International Research Journal of Multidisciplinary Scope (IRJMS), 2026; 7(2): 1181-1195

Original Article | ISSN (O): 2582-631X DOI: 10.47857/irjms.2026.v07i02.09095

Inserting Technology and Balancing of Technological Pedagogical Content Knowledge (TPACK) Venn Diagram

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Abstract

Learning technologies have grown from industrial period 4.0 in education. This study examined Indonesian social studies and geography teachers' Technological Pedagogical Content Knowledge (TPACK) and measured technology's role against the Venn diagram. This study used two stages of questionnaire distribution to survey participants. The first step involved 162 people studying TPACK components. The participants in second stage were 40 teachers who were attending a teacher professional training with a focus on studying the balance of the TPACK Venn diagram. The results showed that teachers' knowledge about TPACK was in the range of fairly good. The balance of the TPACK Venn diagram can be obtained if the difference between Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK) = 0; an almost balanced form of the Venn diagram if the difference between TCK and TPK = 0.01 - 1; and the shape of the Venn diagram is not balanced if the difference between TCK and TPK > 1. In constructivist learning, these findings have different implications. If the function of technology is greater in intersection with subject matter, technology should be used to develop more modern teaching materials such as the development of micro learning, digital teaching materials and/or other computer-based learning tools. On the other hand, if the function of technology is greater in intersection with pedagogy, technology should be used to develop constructive learning.

Keywords: Geography, Inserting Technology, Investigating, TPACK, Venn Diagram.

Introduction

The Technological Pedagogical Content Knowledge (TPACK) framework has been widely discussed in education, particularly in relation to how teachers integrate subject matter, pedagogy and technology in classroom practice. The conceptual roots of TPACK emerged from earlier discussions about Pedagogical Content Knowledge (PCK), which emphasized that effective teaching requires not only mastery of subject matter but also understanding of how to teach specific content effectively (1–4). Studying content and teaching methods separately may reduce learning effectiveness and even lead to student misunderstanding of certain topics (5). Around 2004, the integration of technology began to be formally conceptualized through a triangular relationship among content, pedagogy and technology, later evolving into the TPCK framework and eventually renamed TPACK in 2007. The framework was represented using a Venn diagram showing intersections among knowledge domains such as content knowledge, pedagogical knowledge, technological knowledge, pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge and technological pedagogical content knowledge (6–9). Within this framework, content knowledge refers to factual, conceptual, procedural and metacognitive understanding of subject matter, pedagogy refers to knowledge of instructional strategies and technology refers to knowledge of tools ranging from simple instructional media to digital technologies. When these domains are integrated, they generate contextual knowledge that enables teachers to design more meaningful learning experiences. The integration of TPACK allows teachers to understand student learning difficulties, select appropriate strategies and determine how technology can support conceptual understanding. However, as teachers work in different contexts, subjects and technological environments, TPACK

(Received 10th November 2025; Accepted 12th March 2026; Published 18th April 2026)

implementation always appears in unique combinations depending on classroom conditions (10). Teachers are therefore required to construct balanced TPACK integration according to their disciplinary context. The TPACK framework has been popular in Indonesia since around 2010 and has been frequently used in developing instructional designs. Teachers generally attempt to align content characteristics, pedagogical strategies and technology in their teaching practices (11). However, differences emerge between in-service teachers and prospective teachers. Teacher candidates often begin technology integration from the technological component rather than from content understanding, which may result in strong technological application but weak conceptual delivery of subject matter. As a result, students may find it difficult to understand the material even when technology is used effectively.

Preliminary observations indicate that many teachers believe they already possess sufficient knowledge of content, pedagogy and technology (12). Teachers tend to feel confident about their subject mastery, instructional strategies and use of digital tools. Nevertheless, when asked to determine appropriate pedagogical strategies for specific content types, uncertainty often appears. Similarly, teachers do not always differentiate technological use when teaching factual, conceptual, procedural, or metacognitive knowledge. Instructional delivery often uses uniform pedagogical approaches and identical technologies regardless of content characteristics.

In the broader literature, research on technology integration and constructivist learning shows that technology can support inquiry-based learning environments and student knowledge construction (13-16). Technology facilitates case-based learning, collaboration, information gathering and exposure to multiple perspectives through multimedia resources such as documents, images, audio, video and simulations (17, 18). Constructivist learning environments supported by technology enable students to actively build knowledge when instructional design stimulates cognitive engagement (19-22). Multimedia presentations combining visual and verbal information also help students understand complex contexts more easily and support independent learning, reinforcement and knowledge construction (23-27).

Despite extensive research, criticism of the TPACK framework continues to emerge. Some scholars argue that misunderstandings about TPACK remain widespread and that the traditional three-circle Venn diagram may limit innovation (28). Reviews of more than 3000 publications indicate that teachers' understanding of TPACK concepts, measurement and implementation remains limited (29, 30). Questions about how TPACK should be measured, taught and applied effectively in technology-enhanced learning environments remain open research agendas (31). Other scholars suggest simplifying the conceptual model by focusing on intersections between pedagogical content knowledge and technological knowledge rather than maintaining the canonical three-circle representation (32-37). The conceptual intersection between PCK and TK of the study is an effective teaching with technology emerges from the convergence of technological, pedagogical and subject expertise within educational settings. This edition enhances prior work by broadening theoretical frameworks, analyzing changing contextual factors (including cultural, social and educational environments) and tackling current issues such as research methodologies and the impact of artificial intelligence on teacher knowledge and practice (37).

In the information age, rapid technological development requires teachers to continuously strengthen subject-matter knowledge while also adapting instructional strategies that help students construct knowledge from abundant information sources (38-40). Teachers are expected to shift from information providers to facilitators who guide students in interpreting and using information constructively. However, difficulties in integrating technology effectively into pedagogy and content remain a significant challenge in classroom practice. This study investigates TPACK balance among social science teachers. This study specifically examines the following research inquiries:

(a) What is the extent of instructors' understanding in each TPACK component?

(b) What is the degree of balance in the TPACK Venn diagram concerning the distinction between TCK and TPK?

(c) What is the impact of TCK or TPK dominance on the role of technology in instructional practice?
(d) In what manner may TPACK equilibrium be understood to facilitate constructivist learning design?

Methodology

Research Design

In Indonesia, Social Studies is a subject taught at the Elementary School and Junior High School levels. The content is a combination of a number of social sciences, namely geography, economics, history, sociology and anthropology. The formulation of the objectives of this subject is to develop the character of students to become good citizens, be familiar with concepts related to community life and their environment and have an awareness of social and human values.

This research utilized a sequential explanatory mixed-methods framework with a predominately quantitative design. The initial phase was a comprehensive survey to assess teachers' TPACK components and ascertain the balance of the TPACK Venn diagram by TCK–TPK differential analysis. The second phase encompassed a professional development initiative designed to enhance TPACK equilibrium and elucidate its instructional ramifications. At the High School Level, social sciences as constituents of social science subjects are separated into separate subjects, namely geography, economics, history, sociology and anthropology and must be followed by students in specialization group in social sciences. This policy is of course beneficial, because the social studies subject has provided students with initial knowledge about the essential materials of each social science discipline. Such as geography essential material that studies human life, place and environment, space and scale can be studied since children are still in elementary school and continued in junior high school. At the high school level, the essential material of geography is deepened and expanded in accordance with the applicable curriculum. Social science essential material which is taught on an ongoing basis with geography material in high school. The essential materials of social sciences and geography across education levels are shown in Table 1.

Table 1: Essential Materials of Social Sciences and Geography in ES, JHS and SHS

Social Sciences in ES	Social Sciences JHS	Geography in SHS
Knowledge of maps (Grade IV)	Knowledge of maps (Grade VII)	Basic Mapping Knowledge (Grade X)
Relationship between Natural Appearances and Socio-Cultural Appearances (Grade IV)	Atmospheric Symptoms (Grade VII)	Dynamics of the Lithosphere (Grade X)
N/A	Hydrosphere Symptoms (Grade VII)	Hydrosphere Dynamics (Grade X)
N/A	Relationship between Geographical Position and Climate and Seasonal Changes in Indonesia (Grade VIII)	Atmospheric Dynamics (Grade X)
N/A	Geographical and Astronomical Position of Indonesia (Grade VIII)	Indonesia's Strategic Position as a World Maritime Axis (Grade XI)
Ways for Coping with Natural Disasters (Grade VI)	N/A	Natural Disaster Mitigation (Grade XI)
	The Process of Forming the Face of the Earth (GradeVII)	Earth As Life Space (Grade X)
Natural and Social Appearances of Neighboring Countries (Grade VI)	Developing Countries and Developed Countries (Grade IX)	Cooperation between Developed and Developing Countries (Grade XII)
N/A	Distribution of Flora and Fauna in Indonesia (Grade VIII)	Flora and Fauna in Indonesia and the World (Grade XI)
Types of Natural Resources and Their Distribution Map (Grade IV)	N/A	Management of Indonesia's Natural Resources (Grade XI)
Getting to know Indonesia's Diversity of Natural Appearances (Grade V)	The Impact of the Diversity of the Earth on Human Life (Grade VII)	N/A
Utilization of Natural Resources for Economic Activities (Grade IV)	The Nature of Sustainable Development and Its Characteristics (Grade VIII)	Utilization of natural resources with the principles of sustainable development (Grade XI)
N/A	Population Problems in Indonesia (Grade VIII)	Population Dynamics in Indonesia (Grade XI)
Natural Resources Conservation Efforts (Grade IV)	Forms of Environmental Damage and Environmental Conservation Efforts (Grade VIII)	N/A

The learning process of social studies and geography in Indonesia, both at the elementary, junior high and high school levels, is determined by the government, namely that it is mandatory to use a scientific approach with variants that can be selected, namely the inquiry learning model, problem based learning and project based learning. In the context of the TPACK framework, this regulation does not support the development of social studies and Geography learning innovations. The process standard setting states that a certain model cannot develop teacher creativity in developing learning that is in accordance with the characteristics of the teaching material. Instead of increasing innovation, it will often reduce the quality of scientific learning in the classroom. The scientific learning syntax which consists of five steps, namely observing, asking, looking for data, associating and communicating cannot be fulfilled in a learning cycle. The teacher can only carry out two or three steps of learning and it is not in accordance with the theory of the sequence of scientific learning syntax.

The technological aspects available in schools for social studies and geography subjects are very limited. Government regulations do not require schools to have social studies and geography laboratory rooms. Thus, it can be ascertained that teachers will be limited in utilizing technology in learning. The results of the 2018 study, of the 103 schools surveyed are as follows (Table 2). Each school ideally has 4 - 6 units of Geography learning tools or technologies (data for social studies subjects do not exist). They are summarized in Table 2.

Table 2: Ownership of Geography Learning Tools, Media and Technology (41)

Learning aids	Average of Ownership		
	F	Rounding	% of the expected number (6 pieces)
Atlas	1.8	2	45.04
Laptop	1.8	2	44.63
Computer/Desktop	1.8	2	44.42
Globe	1.7	2	43.60
Sampel Map of Indonesia	1.7	2	43.60
LCD	1.7	2	42.15
Compass	1.2	1	29.34
Image/Chart	1.0	1	25.83
Rock Comparator	1.0	1	24.59
Sampel Topographic Map	0.8	1	18.80
GPS	0.5	0	12.19
Sample Aerial Photos	0.3	0	8.68
Stereoscope	0.3	0	7.02

This study used a survey method (41) which aimed to investigate the level of knowledge of respondents about TPACK components and how teachers integrated technology components in the TPACK framework. The survey consists of two stages; the first was carried out on groups of participants who volunteer to fill out a questionnaire about the TPACK components, the second stage was carried out on teachers who were attending professional education training to measure the balance of the TPACK Venn diagram when determining methods and technology to convey certain materials.

Sample and Data Collection

The study involved social studies and geography teachers who willingly engaged in the initial phase of data collecting by completing an online questionnaire (41). The study employed a non-probability purposive sampling method, selecting participants based on their pertinence to the research purpose, specifically teachers of social studies or geography who engage in classroom learning methods utilizing pedagogy and technology. This methodology was selected to guarantee that the participants had practical experience pertinent to the TPACK framework under examination.

The questionnaire was distributed via teacher professional networks, school communication groups and regional teacher associations. Participation was optional and respondents filled out the questionnaire a single time. Fundamental screening inquiries were employed to verify that individuals were actively instructing social studies or geography during the data gathering period. This technique guaranteed that the gathered data accurately reflected the target population pertinent to the research aims.

Participants who filled out the first stage of the questionnaire were teachers of social studies and geography subjects (41). The number of participants who filled out the questionnaire was 162 people consisting of 64 male (39.51%) and 98 female (60.49%). The education level of participants at the undergraduate level was 146 people (90.12%), 15 people at the master level (9.26%) and 1 person at the doctoral level (0.62%). The age of participants in the range 24 - 31 years was 71 people (43.83%), ages in the range 32 - 43 years were 68 people (41.98%) and ages in the range 44 - 55 were 23 people (14.20%). Participants teaching experience <5 years totaled 53 people (32.72%), 5-15 years experienced totaled 41 people (25.31%), 15-20 years experienced 15 people (9.26%) and experienced in over 20 years as many as 12 people (7.41%). Of this number, there were 60 teachers who had educator certificates (37%) and 102 people who did not have educator certificates (62.96%). The place of teaching assignment as an important component which is presented in Table 3 below that needs to be explained is the place of teaching, namely.

Table 3: Level of Teaching School

Teachers' Status	Total	Percentage (%)
Social studies teacher in elementary school	29	17.90
Social studies teacher in junior high school	59	36.42
Geography Teacher in high school/religious high school	74	45.68
Total	162	100.00

Participants who filled out the second stage questionnaire were teachers of social studies and geography subjects who were attending the training to obtain professional certificates as teachers in social studies and geography. There were 40 participants who were willing to fill out the instrument consisting of 10 male (25%) and 30 female (75%). The age of the participants was between 26 - 57 years with the distribution of social studies teachers in elementary school as many as 11 people (27.5%), social studies teachers in junior high school as many as 10 people (25%) and geography high school teachers as many as 19 people (47.5%).

The first stage of data collection used a questionnaire via google form. The data collected is the teacher's perspective on understanding Content (C), Pedagogy (P), Technology (T), Pedagogical Content Knowledge (PC), Technological Content Knowledge (TC), Technological Pedagogical Knowledge (TP) and Technological Pedagogical Content Knowledge (TPACK). The elements or indicators of investigative instruments were according to the method of a sequential explanatory mixed-methods framework with a predominately quantitative design (3). The second stage also uses google form to dig up information about the choice of methods and technology in a number of materials taught at the elementary, junior high and high school levels. In this study, nine essential materials were selected, namely (a) Map Components, (b) Enlarge/Decrease the Map Scale, (c) Variety of Earth/ Earth Surface Forms as Life Space, (d) Plate Tectonics, (e) Volcanoes, (f) Earthquakes, (g) Types of Natural Resources, (h) Efforts to Conserve Natural Resources and (i) Association of South East Asian Nation (ASEAN) and Developing Countries. Apart from the choice of methods and technology, information was also collected about their effectiveness in learning.

Analyzing of Data

The first stage research data were processed and analyzed quantitatively, namely by determining the level of teachers' knowledge about the components of TPACK. The analysis used descriptive statistics, namely frequency, average and standard deviation. The data on the findings of the second stage were processed by tabulating the overlapping values between TPACK components. The diameter of the circle is assumed to be 5 cm (may also be 10 or some other quantity). The slices between the content - method, method - technology and content - technology circles if they are fully intertwined, they are arranged 5/5 - 5/5 - 5/5. The balanced and unbalanced TPACK Venn diagram to be used as a data analysis approach is shown on Figure 1 below.

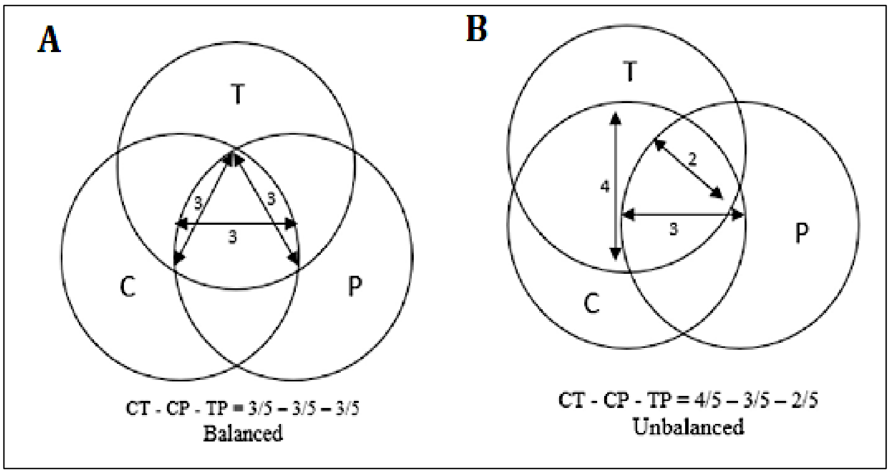

Figure 1: Equilibrium Analysis of the TPACK Venn Diagram: **(A)** Balanced TPACK Venn diagram, **(B)** Unbalanced TPACK Venn diagram

Table 4: Balanced and Unbalanced TPACK Venn

Venn Diagram	PCK	TCK	TPK	Recommendation
Balanced	3/5	3/5	3/5	Determining the type of technology can pay attention to the content or learning methods
Unbalanced	3/5	4/5	2/5	Determining the type of technology is recommended to pay attention to the content components first
Unbalanced	3/5	2/5	4/5	Determining the type of technology is recommended to pay attention to the content components first

A balanced TPACK Venn diagram signifies the ideal amalgamation of technological knowledge, pedagogical knowledge and content knowledge, while an unbalanced arrangement reflects the predominance of one area and restricted integration. The contrast is illustrated in Table 4.

Validity and relevance

Participants were chosen for TPACK measurement and classification relevance. Inclusion criteria were in-service social studies or geography teachers, teachers who completed the PCK, TCK and TPK questionnaire and responses that allowed TPACK Venn diagram balance classification based on component score comparison. When PCK, TCK and TPK scores were equal, the TPACK Venn diagram was balanced. When one component—particularly TCK or TPK—dominated, it was unbalanced. Table 4 lists operational criteria for balanced and unbalanced patterns. Incomplete questionnaire replies, data that could not be sorted into TPACK balance patterns, individuals outside the designated subject areas and invalid or duplicate submissions were excluded.

Results

Investigating Teacher's Knowledge Level about TPACK

Investigation was carried out systematically, namely digging up detailed information on each component and the slices between TPACK components. In each investigation result, a ranking order is carried out. The results of the investigation are presented in seven tables. Each table displays four main columns, namely the statement column, percentage, average and standard division. The statement column is a component of a specific attribute of the TPACK component; percentage column is the proportion of a certain component of the TPACK component; average is the value or quality of the participants' knowledge in understanding the TPACK components; and standard deviation is a representation of data distribution that shows the quality of the data as a whole as presented in Table 5.

Table 5: Ranking of Social Studies and Geography Teacher's Knowledge about Technology (TK)

Statement	(%)	Mean	SD	Ranking
Ability to use software such as word processing (Word), presentation charts (PowerPoint), spreadsheets (Excel)	9.60	3.88	0.90	1
Ability to use computers and other equipment (printers, scanners, digital cameras, projectors and digital whiteboards)	9.57	3.87	0.93	2
Ability to use social media (Twitter, Facebook, Blog and Wikipedia)	9.51	3.85	0.88	3

Ability to use Zoom meeting applications, Google Meeting, WebEx and Whatsapp	9.43	3.81	0.85	4
Ability to use LMS software programs (such as: Google Classroom, Edmodo, etc.)	9.30	3.76	0.89	5
Ability to install required software programs	8.59	3.48	1.08	6
Ability to create and edit videos	8.17	3.30	1.05	7
Ability to overcome technical problems with computers and other accessories (troubleshoot)	7.51	3.04	1.08	8
Ability to create personal websites	7.50	3.03	0.98	9
Ability to use GIS, Remote Sensing and Cartography data processing applications.	7.42	3.00	0.99	10
Ability to use Cloud-based Geographical data (Cloud/Internet data)	6.96	2.81	1.08	11
Ability to create animated media	6.44	2.60	1.01	12
Total	100.00	-	-	
Average		3.37	0.98	

Table 5 shows that the Social Studies and Geography Subject Teachers' Knowledge about Technology (TK) is on average sufficient. However, based on the standard deviation value, the teacher's ability is not evenly distributed. There are teachers who are not yet skilled at installing software programs, editing videos, solving computer technical problems (troubleshoot) and utilizing cloud-based data. Table 5 reveals that social studies and geography instructors have moderate technological knowledge (TK), averaging 3.37, indicating adequate technology utilization. The top competencies are word processing, presentation software, spreadsheets, computer equipment, social media and online meeting apps, indicating that teachers are comfortable using technology for instruction and communication. Software installation, video editing, troubleshooting, website building, GIS and remote sensing applications, cloud-based geographical data utilization and animation media development scored lower. These findings suggest that teachers are better at broad operating skills than advanced or subject-specific ones. Teachers' high standard deviation values reflect uneven technological ability. This condition may affect TPACK balance, notably in enhancing Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK) for better social science technology integration.

The teacher's ability to use software such as word processor, power point, spreadsheets, social media applications, Learning Management System (LMS) applications and using computer devices such as printers, scanners, digital cameras, projectors and digital whiteboards is relatively mastered which is presented in Table 6.

Table 6: Rank of Social Studies and Geography Teacher's Knowledge about Pedagogy (PK)

Statement	(%)	Mean	SD	Ranking
Class management ability	17.61	3.31	0.49	1
Ability to plan learning activities both in groups and classically	17.22	3.24	0.53	2
Ability to connect various concepts in Inquiry or Scientific learning	16.50	3.10	0.53	3
The ability to assess student competencies, both cognitive, affective and psychomotor by various methods	16.46	3.10	0.58	4
Ability to apply various teaching methods (such as: Inquiry, Scientific, Problem Based Learning, Project Based Learning, Cooperative, etc.)	16.46	3.10	0.56	5
Knowledge of common mistakes or misconceptions in Social Studies and Geography subjects	15.74	2.96	0.48	6
Total	100.00	-	-	
Average	-	3.14	0.53	

Table 6 describes the teachers' perceptions of their own abilities in managing the class, starting from planning lessons, applying learning models and assessing student competencies. His self-assessment was above 3.0 on a scale of 1 - 5. Except for the ability to detect common mistakes and misunderstandings in the subject, participants only rated himself 2.96 (less capable). It shows percentage distribution, mean scores and ranking of instructors' PK across six abilities. PK scores averaged 3.14 (SD = 0.53), showing strong teaching skill.

Class management (Mean = 3.31) was the highest-ranked competency, followed by learning activity planning [3.24]. Connecting concepts in inquiry learning, assessing student competencies and applying multiple teaching approaches had equal mean scores (Mean = 3.10). Knowledge of student social studies and geography misunderstandings was lowest (Mean = 2.96). Data show teachers have balanced pedagogical knowledge, with greater classroom management and instructional planning skills. Table 7 below displayed the distribution of participants' knowledge of course materials of the participants.

Table 7: Ranking of Social Studies and Geography Teacher's Knowledge about Teaching Material (CK)

Statement	(%)	Mean	SD	Ranking
Have enough confidence to master the subject matter	13.61	3.85	0.85	1
Have sufficient information about the subjects he teaches	13.46	3.81	0.82	2
Have the ability to assist colleagues with knowledge and skills in subjects	12.98	3.67	0.87	3
Actively participates in conferences, seminars, training according to subject areas.	12.58	3.56	0.96	4
Able to follow up on new information in accordance with scientific developments from journals, books and others	12.13	3.43	0.89	5
Know the different types of factual, conceptual, procedural and metacognitive knowledge in the subjects	12.13	3.43	0.91	6
Able to quote expert opinion in accordance with the subject area	11.97	3.39	0.87	7
Adequately know the experts and scholars in the field of specialization of the subject	11.15	3.15	0.95	8
Total	100.00	-	-	
Average		3.54	0.89	

Table 7 shows the data on the distribution of participant knowledge about teaching materials. Participants rated themselves around 3.54 with a standard deviation of 0.89. Of the eight components investigated, the percentages were very even, with the highest score being 13.61 and the lowest being 11.15. Based on these data, it can be concluded that teachers have sufficient competence to teach their subjects. They master the teaching material quite well. It shows moderate to high Content Knowledge (CK) among teachers (M = 3.54). The highest indications are teachers' trust in subject content and subject knowledge. Professional development and teamwork improve information comprehension. Less acquaintance with scholars, capacity to reference expert opinions and comprehension of diverse knowledge categories reflect restricted academic and disciplinary perspectives. These findings show that teachers' practical CK is strong but needs academic and conceptual improvement to promote TPACK integration. The value changes. Self-assessment showed low scores for technological and pedagogical proficiency are displayed in Table 8.

Table 8 shows the shift in values. At the time of self-assessment separately, namely knowledge of technology and pedagogy, both showed low scores. The average knowledge of technology is 3.37 and knowledge of pedagogy is 3.14. However, when combined into Technological Pedagogical Knowledge (TPK), the score increased to 3.64. This fact shows that the integration between components has a positive value. Participants find it easier to manage and use learning models in the classroom when they are supported by technology. In Table 8, teachers' Technological Pedagogical Knowledge (TPK) is generally good (Mean = 3.64; SD = 0.88). Social media in teaching and video-conferencing platforms for distant learning are the greatest competencies, demonstrating significant communication-based technology knowledge. Technology utilization for classroom administration and learning evaluation, which ranked lower, indicate that technology integration is still evolving.

Table 8: Rank of Social Studies and Geography Teacher's Knowledge about Pedagogical Technology (TPK)

Statement	(%)	Mean	SD	Ranking
Ability to use social media in teaching	14.81	3.78	0.87	1
Ability to use conference media (Zoom, WebEx, Google Meet) in distance learning	14.55	3.71	1.00	2
Ability to use new technology to increase student engagement in learning	14.33	3.65	0.82	3
Ability to use new technology to develop learning approaches and processes	14.13	3.60	0.84	4
Able to choose suitable new technology to motivate student learning	14.11	3.60	0.85	5
Ability to manage classrooms supported by new technology effectively	14.06	3.59	0.94	6
A ability to use new technology in evaluating student learning outcomes	14.01	3.57	0.85	7
Total	100.00	-	-	
Average	-	3.64	0.88	

Table 9: Ranking of Social Studies and Geography Teacher's Knowledge about Pedagogical Content Knowledge (PCK)

Statement	(%)	Mean	SD	Ranking
Ability to prepare effective lesson plans (scenarios) to deliver subject matter	20.30	3.73	0.80	1
Ability to achieve learning objectives as planned	20.30	3.73	0.78	2
Ability to assist students in connecting between subject matter concepts according to scientific disciplines	20.03	3.68	0.84	3
Knowledge about learning methods that are in accordance with the characteristics of the teaching material	19.72	3.62	0.83	4
Ability to develop learning outcome assessment tools	19.66	3.61	0.88	5
Total	100.00	-	-	
Average	-	3.67	0.83	

For a more balanced TPACK Venn diagram, TPK integration must be strengthened because technology is used more for instructional delivery and student engagement than assessment and classroom administration. The results for each instructional component and content understanding are shown in Table 9, which reveals an unexpected score.

Table 9 shows a surprising score; the scores for each pedagogic component and material knowledge are only 3.14 and 3.54. However, when combined into Pedagogical Content Knowledge (PCK) the value increased to 3.67. This data also shows that teachers have the potential to generate creativity and new ideas in developing learning methods that are relevant to the teaching material. The ability to prepare a lesson plan to deliver certain material has the highest score, namely 3.73 (capable). The five Pedagogical Content Knowledge (PCK) indicators were reported using percentage distribution, mean scores, standard deviation and ranking (Table 9). Teachers' lesson planning and learning objectives were the highest-ranked indicators (mean = 3.73). After these, the capacity to help students connect subject-matter concepts (mean = 3.68), knowledge of relevant instructional approaches [3.62] and ability to construct learning outcome evaluation tools [3.61] followed. The average PCK score was 3.67 with a standard deviation of 0.83, indicating instructors' pedagogical topic knowledge across indicators. Table 10 provides a summary of the levels of Technological Content Knowledge (TCK), technology knowledge and teaching material knowledge at different times.

Table 10: Rank of Social Studies and Geography Teacher's Knowledge about Technological Content Knowledge (TCK)

Statement	(%)	Mean	SD	Ranking
Ability to use social media to enrich knowledge in subject matter	14.93	3.82	0.86	1
Ability to use the internet to increase knowledge of subject matter	14.42	3.69	0.93	2
Ability to develop subject knowledge using a variety of new technologies (always updating knowledge by utilizing technology)	14.30	3.66	0.87	3
Ability to choose new technology in delivering teaching materials	14.23	3.64	0.92	4
Knowledge of new technology to deliver teaching materials	14.18	3.63	0.89	5
Ability about the influence of technology on the effectiveness of the delivery of learning material	14.06	3.60	0.90	6
Ability to use new technologies suitable for packaging subject matter (such as multimedia, animation, video, simulation and modeling)	13.87	3.55	0.96	7
Total	100.00	-	-	
Average	-	3.66	0.91	

Table 10 is an overview of the level of knowledge of Technological Content Knowledge (TCK). At the separate time, knowledge of technology was 3.37 and knowledge of teaching materials was 3.54. However, after being combined the score became 3.66. Research analysis shows that the existence of technology makes it easy to package and deliver teaching materials. Teachers have ample opportunities to convey new information on their subjects so that students are more motivated to continue learning. It presents the ranking of social studies and geography educators' proficiency in Technological Content Knowledge (TCK). The mean score of TCK is 3.66, with a standard deviation of 0.91, suggesting that teachers typically exhibit a considerable proficiency in integrating technology with subject matter. The data reveal that teachers exhibit uniform levels of technological content knowledge across all metrics, displaying marginally greater confidence in utilizing digital platforms to access and enhance subject knowledge than in creating technology-enhanced instructional materials. Table 11 below displays information that integrates the three TPACK components: content, pedagogy and technology.

Table 11: Rank of Social Studies and Geography Teacher's Knowledge about Technological Pedagogical Content Knowledge (TPACK)

Statement	(%)	Mean	SD	Ranking
Ability to use learning management systems, such as (Google classroom, Edmodo, Moodle) in the learning process.	20.55	3.67	0.96	1
Ability to use social media (such as Facebook, Whatsapp, email, blog, Wkipedia, Instagram) to design effective teaching activities on subjects.	20.42	3.64	0.95	2
Ability to integrate effective teaching methods that are appropriate to new technology and relevant to the material being taught.	20.03	3.57	0.84	3
Ability to design educational activities in subjects that are managed by using new technology.	19.58	3.49	0.87	4
Able to assist others in teaching learning materials in accordance with appropriate subjects and teaching methods and new technology.	19.41	3.46	0.86	5
Total	100.00	-	-	
Average	-	3.57	0.90	

Table 11 is data that combine the three components of TPACK, namely content, pedagogy and technology. The score for the combination of the three components of TPACK tends to decrease compared to the score for the combination of the two components alone. The decrease in score is thought to be due to the difficulty in integrating the three TPACK components in a contextual formula in the classroom. To prove this hypothesis, the researcher tried to conduct further research at the second stage with different respondents according to the research design.

It demonstrates that educators' Technological Pedagogical Content Knowledge (TPACK) is at a moderate to high level (M = 3.57; SD = 0.90). The most significant competences pertain to the utilization of learning management systems (M = 3.67) and social media for instructional purposes (M = 3.64), indicating that educators possess considerable confidence in employing digital means for communication and information dissemination. Nonetheless, marginally lower results in the creation of technology-based learning activities (M = 3.49) and in facilitating the integration of technology with pedagogy and content (M = 3.46) suggest that the integration of instructional design is still underdeveloped. The findings indicate that the incorporation of technology in teaching remains predominantly tool-focused rather than integration-focused, underscoring the necessity for professional development that enhances the equilibrium among technology, pedagogy and content within the TPACK framework. Meanwhile, the teachers' views on the efficacy of various methods and technologies in imparting specific content are detailed in Table 12 below.

Table 12: The insertion of Technology component and the Shape of TPACK Venn Diagram

Content (CK)	Method (PK)	Technology (TK)	Intersection Area of PCK	Intersection Area of TCK	Intersection Area of TPK	Difference of TCK - TPK	Venn Diagram of TPACK
Map Component	Simulation and class Presentation	Globe/props and power point	3.97	3.95	3.92	0.03	Almost Balanced
Enlarge/Reduce Map Scale	Demontration and Simulation	Globe/props and power point	3.77	3.75	3.82	-0.07	Almost Balanced
Various Forms of the Earth's Surface/Earth as a Living Space	Demontration and Simulation	Power point and Video/animation from Youtube	4.00	4.02	4.05	-0.03	Almost Balanced
Plate Tectonics	Demontration	Power point and Video/animation from Youtube	4.07	4.10	4.07	0.03	Almost Balanced

Volcanos	Demontration and Simulation	Power point and Video/ani mation from Youtube	4.02	3.97	4.10	-0.13	Almost Balanced
Earthquake	Demontration	Power point and Video/ani mation from Youtube	3.97	4.00	4.05	-0.05	Almost Balanced
Types of Natural Resources	Demontration	Power point	3.90	4.00	4.00	0.00	Balanced
Natural Resources Conservation Efforts	Demontration	Power point	3.95	4.00	3.95	0.05	Almost Balanced
ASEAN and Developing Countries	Demontration and Simulation	Globe/props and power point	3.97	4.00	3.97	0.03	Almost Balanced

Table 12 is a description of teachers' perceptions of the effectiveness of using methods and technology in delivering certain material. Each teacher has different perceptions of the various methods (pedagogy) and technology used. Indicators of effectiveness can be seen from three things, namely increased learning outcomes, better motivation to learn and teachers do not experience difficulties in delivering material. In this study, only data was obtained from the aspect of teacher difficulties in delivering materials.

The benefits of this research can be used as an evaluation tool for learning performance. As an illustration, the results of TPACK investigation have been obtained:

C = 3.54
P = 3.14
T = 3.37
PCK = 3.67
TCK = 3.66
TPK = 3.64

TCK – TPK = 3.66 – 3.64 = 0.02 (almost balanced), with a fairly good area of intersection which is > 3.00.

Table 12 illustrates educators' opinions regarding the integration of technology in educational methodologies and material dissemination. In nine themes, the intersection scores of PCK, TCK and TPK regularly exceed 3.00, signifying a robust integration of content, pedagogy and technology. The disparity between TCK and TPK spans from −0.13 to 0.05, indicating that the majority of topics reside within the nearly balanced TPACK category, with one topic achieving a fully balanced state. Demonstration and simulation techniques, together with presenting tools like PowerPoint, globe props and video/animation, were frequently employed to enhance geographically focused information. The overall component scores (C = 3.54; P = 3.14; T = 3.37; PCK = 3.67; TCK = 3.66; TPK = 3.64) suggest a nearly balanced TPACK Venn diagram, with a negligible difference of 0.02 between TCK and TPK. The findings indicate that technology is typically incorporated to enhance both content representation and pedagogical procedures, leading to a nearly balanced TPACK configuration rather than the predominance of a single component.

Discussion

Insertion of Technology component and the Balance of TPACK Venn Diagram

The second stage of data collection was to find out the impact of the insertion of technology components in the context of the TPACK framework. In the first stage, it is known that the existence of technology is very significant in improving TPACK's performance, especially in packaging and delivering teaching materials. In the second stage, data is obtained about the effectiveness of learning which is influenced by methods and technology separately. The value of learning effectiveness is obtained from teachers' perceptions of learning methods and technologies. The incorporation of the technology component inside the TPACK framework should be perceived not just as the inclusion of digital instruments, but as the enhancement of educators' integrated knowledge and methodologies for effective technology-enhanced instruction. Research indicates that successful technology integration relies on continuous teacher learning, professional development and a contextual comprehension of the interplay between technology, pedagogy and content. In this context, harmonizing the TPACK Venn diagram necessitates that educators integrate technological knowledge with pedagogical approaches and subject-specific attributes, rather than considering technology as a standalone teaching component. This outcome aligns with prior research indicating that technology integration improves instructional design and facilitates meaningful learning when paired with pedagogical methodologies and subject-matter expertise (42). The effectiveness value is considered as the "area of the cut" between TPACK components. The range of teacher perceptions of the effectiveness value is set between 1 and 5. This means that if it has a value of 5 then two or three circles are considered to have a full cross section.

The insertion of technology components is placed at the last stage after the content and pedagogical circles have been superimposed. The technology component circles are embedded in both the content and pedagogical circles. If the effectiveness value (the intersection between circles) has the same area, both for content and for the method, the TPACK Venn diagram is balanced. This discovery substantiates the assertion that a harmonious integration of technology with pedagogy and content results in more effective educational methodologies. Moreover, TPACK is progressively recognized as encompassing both knowledge and pedagogical activity. The equilibrium among TPACK components signifies educators' capacity to convert conceptual comprehension into classroom application, especially in choosing suitable technology instruments for particular learning objectives. From an educational standpoint, technology-enhanced representations, such as static and dynamic visualizations, can improve conceptual comprehension when they are congruent with pedagogical design and content attributes, underscoring the significance of balance among TPACK components. This reinforces the assertion that technology ought to facilitate educational objectives rather than dictate them, a premise extensively highlighted in technology integration research (43-45). We recommend that if one slice is wider than the other, then the TPACK Venn diagram will be unbalanced. In the trial, the researchers chose nine subjects or material. The teachers were asked to determine the methods that were often used in the classroom and the types of media, tools, or technology that were often used for each subject. After selecting one of the methods, the teacher was asked to determine the degree of effectiveness so that the price of the circle slices was obtained. Likewise, at the technology selection stage, teachers were asked to determine the level of its effectiveness both on the material and method. As for determining the shape of the TPACK Venn diagram equilibrium, it is determined from the difference between the area of the TCK slice and the area of the TPK slice. The balance of the TPACK Venn diagram occurs if the difference between TCK - TPK = 0; TCK - TPK = 0.01 - 1 (almost balanced); > 1 (unbalanced). The difference obtained is both positive and negative.

The difference between TCK and TPK can have a positive or negative value. The value is positive if technology has a greater support for content while it is negative if technology has greater support for pedagogy. In constructivist learning, the value of technology support has different implications. The role of technology, which is more of content, can be utilized at the learning planning stage. The form of technology support for teaching materials is to help package more modern teaching materials. At the planning stage, learning materials can be designed according to the principle of constructivism, namely the distribution of smaller teaching materials but by maintaining an intact material concept. In this context, technology can play a role in the development of microlearning, digital teaching materials, LMS development and various other learning tools. The role of technology which is more on the learning method (pedagogy), can be optimized at the learning implementation stage. This underscores the fundamental concept of the TPACK paradigm, which posits that effective technology integration transpires when educators can concurrently align technological affordances with educational objectives and content attributes (43, 44).Technology plays a role in making it easier for teachers to deliver teaching materials so that students understand teaching materials more quickly. The role of technology in constructivist learning makes it easier for students to build their knowledge because the available information is very abundant.

Conclusion

The integration of technology in education is becoming increasingly vital in the Industry 4.0 age and the TPACK framework offers a valuable basis for harmonizing content, pedagogy and technology in instructional practices. This study enhances the literature by analyzing the equilibrium of TPACK components among social science and geography educators and suggesting a functional interpretation of TPACK balance through the comparison of TCK and TPK intersections. The results suggest two potential patterns of technology integration. When the TCK intersection prevails, technology proves more efficacious in the creation of educational resources, including microlearning and multimedia content. When the TPK intersection is predominant, technology significantly enhances constructivist learning processes and facilitates students' knowledge creation. These findings indicate that educators ought to create a contextual TPACK Venn diagram for each instructional content instead of implementing technology equally across subjects. This study provides a pragmatic approach to interpreting TPACK balance and relates the concept of equilibrium (TCK–TPK = 0) with instructional decision-making. The study is constrained to particular topic areas and predominantly depends on teacher-reported data, which may not comprehensively reflect classroom execution. Future research ought to incorporate educators from many disciplines, encompass classroom-based evidence of technology integration and investigate longitudinal changes in TPACK development. It is also advisable to further enhance instruments for assessing TPACK equilibrium.

Abbreviations

ASEAN: Association of South East Asian Nation, ES: Elementary School, JHS: Junior High School, LMS: Learning Management System, PK: Pedagogical Knowledge, SHS: Senior High School, TCK: Technological Content Knowledge, TPACK: Technological Pedagogical Content Knowledge, TPK: Technological Pedagogical Knowledge.

Acknowledgment

The researchers wish to thank Universitas Pendidikan Indonesia and the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia for providing funding for the research. This paper is an outcome of the 2023 Research scheme. Gratitude is also extended to the reviewers who provided feedback and suggestions.

Author Contributions

Ahmad Yani: conceptualization, design, analysis, writing, Jaka Waluya: editing/reviewing, supervision, Mushoddik: data acquisition, data analysis / interpretation, Totok Daya Pamungkas: statistical analysis, admin, Rosita: technical or material support, Budi Setiawan: content, technical support.

Conflict of Interest

There are no conflicts of interest to declare.

Data Availability

All data collecting and storage protocols were authorized by the Institutional Review Board as an exempt study for program enhancement. Participant identifiers were removed to ensure anonymity.

Declaration of Artificial Intelligence (AI) Assistance

The authors declare no use of artificial intelligence (AI) for the write-up of the manuscript.

Ethics Approval

All the participants in this study were notified of its intentions. Every participant has duly executed a confidentiality agreement and a data transfer form. Similarly, all data has been de-identified, ensuring the confidentiality of the participants.

Consent to Publish Statement: The authors affirm that all people whose identifying information appear in this work have granted prior written informed consent for publishing. Participants were thoroughly apprised of the study's objective, the characteristics of the publication and the possible distribution of their data in both academic and public spheres.

Consent was acquired from parents, legal guardians, or authorized representatives for participants who were underage or incapable of independently providing consent, where relevant. The authors have exerted all reasonable measures to anonymize personal data; nevertheless, in instances where anonymity could not be entirely assured, specific consent for identifying publication has been acquired.

All procedures involving human subjects in this study adhered to institutional and national ethical standards, as well as the principles of the Declaration of Helsinki. The relevant author securely retains written consent paperwork, which can be supplied to the journal upon reasonable request.

Funding

These researches receive funding from Universitas Pendidikan Indonesia and the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia for providing financial assistance and guidance in this research.

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How to Cite: Yani A, Waluya J, Mushoddik, Pamungkas TD, Rosita, Setiawan B. Inserting Technology and Balancing of Technological Pedagogical Content Knowledge (TPACK) Venn Diagram. Int Res J Multidiscip Scope. 2026; 7(2): 1181-1195. DOI: 10.47857/irjms.2026.v07i02.09095