Systematic Literature Review of TPACK Scale Development in Science Learning (2006-2022)

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Abstract. The success of integrating technology in learning through the TPACK framework can be seen from the extent of the measurement results using the TPACK instrument. Various instruments to measure TPACK have been developed by researchers in different research contexts regarding the application of the TPACK framework in learning. This article aims to analyze in depth various articles related to the development of the TPACK instrument that has been carried out, especially in the scope of science learning. By using the Systematic Literature Review method , 9 publications originating from the google schoolar database between 2006-2022 will be analyzed by focusing on the form of the TPACK instrument developed, the TPACK indicator used to construct item items and the context in which the TPACK instrument was developed. The results of this study show that all instruments developed to measure TPACK in science learning are in the form of a self-assessment survey questionnaire with reference to 7 aspects of TPACK as proposed by Mishra and Koehler in 2006. The indicators of mastery of technology that are required to be mastered by teachers continue to develop along with technological advances.

Keywords: Systematic literature review, TPACK scale, science learning.

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INTRODUCTION

Quality teachers are often identified with teachers who have the most experience in the field of knowledge about the subject to be taught. Shulman criticized this definition and suggested that qualified teachers are those who have knowledge of material content as well as pedagogical knowledge as an effective learning process, so the concept of pedagogical content knowledge (PCK) was introduced to provide a practical theoretical framework in the field of teacher professionalism training (Shulman, 1986, 1987). However, with the broad developments in the use of ICT in various sectors of life, including in the learning process, Mishra & Koehler (2006) propose an expansion of the PCK model to include technological knowledge as the third core component that teacher candidates must possess in order to produce effective learning in the era of globalization. digital. The proposed framework is Technology Pedagogical Content Knowledge (TPACK) which is based on three core components including pedagogical knowledge (PK), content knowledge (CK), and technological knowledge (TK), and four hybrid components formed from the intersection of the three core components, namely pedagogical content knowledge (PCK). knowledge of pedagogic technology (TPK), knowledge of content technology (TCK), and knowledge of content pedagogic technology (TPACK). TPACK provides one direction for a teacher to be able to integrate technology into learning. In this approach, teachers are required to be able to utilize technology to create a learning environment but still pay attention to the pedagogical elements inherent in learning content when the content is taught to students (Niess, 2008).

Along with the development of the application of the TPACK framework as an approach to training teachers' professional abilities in technology integration in several aspects such as the preparation and presentation of lesson plans (Akyuz, 2018; Chai et al, 2017; Dalal et al., 2017; Koh et al., 2017; Tseng et al., 2019), Micro teaching (Chai et al., 2010; Durdu & Dag, 2017; Tokmak, 2013), learning media (Koh & Divaharan, 2011; Özgün et al., 2011) and digital teaching materials (Rukmana & Handayani, 2020, 2021), various instruments to measure TPACK abilities have also been developed in various forms such as survey questionnaires, observation sheets and tests. The development of an instrument to measure TPACK is not only based on the research context, but also based on the specific content of the material. This is important because each material content has its own characteristics so that it will require different technologies in learning. In addition, the integration of technology in learning will also be related to the application of the pedagogical aspects inherent in the content of the material when taught in the classroom.

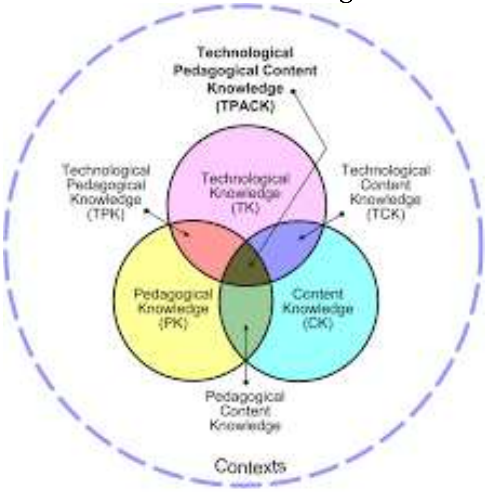

Figure 1. TPACK framework

Based on the above background, in this study the author intends to conduct an in-depth analysis of a number of literatures between the years 2002-2022 relating to the development of the TPACK instrument in science research. Literature analysis will focus on 3 aspects that are the questions of this research, including: (1) How is the form of the TPACK assessment instrument developed?, (2) What are the indicators used to build the TPACK instrument item?, and (3) In what research context is the instrument? TPACK instrument used?

METHOD

This study uses a systematic literature review (SLR) method which aims to find and synthesize a research theme comprehensively using an organized, transparent procedure, where every step in the process can be replicated in (Higgins et al, 2011). Transparency in question includes informing all terms in the inclusion criteria where a literature is used as well as the reasons that justify a literature being excluded (Greyson et al. 2019). The process in SLR allows researchers to be able to find patterns of previous research results, understand the depth and details of existing knowledge, and identify gaps for further exploration (Shafril et al, 2020).

The SLR steps that will be used in this research include eight steps: eight general steps: (1) formulating the research problem; (2) developing and validating literature review measures; (3) search for literature; (4) filtering the literature; (5) assess the quality of the literature; (6) data mining; (7) analyze and synthesize data; and (8) report findings (Xiao & Watson, 2019). Clearly, these steps can be seen in Figure 2.

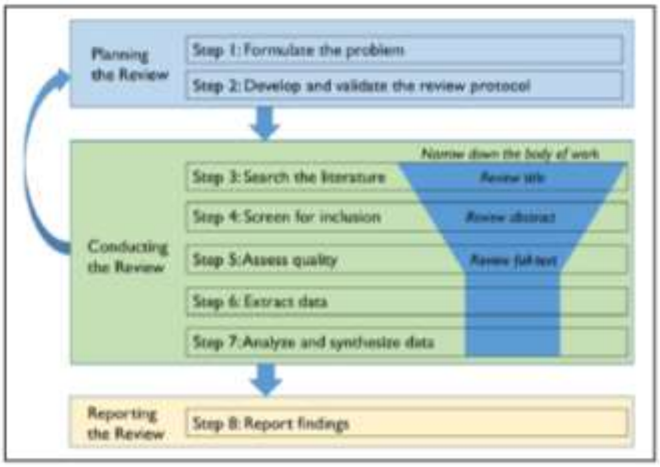

Figure 2. Process of systematic literature review.

The eight steps of SLR as shown in Figure 2 can be categorized into 3 main steps, namely: (1) planning a review, (2) implementing a review, and (3) reporting the results of the review. In the first step, the researcher formulates a research problem that will guide the review process, arranges a number of strategies for literature search including preparing the software to be used and determining the keywords to be used for the literature search. In this study, the software that will be used to search the literature is Harzing Publish or Perish 8.2 by using a title search containing the keywords "Instrument TPACK" ("Instrument" AND "TPACK") and the keywords "TPACK Scale" ("TPACK" AND " Scale") on the Google Schoolar database by limiting the search year between 2006-2022.

In the second stage, the literature search process begins according to the procedures planned in the first stage. At this stage, the literature that has been found on the search engine is downloaded and organized in a storage folder based on the name of the researcher and the year of publication to facilitate the analysis process. After the search is complete, the next step is to filter the articles that are relevant to the research, starting from the suitability of keywords with the title, abstract to reviewing the entire content of the article. The literature that has passed the screening stage is then analyzed and synthesized data to answer research questions. In this study, the initial search results obtained 82 literatures sourced from the Google Schoolar database . The next step is to conduct a rigorous literature screening with the following criteria: (1) The literature contains the development of the TPACK instrument for teachers or prospective teachers; (2) The developed TPACK instrument is intended for science learning (Mathematics, Physics, Biology, Chemistry); (3) articles in English; (4) It is a journal article or proceedings that has a year of publication between 2006 and 2022, (5) has access to download the complete article and (6) has complete instrument attachments. The complete literature screening process is shown in Figure 3.

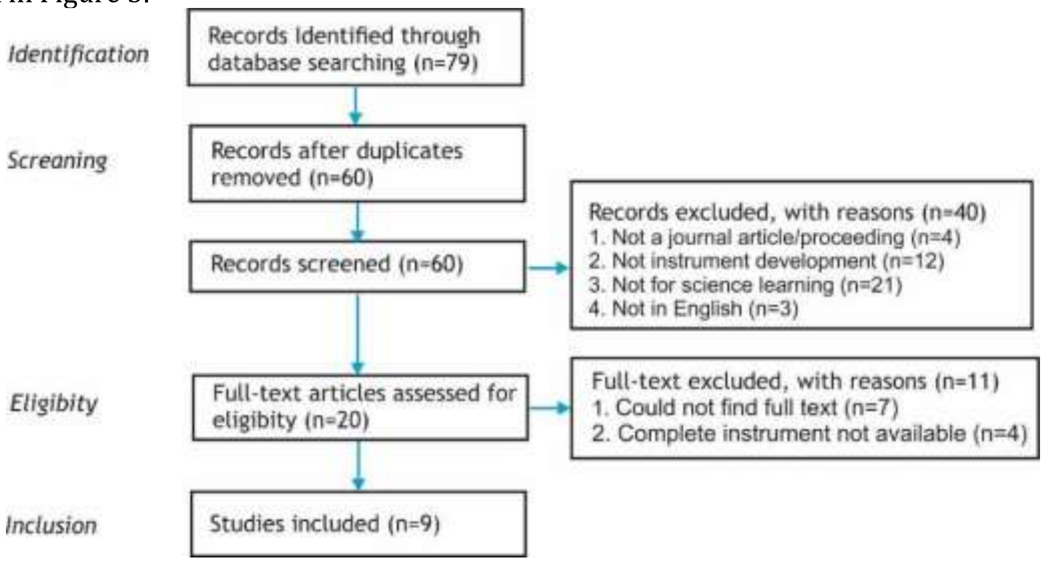

Figure 3 . Flow diagram of search data and extraction

The search results on publish of perish from Google Scholar data related to the development of the TPACK instrument in science learning were 79. This data was then sorted and duplicated data was found so that only 60 remained. After the sources were read one by one on keywords and abstracts, there were 40 journals listed. assessed as irrelevant to the required criteria according to the research questions so that only 20 articles were enrolled. After reading the titles and abstracts of 20 articles related to the development of the TPACK instrument in science learning, the next step is to read the journals one by one thoroughly with the main aim of finding out in general terms. In this step, there are 11 irrelevant sources so that in the final stage there are 9 sources that will be further analyzed to answer research questions.

RESULTS

Systematic studies on various publications provide an overview that the development of TPACK instruments in science learning is almost continuously carried out. This is reasonable to do because technological developments continue to advance rapidly so that the integration of technology in learning must continue to be updated. Every prospective teacher needs to equip themselves with the latest technological capabilities so that they can continue to produce learning that is in line with technological developments.

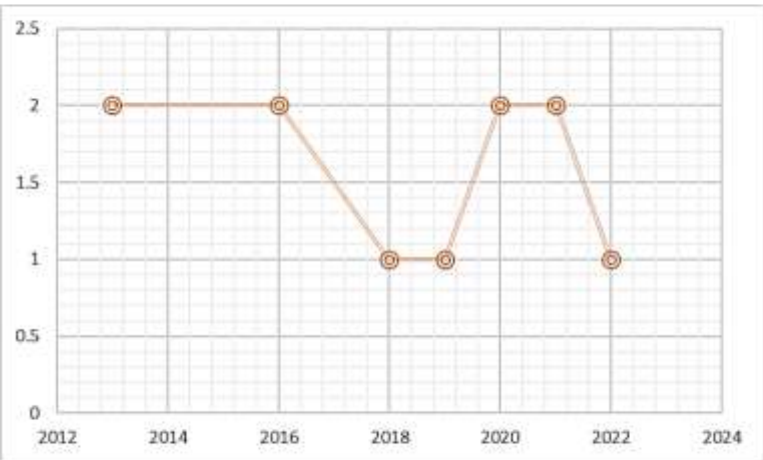

Figure 4. Research trends in the development of TPACK instruments in the last 10 years

Although the search year limit was set from 2006 (the year the TPACK framework was first introduced) to 2022, based on the data obtained, the development of the TPACK instrument specifically for science learning has only emerged in the last 10 years . The results of the study show that mathematics dominates the context of the development of the TPACK instrument (4 studies), which is then followed in the field of science in general (3 studies), physics (1 research) and chemistry (1 research). In terms of the validity and reliability test techniques, it was dominated by the EFA and CFA analysis techniques (6 studies), followed by the Rasch Model (2 studies) and *Intraclass Correlation Coefficient* (1 research) techniques. Next, if it is reviewed by country of origin, Turkey and Indonesia dominate the place where a lot of research on the development of the TPACK instrument is carried out in science subjects (4 studies each) followed by America (1 study). Finally, in the aspect of indicators that are used as a reference for developing the TPACK instrument, most of them use the 7 factors of the TPACK framework proposed by Koehler and Mishra (2006) (7 studies) and the rest only develop instruments from some of the 7 existing factors. The results of the complete analysis can be seen in table 1.

Table 1. Results of a systematic study on the theme of research on the development of the TPACK Instrument

Study	Purpose	Sample	Method	Result
Bilici et al. (2013)	Develop a comprehensive instrument to determine the self-efficacy beliefs of science teacher candidates towards TPACK (TPACK-SeS)	808 prospective science teachers in 17 universities in Turkey	EFA for factorial structure analysis and CFA for structural model confirmation	52 survey items with a scale of 0-100 reliability analysis (PK = 8 items, CK = 6 items, TK = 6 items, PCK = 10 items, TCK = 4 items, TPK = 7 items, TPACK = 6 items, CxK = 5 items)

Study	Purpose	Sample	Method	Result
Zelkowski et al. (2013)	Build a valid and reliable instrument to monitor and assess the development of TPACK for prospective junior high school mathematics teachers	300 prospective science teachers from 15 American colleges	EFA for building item structure, CFA for structural model verification and Cronbach alpha for reliability	22 survey items with a Likert scale of 1-5 (TK=6 items, CK=5 items, PK=5 items, TPACK=6)
Kiray (2013)	Develop a TPACK self-efficacy scale for science teacher candidates by following the TPACK theoretical framework, as suggested by Koehler and Mishra (2006).	467 science teacher candidates from four different universities in Turkey	CFA to see the suitability of the scale with the theory. Cronbach alpha for reliability	55 survey items with a Likert scale of 1-5 (TK=9 items, PK=9 items, CK=9 items, TPK=7 items, TCK=7 items, PCK=7 items, TPACK=7)
Onal (2016)	Develop a valid and reliable scale to measure the TPACK of prospective mathematics teachers.	316 prospective mathematics teachers at seven different universities in Turkey	EFA for identifying factor structures and CFA for model fit analysis	59 survey items on a scale of 1-5 (TK=7, PK=11, CK=9, TPK Offline=3, TPK online=3, TCK=5, PCK=7, TPACK=9, CxK=5)
Cetin & Erdoğan (2018)	Develop a valid and reliable measuring tool that can be used to determine the efficiency of the TPACK of prospective mathematics teachers	453 primary and secondary school mathematics teachers from 4 different regions of Turkey	Cronbach's Alpha for reliability analysis, EFA for grouping item structure and CFA for testing structure.	79 survey items on a scale of 1-5 (PK=8, TK=16, CK=5, PCK=19, TPK=10, TCK=8, TPACK=13)
Hidayat (2019)	Develop and validate an instrument to assess the TPACK of prospective physics teachers in a technology-supported classroom environment	1005 pre-service and in-service science teachers in Indonesia	Confirmatory factor analysis using the factor axis principle (PFA)	61 survey items with a Likert scale of 1-6 (CK=9, PK=14, TK=7, PCK=12, TCK=5, TPK=7, TPACK=7

Study	Purpose	Sample	Method	Result
Puspitasari (2020)	Develop the TPACK instrument to assess the ability of prospective chemistry teachers (TTMC TPACK)	7 education experts, 1 material expert, and 1 test construction expert	Rasch Model	21 items two-tier survey scale (scale 1-4) TK=3, PK=3, CK=3, TPK=3, TCK=3, PCK=3, TPACK=3)
Suryani et al. (2021)	Develop a valid and reliable TPACK instrument for elementary school teachers in learning Mathematics.	1490 elementary school teachers in 14 sub-districts in Bogor Regency, Indonesia.	Rasch models.	43 survey items on a scale of 1-5 (PK=8, CK=7 TK=9, PCK=4, TPK=3, TCK=7 TPACK=5)

The results of the analysis of the instrument items developed for each TPACK factor obtained a general picture that each researcher constructs items that vary according to their respective research contexts, although there are a number of slices that show similarities and similarities in several items. The results of the complete analysis can be seen in table 2 to table 9.

Indicators of Technology Knowledge (TK)

Technological knowledge is knowledge related to the basics of technology that can be used to support learning, it can be in the form of using software, animation programs, the internet, digital modeling, virtual laboratories and others. Indicators of technological knowledge based on the results of a systematic analysis of the literature are shown in table 2.

Table 2. Indicators of Technology Knowledge (TK)

No	Study	Item indicator
1	(Bilici et al., 2013)	Explain the differences and similarities between hardware and software, troubleshoot hardware problems, install and use software and select appropriate technology tools
2	(Zelkowski et al., 2013)	Solve technical problems related to technology, learn technology, have a lot of knowledge about technology, keep up with the latest technology developments and use technology as needed.
3	(Kiray, 2016)	Using science laboratory tools, using electronic learning tools, using software, using interactive learning tools, using mobile learning tools, using multimedia and using distance learning platforms
4	(Önal, 2016)	Solve technical problems related to technology, choose the right technology, use new technology, troubleshoot hardware problems, install software, use software, help students, solve computer related problems
5	(Çetin & Erdoğan, 2018)	Troubleshooting computer technical problems Keeping up to date with the latest technology Have technical knowledge of technology Using my smartphone Using cloud storage technology Downloading videos via websites
6	(Hidayat, 2019)	Help students solve hardware problems, use various computer applications, learn new digital technologies easily, solve computer problems themselves, know the network between computers.

No	Study	Item indicator
7	(Puspitasari et al., 2020)	Various knowledge related to technology that is suitable for learning
8	(Suryani et al., 2021)	Designing learning media, using MS word, accessing the internet, displaying teaching materials in Power Point

Based on the results of the analysis of the indicators in the aspect of technological knowledge (TK), it can be seen that these indicators are generally divided into two groups. The first is the ability related to the mastery of general technology that is commonly used for learning at the time when articles are published (such as mastery of computer hardware and software, laboratory equipment, internet, etc.). Second, abilities related to efforts to learn independently about new technologies that will develop (such as willingness to learn new technologies and keep up with new technology developments).

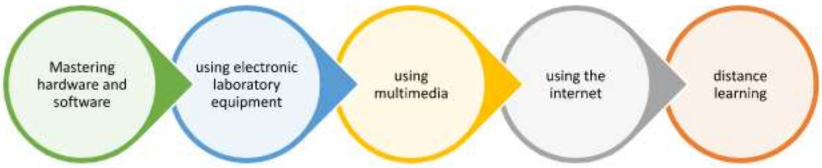

Figure 5. Development of knowledge technology (TK) indicators from 2006-2022

In the aspect of mastering technology to support learning in the classroom, over time there are changes in standards that must be mastered. This is natural because technology continues to develop so teachers must continue to adapt. In general, the development of technological capability standards that are required to be mastered by science teachers from year to year is shown in Figure 4. In the early days of TPACK's introduction, the demands of teachers' technological capabilities were limited to mastering software and hardware, but now developing on internet technology and distance learning.

Indicators of Pedagogical Knowledge (PK)

Pedagogic knowledge is knowledge related to teaching and learning theory and practice which includes objectives, processes, methods, strategies and learning assessments. An educator who masters pedagogic knowledge at least has an understanding of the cognitive, affective aspects and so he knows how to improve the three aspects in students. Indicators of pedagogic knowledge based on the results of a systematic analysis of the literature are shown in table 3.

Table 3. Indicators of Pedagogical Knowledge (PK)

No	Study	Item indicator
1	(Bilici et al., 2013)	Recognizing individual student differences; take steps to reduce disruptive student behavior; can manage the class effectively; prepare assessment tools; use various learning strategies and methods effectively; identify differences in student learning styles.
2	(Zelkowski et al., 2013)	Assess student performance; adjust teaching based on student understanding; adapt teaching styles to different learners; assessing student learning; using a variety of teaching approaches; recognize understandings and misunderstandings; can organize and maintain classroom management; use a variety of teaching approaches appropriately.

No	Study	Item indicator
3	(Kiray, 2016)	Develop daily, annual and unit plans; use measuring and assessment tools; using different teaching strategies, methods, techniques, approaches and models; taking into account the individual differences of students; Classroom management according to different teaching and learning approaches.
4	(Önal, 2016)	Up-to-date with instructional strategies, methods and techniques; detect students' misconceptions; use the best instructional strategies and methods to teach certain concepts; use instructional techniques based on student performance; take into account the potential for individual differences; take action on potential problems in the classroom; effective classroom management; prepare the right measuring tools; decide how to assess student performance; eliminate students' misconceptions, make the class interesting.
5	(Çetin & Erdoğan, 2018)	Prepare learning according to student learning styles; choose a classroom management strategy in accordance with the methods, techniques and materials; apply different learning approaches; know the necessary precautions against negative situations in the classroom.
6	(Hidayat, 2019)	Manage the class to keep students organized, orderly and focused; adapting different ways of teaching to keep students productive; Identify different types of learners; Adjust teaching based on student understanding; sequencing of targeted skills; adjust teaching according to student feedback; Designing lesson plans according to the objectives; Prepare answers to predict student responses; Knowing theoretical teaching methods; Identify the characteristics of various teaching methods; Identify the skills students need; Knowing thinking skills can be conveyed through learning certain concepts; identify possible positive dispositions through learning certain concepts; Familiar with common student understandings and misconceptions.
7	(Puspitasari et al., 2020)	Knowledge of curriculum, design, implementation, assessment, and evaluation of learning.
8	(Suryani et al., 2021)	Understanding of the use of models, strategies, learning methods to present/teach subjects.

Based on the results of the analysis of the indicators in the aspect of pedagogical knowledge (PK), it can be seen that these indicators are generally divided into three groups. First, abilities related to the use of strategies, methods, approaches and learning models to be used by teachers in the classroom that are adjusted to the conditions and diversity of student learning styles. Second, the ability related to mastery of classroom management to overcome various problems that may arise in learning. Third, skills related to curriculum understanding and learning administration, such as preparing lesson plans and student activity sheets.

Figure 6. The development of the focus of pedagogical knowledge indicators in the development of the TPACK instrument in the last 10 years

Based on the indicators developed by various researchers in the aspect of mastering pedagogic knowledge to support learning in the classroom, over time there is a change in focus that is expected to be mastered. This happens because the condition and character of students in each era continues to develop along with developments in other aspects of life so that teachers must continue to adjust. In general, the development of pedagogical ability standards that science teachers are required to master from year to year is shown in Figure 5. In the early days of TPACK's introduction, the demands of teachers' technological capabilities were limited to mastery of learning strategies and classroom management, but along with the development of various learning theories and demands changes in the teacher's curriculum are required to continuously update their pedagogical abilities by focusing on the development of various thinking abilities of students.

Indicators of Content Knowledge (CK)

Content knowledge is knowledge related to the subject matter to be studied as contained in the curriculum. Someone who masters content knowledge at least has a thorough understanding of the curriculum content according to the field of science he has and can apply it. Content knowledge includes knowledge of concepts, theories, ideas, frameworks, scientific methods and their application in everyday life. Indicators of content knowledge based on the results of a systematic analysis of the literature are shown in table 4.

Table 4. Indicators on Content Knowledge (CK)

No	Study	Item indicator
1	(Bilici et al., 2013)	Can explain various concepts of chemistry, physics, biology, geology and astronomy; teach a content area (eg biology, chemistry, physics); create appropriate relationships with other content fields.
2	(Zelkowski et al., 2013)	Have sufficient knowledge of mathematics; can use mathematical thinking; have a variety of strategies to develop mathematical understanding; know various examples of the application of mathematics in the real world; have a deep and broad understanding of algebra, geometry, calculus and advanced mathematics.
3	(Kiray, 2016)	Knowing the content of physics, chemistry, biology, astronomy and earth science; knowing the content of the interaction of science-technology-society-environment; know scientific process skills and the nature of science; know common scientific misconceptions; know the content of the concepts, principles, generalizations, theories and laws of Science.
4	(Önal, 2016)	Use mathematical knowledge; solve everyday problems with mathematical thinking; decide the scope of mathematics subjects; decide the order of subjects and mathematical concepts; use various methods and strategies to solve mathematical problems; explain the objectives of mathematics subjects according to grade level; improvising math examples and problems; associate mathematics with other subjects; Give examples of the application of mathematics in everyday life.

No	Study	Item indicator
5	(Çetin & Erdoğan, 2018)	Have sufficient knowledge of algebra, numbers and mathematical operations; attend symposiums, panels and conferences related to mathematics; keep up with curriculum changes related to mathematics; know the history of the development of mathematics.
6	(Hidayat, 2019)	Knowing how high the concept of physics is in a certain topic; knowing the scope of content in the curriculum; Sufficient knowledge of physics concepts at intermediate level; Knowing different ways to understand a certain concept; Using physics thinking to develop understanding of physics concepts; Using physics thinking in the classroom; Identify curriculum standards related to certain concepts; knowing the physics material to be taught; order certain physics concepts.
7	(Puspitasari et al., 2020)	Knowing the chemical concepts of exothermic reactions, endothermic reactions, enthalpy changes, types of reactions, determination of H based on a calorimeter, Hess's law, enthalpy changes, standard reaction enthalpies, and bond energies
8	(Suryani et al., 2021)	Good mastery of the material with the latest and accurate references

Based on the results of the analysis of the indicators on the aspect of content knowledge (TK), especially on the content of science material, it can be seen that these indicators are generally divided into three groups. First, abilities related to science material content such as mathematics, physics, chemistry and biology. Second, abilities related to the application of mastery of science content in solving problems in everyday life. Third, the ability to develop skills in the field of material content mastered by attending various conferences and studying the latest reference sources.

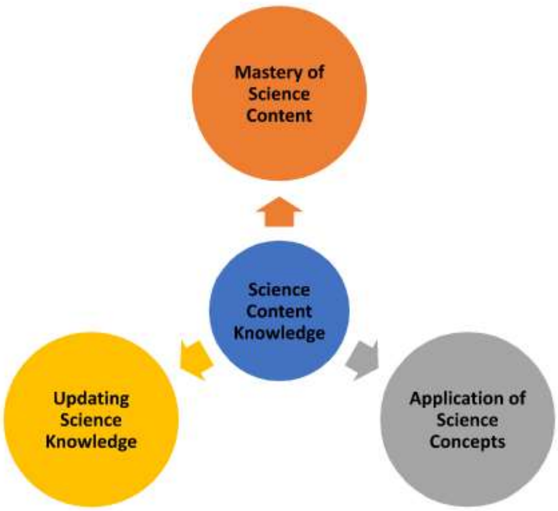

Figure 7. The focus of science content knowledge indicators in the development of the TPACK instrument in the last 10 years

Based on the indicators developed by various researchers on the aspect of mastering pedagogical knowledge to support learning in the classroom, over time there is a change in focus that is expected to be mastered. This happens because the condition and character of students in each era continues to develop along with developments in other aspects of life so that teachers must continue to adjust. In general, the development of standards for pedagogic abilities that science teachers are required to master from year to year is shown in Figure 5. In the early days of TPACK's introduction, the demands of teachers' technological abilities were limited to mastery of learning strategies and classroom management, but along with the development of various learning theories and demands teacher curriculum changes are required to continuously update their pedagogical abilities by focusing on developing students' various thinking abilities.

Indicators of Pedagogical Content Knowledge (PCK)

Pedagogic knowledge is knowledge related to theory and practice to organize learning on a material content as a form of implementing curriculum content. This knowledge includes the use of learning objectives, processes, methods, strategies and assessments that are suitable for a particular material content. An educator who masters content pedagogic knowledge at least has an understanding of how to teach suitable for certain materials so that learning becomes more effective. Indicators of pedagogic knowledge based on the results of a systematic analysis of the literature are shown in table 5.

Table 5. Indicators on Pedagogical Content Knowledge (PCK)

No	Study	Item indicator
1	(Bilici et al., 2013)	Can teach science courses according to the theoretical framework of the national curriculum; identify instructional objectives for each science topic at each grade level; use a variety of learning strategies and methods to teach science; overcome students' difficulties in learning science; overcome students' misconceptions in science learning; provide opportunities for students to conduct research on science topics; selecting appropriate assessment tools to evaluate science learning; determine scientific concepts and skills that need to be assessed in science learning.
2	(Zelkowski et al., 2013)	Choose an effective teaching approach to guide students' thinking and learning in mathematics; know the teaching approach to teach the concepts of ratio, proportion, probability, statistics, algebra, geometry, trigonometry and calculus.
3	(Kiray, 2016)	Prepare lesson plans according to the science curriculum; choose theories, approaches, models, strategies, methods and techniques that are in accordance with the objectives in the science curriculum; evaluate using an assessment tool that is in accordance with the science curriculum; designing activities in the classroom and outside the classroom in accordance with the science curriculum; prepare science content taking into account the individual differences of students; teach science concepts in a way that is easier to understand and comprehensive; overcoming common misconceptions in science.
4	(Önal, 2016)	Teach mathematics according to the curriculum; explain the content of mathematics subjects in the curriculum; determine appropriate learning strategies, methods and techniques for mathematics subjects; encourage students to conduct research on mathematics subjects; identify learning difficulties in mathematics; overcoming students' misunderstandings in mathematics; help students associate certain mathematical subjects or concepts with other subjects or concepts.
5	(Çetin & Erdoğan, 2018)	Choose appropriate teaching strategies for learning; provide a classroom environment to improve students' critical thinking skills; organize activities to improve students' problem solving skills/strategies; create a learning environment that allows different mathematical concepts to be linked to one another; identify students' learning difficulties and

No	Study	Item indicator
		misconceptions in mathematics; choose an appropriate assessment tool for mathematics subjects.
6	(Hidayat, 2019)	Choose the right teaching approach in physics; Produce lesson plans with appropriate topics; Knowing various physics teaching strategies; know the boundaries of concepts related to the curriculum; adjust the sequence of concepts in accordance with the objectives of the curriculum; discuss certain concepts with learning objectives; know various representations in physics concepts; use a better representation for physics lessons; Coping with specific concepts with students' proximal development as they learn collaboratively; Identify scientific literacy on a particular topic; predicting the possibility of students' misconceptions in certain topics; distinguish between correct concepts, do not know concepts and misconceptions in certain topics.
7	(Puspitasari et al., 2020)	Designing, implementing and evaluating chemical concepts (exothermic and endothermic, enthalpy changes and types of reactions and determining H)
8	(Suryani et al., 2021)	Knowledge of the use of analogies in teaching and providing concrete examples in everyday life so that the material is easy to understand.

Based on the results of the analysis of the indicators on the content pedagogical knowledge aspect (PCK), it can be seen that these indicators are generally divided into four groups. First, abilities related to the use of science learning strategies, methods, approaches and models that can facilitate and reduce student misunderstandings. Second, the ability to design science materials that are tailored to students' learning styles. Third, the ability to implement the science curriculum in compiling learning tools and implementing them in learning activities. Fourth, using various representations to explain science concepts. Fifth. Making efforts to improve students' thinking skills through science learning.

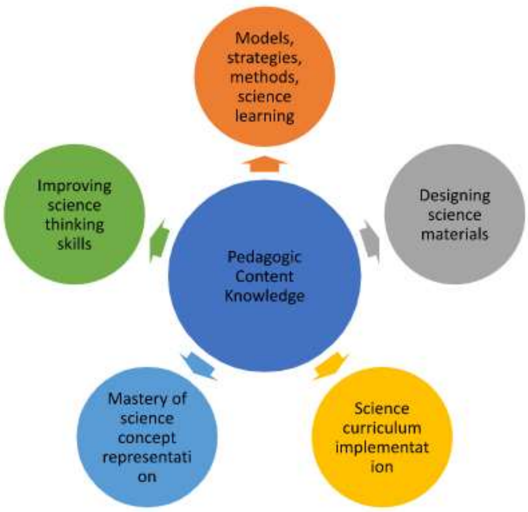

Figure 9. The focus of PCK knowledge indicators in the development of the TPACK instrument in the last 10 years

Based on indicators developed by various researchers on the aspect of mastery of pedagogic content knowledge (PCK), especially on science content, it can be seen that mastery of pedagogic knowledge related to science material content is not limited to mastering science learning models, strategies and methods, but also includes the ability to design science teaching materials , the use of multiple representations in science learning and improving 21st century thinking skills through science learning as shown in Figure 9.

Indicators of Technology Content Knowledge (TCK)

Content technology knowledge is knowledge related to the use of technological devices related to a particular material content. A person who has this knowledge can choose and use technological assistance in the form of hardware and software to support learning on a particular material content. Indicators of pedagogic knowledge based on the results of a systematic analysis of the literature are shown in table 2.

Table 6. Indicators of Technology Content Knowledge (TCK)

No	Study	Item indicator
1	(Bilici et al., 2013)	Prepare a science learning model with technology tools; use technological tools to collect data and analyze scientific data; explain the advantages of using technology in science education.
2	(Zelkowski et al., 2013)	Know the technology that can be used to understand the material ratio and proportion, probability and statistics, algebra, geometry, trigonometry and calculus; Knowing that using appropriate technology can improve understanding of mathematical concepts.
3	(Kiray, 2016)	Decide on appropriate teaching technologies for different areas of Science learning; utilizing technology that allows to learn science concepts better, easier and more meaningfully; decide on the technology according to the characteristics of the Science content; integrating knowledge of science content with appropriate technology; utilize technology in the right place at the right time when teaching science content.
4	(Önal, 2016)	Use computer software for mathematics; use flash animations and graphic images to enrich mathematics learning; create multimedia or presentations to teach mathematics subjects; search for mathematics learning resources on the Web; explain the advantages of using technology in teaching mathematics.
5	(Çetin & Erdoğan, 2018)	Have sufficient knowledge to use technology in learning mathematics; consider possible technologies that can be used for teaching mathematics; use Dynamic Mathematics / Geometry Software effectively; use calculators effectively and competently; using a Computer Algebra System; use the internet effectively to access programs related to learning mathematics.
6	(Hidayat, 2019)	Choose physics content that suits the needs of the technology; Choose existing technology as body of knowledge application; understand the representation of concepts related to technology; Knowing the specific technology that is suitable for use in the classroom; Identify content to determine the right technology.
7	(Puspitasari et al., 2020)	Knowledge of certain technologies related to chemical concepts (exothermic and endothermic, enthalpy changes and types of reactions, and determination of H)
8	(Suryani et al., 2021)	Knowledge of the selection of suitable media to be used based on the material being studied, for example learning videos are used to explain abstract material.

Based on the results of the analysis of the indicators in the aspect of content pedagogic knowledge (TCK), it can be seen that these indicators are generally divided into four groups. First, the ability to use technology as a science learning supplement. Second, the ability to use technology to better understand science concepts. Third, using technology to find science learning resources. Fourth, using technology to display various representations of science concepts.

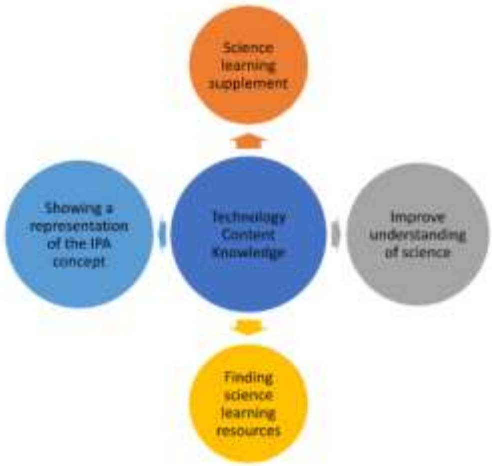

Figure 10. The focus of PCK knowledge indicators in the development of the TPACK instrument in the last 10 years

Based on the indicators developed by various researchers on the aspect of mastery of content technology knowledge (TCK), especially on science content, it can be seen that the mastery of technology possessed by a science educator will greatly affect the quality of science learning. An education who has good mastery of technology related to science learning can at least make the technology a science learning supplement, display multiple representations of science concepts, find more current science learning resources so that in the end it will increase students' understanding of science content.

Indicators of Technology Pedagogical Knowledge (TPK)

Technology Pedagogic knowledge is knowledge related to the use of technological devices to support the application of models, strategies and learning methods to create a learning atmosphere that can facilitate students to achieve the expected competencies. A person who has this knowledge can choose and utilize technology in the form of hardware, software and information technology to support the process in the classroom. Indicators of knowledge of pedagogic technology based on the results of a systematic analysis of the literature are shown in table 7.

Table 7. Indicators on Technology Pedagogical Knowledge (TPK)

No	Study	Item indicator
1	(Bilici et al., 2013)	Determine the appropriate technology for the grade level of students; explain how to use technology in lesson plans; explain how to manage a classroom equipped with technology; answer students' questions about the use of technology in the classroom; utilizing technological tools to make the teaching process more productive; explain how technology affects student learning; assess student learning in technology-rich lessons
2	(Zelkowski et al., 2013)	Choosing technology to improve teaching quality; think more about how technology can affect teaching approaches; think critically about how to use technology in the classroom; adapting the use of technology to different teaching activities; choosing different technologies for different

No	Study	Item indicator
		teaching approaches; have the technical skills to use technology appropriately in teaching; have classroom management skills to use technology appropriately in teaching; using technology in different learning approaches; changing the teaching approach using technology; know how to use technology to teach.
3	(Kiray, 2016)	Use appropriate technology with different theories, approaches, and teaching models; use appropriate technology with different teaching strategies, methods and techniques; utilize technology according to the individual differences of students; use technology when measuring and assessing; deciding which new technologies are suitable for teaching; classroom management while using different teaching technologies; use technology in a way that positively affects learning.
4	(Önal, 2016)	Planning the use of technology for instructional purposes; predict how technology can affect the teaching and learning process; evaluate students where technology is being used effectively; providing students with an online environment that contributes to students' knowledge and skills; using a variety of methods and approaches during online teaching; promote online learning among students.
5	(Çetin & Erdoğan, 2018)	Use appropriate technology for individual differences; use technology according to student groups; use technology for assessment and evaluation processes; use technology to practice skills beyond cognition.
6	(Hidayat, 2019)	Creating an online environment that allows students to build new knowledge and skills; Define various online teaching methods; communicate online with students; Moderate interactivity between students using ICT; Identify the use of technology learned during learning; choosing technologies that enhance teaching approaches; choose technologies that improve the quality of learning.
7	(Puspitasari et al., 2020)	Knowledge of the design or use of technology in learning
8	(Suryani et al., 2021)	Students learn by using ICT as a cognitive tool, and assistants in finding references to create learning tools. ICT also supports collaborative learning.

Based on the results of the analysis of the indicators in the aspect of pedagogical technology knowledge (TPK), it can be seen that these indicators are generally divided into five groups. First, the ability to use technology to provide an effective learning environment. Second, the ability to use technology in accordance with the conditions and needs of students. Third, using technology to practice thinking skills. Fourth, use technology to improve the quality of learning tools (eg preparation of lesson plans, learning media, evaluation of learning. Fifth, use technology to create a distance learning environment.

Figure 11. Focus of TPK indicators in the development of TPACK instruments in the last 10 years

Based on the indicators developed by various researchers on the aspect of mastery of pedagogic technology knowledge (TPK), it can be seen that the mastery of technology possessed by an educator will greatly affect the improvement of the quality of the implementation of learning carried out by a teacher. An educator who has good mastery of pedagogical technology can at least make mastery of the technology to create a more effective learning environment, create a learning environment as needed, train thinking skills, improve the quality of learning tools and create a distance learning environment.

Indicators of Technology Pedagogical Content Knowledge (TPACK)

Technology Pedagogical Content Knowledge is a learning framework where the use of technology cannot be separated from each other from the content of the material being taught (C), how to teach it (P). Someone who has this knowledge can integrate technology well to be able to carry out the learning process in the classroom to achieve the expected competencies in a specific specific material content. Indicators of content pedagogic technology knowledge based on the results of a systematic analysis of the literature are shown in table 8.

Table 8 Indicators of Technology Pedagogical Content Knowledge (TPACK)

No	Study	Item indicator
1	(Bilici et al., 2013)	Use technological tools to determine students' misconceptions about science; using technology tools to assess students' science learning; apply technological knowledge, content knowledge, and pedagogical knowledge to create an effective learning environment; develop quality learning plans using technological knowledge, content knowledge, and pedagogical knowledge; use technology to assess students' prior knowledge of science topics; using technology to address students' misconceptions about science topics.
2	(Zelkowski et al., 2013)	Using a strategy that combines mathematics, technology, and learning approaches; choosing technologies that enhance mathematics learning; choose technology to improve what I teach, how I teach, and what students learn; helping others to coordinate the use of mathematics, technology, and teaching approaches; teach lessons that combine approaches to mathematics, technology, and teaching appropriately, Integrating technology in mathematics teaching will be easy and straightforward; combine ratios and proportions, technology, and

No	Study	Item indicator
		teaching approaches appropriately; combine probability and statistics, technology and teaching approaches appropriately; combine algebra, technology and teaching approaches appropriately; combine geometry, technology and teaching approaches appropriately; appropriately combines trigonometry, technology and teaching approaches; combines calculus, technology, and teaching approaches appropriately.
3	(Kiray, 2016)	Integrating science with appropriate strategies, methods, techniques, and technology; choose the right strategies, methods, techniques and technology for better Science learning; determine appropriate pedagogical and technological applications for the field of science learning; integrate content knowledge with pedagogical and technological knowledge to enhance learning value; adapting strategies, methods, techniques, models, and technology with science content; guiding my colleagues in integrating science results with appropriate technology and pedagogy; restructuring content knowledge by using technological and pedagogical knowledge in different ways.
4	(Önal, 2016)	Consider relevant mathematics content, teaching-learning strategies, and new technologies during lesson planning; using technology-assisted evaluation tools when assessing the teaching and learning process; utilizing technological tools to measure students' prior knowledge of mathematics subjects; utilizing technology tools to identify students' misconceptions about mathematics; use technology to strengthen students' skills, understanding, and predictions about specific math subjects; use technology to provide effective examples in parallel with math textbooks; meet student requirements during online math instruction; integrate technology with mathematics classes appropriately and effectively to make it easier and more understandable; assist others in the school with the use of mathematical, technological and instructional strategies.
5	(Çetin & Erdoğan, 2018)	Keep up with the latest applications and developments in mathematics; organize different learning activities for different technologies to be used in mathematics education; display multiple representations of geometric concepts with dynamic geometry software; compose electronic worksheets that enhance mathematical reasoning abilities, identify using a Computer Algebra System and Dynamic Geometry and Mathematical Software as appropriate.
6	(Hidayat, 2019)	Using the right technology for better content representation; Modify teaching strategies in terms of involving technology in certain concepts; Adapting technology to reduce students' misconceptions; Adapting technology to better represent concept knowledge; Adapting technology to describe the new epistemology; Acquire knowledge, skills, abilities, and attitudes to deal with ongoing technological changes; using strategies that combine content, technology, and teaching approaches.
7	(Puspitasari et al., 2020)	Knowing the integration of technology and pedagogy in learning related to chemical concepts (exothermic and endothermic, enthalpy changes and types of reactions, determination of H in learning)
8	(Suryani et al., 2021)	Knowledge of the use of various learning media in facilitating teachers in teaching a material.

Based on the results of the analysis of the indicators on the knowledge aspect of content pedagogical technology (TPACK), it can be seen that these indicators are generally divided into four groups. First, the ability to use technology to provide an effective science learning environment. Second, the ability to use technology to reduce misconceptions in science learning. Third, using technology to display the representation of science concepts. Fourth, use technology to improve the quality of science learning tools (eg preparation of lesson plans, learning media, teaching materials, evaluation of learning. Fifth, use technology to create a distance science learning environment.

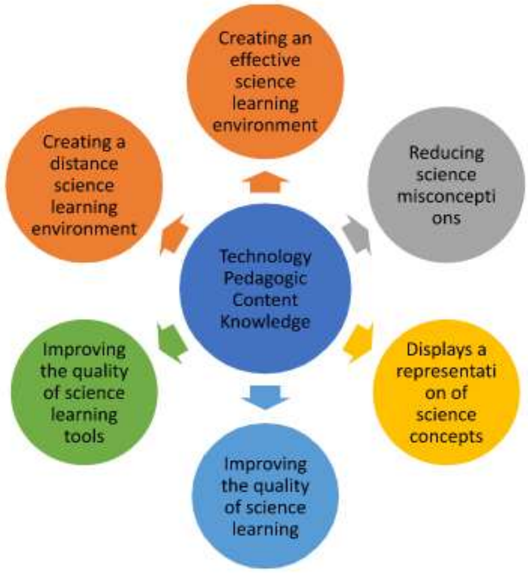

Figure 12. Focus of TPK indicators in the development of TPACK instruments in the last 10 years

Based on the indicators developed by various researchers on the aspect of mastery of content pedagogical technology knowledge (TPACK), it can be seen that mastery of this knowledge will greatly affect the improvement of the quality of the implementation of learning carried out by a teacher. A science educator who has good TPACK mastery can at least create a more effective learning environment, create a learning environment according to needs, train thinking skills, improve the quality of learning tools and create a distance learning environment.

CONCLUSION

Based on the results of data analysis, it can be concluded that since its emergence in 2006, the TPACK framework has been widely used in various contexts of increasing the professionalism of prospective teachers, especially those related to technology. All instruments developed to measure TPACK in science learning are in the form of a self-assessment survey questionnaire with reference to 7 aspects of TPACK as proposed by Mishra and Koehler in 2006. The indicators of mastery of technology that are required to be mastered by teachers continue to develop along with technological advances. This implies that in developing an instrument to measure TPACK, it must continue to be adapted to technological advances, so that no instrument can always be suitable to be used at different times because technology continues to develop. The results of this study can be a recommendation for researchers who intend to develop TPACK instruments for specific research contexts, especially in science subjects.

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