A.O. & Saka ozturk, H. (2019). Teachers' TPACK levels and students' self-efficacy as predictors of students' academic achievement. *International Journal of Research in Education and Science (IJRES)*, *5*(1), 283-294.

Angeli, C., & Valanides, N. (2008). *TPACK in pre-service teacher education: Preparing primary education students to teach with technology*. Paper presented at the 2008 Conference of the American Educational Research Association, New York City, NY.

Bakar, N. S. A., Maat, S. M., & Rosli, R. (2020). Mathematics Teacher's Self-Efficacy of Technology Integration and Technological Pedagogical Content Knowledge. *Journal on Mathematics Education*, *11*(2), 259–276. https://doi.org/10.22342/jme.11.2.10818.259-276

Barham, B. L., Chavas, J., Fitz, D., & Schechter, L. (2018). Receptiveness to advice, cognitive ability, and technology adoption. *Journal of Economic Behavior & Organization*, *149*, 239–268. https://doi.org/10.1016/j.jebo.2017.12.025

Bewick, V., Cheek, L., & Ball, J. (2003). Statistics review 7: Correlation and regression. *Critical care (London, England), 7*(6), 451-459. https://doi.org/10.1186/cc2401

Elim, E. H. S. Y. (2024). Promoting cognitive skills in AI-supported learning environments: the integration of bloom's taxonomy. *Education 3-13*, 1-11. https://doi.org/10.1080/03004279.2024.2332469

Hiebert, J., Miller, E., & Berk, D. (2017). Relationships between mathematics teacher preparation and graduates' analyses of classroom teaching. *The Elementary School Journal*, *117*(4), 687–707. https://doi.org/10.1086/691685

Jia, X., & Yang, Z. (2024). Research on the Cognitive Situation of Pre-Service Mathematics Teachers for Teaching Evaluation of High School Mathematics under the New Curriculum Standards in China. *Asian Journal of Education and Social Studies*, *50*(9), 90–104. https://doi.org/10.9734/ajess/2024/v50i91572

Juanda, A., Shidiq, A. S., & Nasrudin, D. (2021). Teacher Learning Management: Investigating Biology Teachersâ€TM TPACK to conduct learning during the COVID-19 outbreak. *Jurnal Pendidikan IPA Indonesia*, *10*(1), 48–59. https://doi.org/10.15294/jpii.v10i1.26499

Kartal, B., & Çınar, C. (2022). Preservice mathematics teachers' TPACK development when they are teaching polygons with geogebra. *International Journal of Mathematical Education in Science and Technology*, *55*(5), 1171–1203. https://doi.org/10.1080/0020739x.2022.2052197

Kennedy, M. (2015). *Practical Petrophysics*, Development in Petroleum Science, Chapter-2, Vol. 62, p.21-72, 1st edition, Elsevier

Kersting, N. B., Givvin, K. B., Sotelo, F. L., & Stigler, J. W. (2009). Teachers' Analyses of Classroom Video Predict Student Learning of Mathematics: Further explorations of a novel measure of teacher knowledge. *Journal of Teacher Education*, *61*(1–2), 172–181. https://doi.org/10.1177/0022487109347875

Klassen, R. M., & Kim, L. (2019). Selecting teachers and prospective teachers: A meta-analysis. *Educational Research Review*, *26*, 32-51.

Kryscynski, D., Reeves, C., Stice, Lusvardi, R., Ulrich, M., & Russell, G. (2017). Analytical abilities and the performance of HR professionals. *Human Resource Management*, *57*(3), 715–738. https://doi.org/10.1002/hrm.21854

Kwak, S. K., & Kim, J. H. (2017). Statistical data preparation: Management of missing values and outliers, *Korean Journal of Anesthesiol, 70*, 407-411

Li, M., & Li, B. (2024). Unravelling the dynamics of technology integration in mathematics education: A structural equation modelling analysis of TPACK components. *Education and Information Technologies*. https://doi.org/10.1007/s10639-024-12805-w

Mansour, N., Said, Z., & Abu-Tineh, A. (2024). Factors impacting science and mathematics teachers' competencies and self-efficacy in TPACK for PBL and STEM. *Eurasia Journal of Mathematics Science and Technology Education*, *20*(5), em2442. https://doi.org/10.29333/ejmste/14467

Marbán, J. M., & Sintema, E. J. (2021). Pre-service teachers' TPACK and attitudes toward integration of ICT in mathematics teaching. *International Journal for Technology in Mathematics Education*, *28*(1), 37-46.

McLay, K. F., & Reyes Jr, V. C. (2024). Beyond TPACK: A case for foregrounding affect in technology rich 21st century teaching and learning. *Journal of Computer Assisted Learning*, *40*(6), 3201-3214. https://doi.org/10.1111/jcal.13055

Mehdi, B. (2005). Non-verbal Test of Creative Thinking (NVTCT) Manual. *National Psychological Corporation*.

Mishra, P. (2019). Considering Contextual Knowledge: The TPACK Diagram Gets an Upgrade. *Journal of Digital Learning in Teacher Education*, *35*(2), 76–78. https://doi.org/10.1080/21532974.2019.1588611

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A Framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054.

Ning, Y., Zhang, C., Xu, B., Zhou, Y., & Wijaya, T. T. (2024). Teachers' AI-TPACK: Exploring the relationship between knowledge elements. *Sustainability*, *16*(3), 978. https://doi.org/10.3390/su16030978

Norton, S. (2019). Middle school mathematics pre-service teachers' content knowledge, confidence and self-efficacy. *Teacher Development, 23*(5), 529-548.

Ozudogru, F., & Ozudogru, M. (2019). Technological Pedagogical Content Knowledge of Mathematics Teachers and the Effect of Demographic Variables. *Contemporary Educational Technology*, *10*(1), 1–24.

Retnawati, H., Djidu, H., Kartianom, K., Apino, E., & Anazifa, R. D. (2018). Teachers' knowledge about higher-order thinking skills and its learning strategy. *Problems of Education in the 21st Century*, *76*(2), 215–230. https://doi.org/10.33225/pec/18.76.215

Rousseeuw P., Yohai V. (1984) Robust Regression by Means of S-Estimators. In: Franke J., Härdle W., Martin D. (Eds) Robust and Nonlinear Time Series Analysis. *Lecture Notes in Statistics*, 26. Springer, New York, NY. https://doi.org/10.1007/978-1-4615-7821-5_15

Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation Coefficients: Appropriate use and interpretation, *Anesthesia & Analgesia, 126*(5), 1763-1768.

Selart, M., Johansen, S. T., Holmesland, T., & Grønhaug, K. (2008). Can intuitive and analytical decision styles explain managers' evaluation of information technology? *Management Decision*, *46*(9), 1326–1341. https://doi.org/10.1108/00251740810911975

Utari, R. S., Amalia, L., & Rohman, N. (2024). Developing a local instructional theory using TPACK framework to support students' collaborative skills. *AIP Conference Proceedings*. https://doi.org/10.1063/5.0201052

Van Es, E. A., & Sherin, M. G. (2002). Learning to notice: Scaffolding new teachers' interpretations of classroom interactions. *Journal of Technology and Teacher Education, 10*(4), 571-596.