Implementation of TPACK in STEAM-Based Chemistry Learning in Higher Education: A Bibliometric Analysis

Evi Sapinatul Bahriah[1*], Etin Solihatin[2], Ivan Hanafi[3]

[1*,2,3] Department of Educational Technology, State University of Jakarta, DKI Jakarta,13220, Indonesia

e-mail: *evi_9902922004@mhs.unj.ac.id[1], etinsolihatin@yahoo.com[2], ivan.hanafi@unj.ac.id[3]
* Corresponding Author

Abstract: *Students in the era of industrial revolution 4.0 and society 5.0 must have good competence and skills. Therefore, the implementation of Technological Pedagogical Content Knowledge (TPACK) in STEAM (Science, Technology, Engineering, Art, and Mathematics) Education is very suitable to be adapted in basic chemistry learning in higher education. Therefore, this study aims to find out research trends related to implementation TPACK in STEAM-Based Chemistry learning in higher education. The method used is Systhematic Literatute Review. The data collection technique used was to conduct research studies for the last 9 years (2014-2024) according to the keywords. The inclusion and exclusion criteria for article search include TPACK, STEAM Education, STEAM-based learning, chemistry learning, STEAM in higher education, etc. The research data obtained were analyzed using a bibliometric approach with the help of the VOSviewer program. This study based on Google Scholar. The results of the study show many research trends related to TPACK in STEAM-based chemistry learning. The integration of TPACK in STEAM-based chemistry learning is generally effective in improving the learning process and learning outcomes. Therefore, it is necessary to adapt and further modify STEAM-based learning, especially in basic chemistry learning at higher education.*

Key Words*:* Implementation of TPACK; STEAM-based Learning; Chemistry Learning; Higher Education; Bibliometric Analysis.

Introduction

Education is one of the proofs that a nation has been independent because education plays an important role in the sustainability of a nation. If a nation is likened to a building, then education is one of its pillars, if the pillar is empty, the building will easily collapse. Education should be implemented properly so that it can produce students who have intelligence, are reliable and also competent in accordance with the Law of the Republic of Indonesia Number 20 of 2003. Namely, creating a learning atmosphere and learning process so that students actively develop their potential to have spiritual religious strength, self-control, personality, intelligence, noble morals, and skills needed by themselves, society, nation and state (Law of the Republic of Indonesia, 2003).

Teachers and lecturers are one of the spearheads of education implementation in schools and higher education. Therefore, they are required to have professional competence. Professional teachers certainly have adequate knowledge so that in the teaching and learning process, teachers can provide knowledge related to the content of the subject. More than that, teachers are also required to have competence related to pedagogical science so that teachers can adjust how to help students solve problems in learning.

The impact of the globalization era has made a number of drastic changes in the 21st century, including in the fields of technology and education. The rapid and fundamental

development of science and information technology is a challenge that teachers must address by prioritizing professionalism. According to the Ministry of Religion (2005), teachers are said to be professional if they master all about education, teaching, other sciences and have received teacher education and have special skills that can support their profession.

Nowadays children grow up with technology and it is very important for them. However, it is a known fact that teachers' technological capabilities related to knowledge, skills, and competencies are not better when compared to students' native abilities in using technology (Belland, 2009; Lim & Khine, 2006). This can be interpreted that not only teachers lack in using technology but also in integrating technology in applying their pedagogy (Ersanli, 2016). Teachers also have an important role to educate students to be able to use technology, produce and be able to reach extensive information quickly (Sen & Temel, 2016). According to Keengwe, et al. (2009) teachers in all disciplines must learn how to design and develop technology that can foster student success in today's modern learning environment. So in order to achieve this, the ability of Chemistry teachers and prospective teachers to integrate their technology-related knowledge with Technological Pedagogical Content Knowledge (TPACK) competencies is a necessity.

Technological Pedagogical Content Knowledge (TPACK) is a perfect combination of three domains of knowledge (consist of content, pedagogy, and technology) which emphasizes the relationship between technology, curriculum content, and pedagogical approaches that aim to develop basic knowledge when a teacher learns the subject matter and understands how technology can enhance learning opportunities and experiences for students while knowing the right pedagogy to enhance the content of the learning (Ariani, 2015; Harris, Mishra, & Koehler, 2006). This knowledge makes the subject of learning easier for students with the right pedagogy and technology (Koehler & Mishra, 2006; Schmidt et al., 2009). The concept of TPACK is that teacher information must be included to create an effective integration of technology and education.

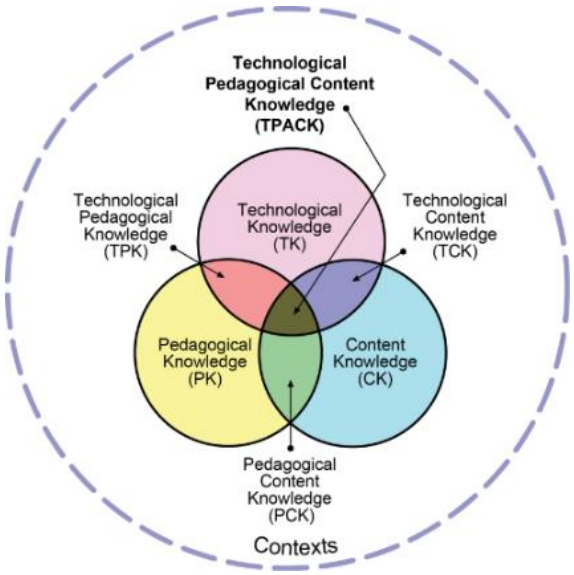

Figure 1. Technological Pedagogical Content Knowledge (TPACK) framework and its components (Mishra & Koehler, 2006; TPCK.org, 2013)

There are seven variables that influence TPACK, consist of: (1) Technological Knowledge (TK) is knowledge about how to operate computers and relevant software; (2) Pedagogical Knowledge (PK) is the ability to manage student learning; (3) Content Knowledge (CK) is subject matter knowledge such as knowledge of language, Mathematics, Natural Sciences etc.; (4) Technological Content Knowledge (TCK) is knowledge about how content can be researched or represented by technology; (5) Pedagogical Content Knowledge (PCK) is knowledge about how to represent and formulate subjects that make them understandable to others; (6) Technological Pedagogical Knowledge (TPK) is knowledge about how technology can facilitate pedagogical approaches; (7) Technological Pedagogical Content Knowledge (TPCK) is knowledge about how to facilitate student learning of certain content through pedagogical and technological approaches (Wilcox & Graham, 2017, Mishra & Koehler, 2006; Shulman, 1986).

Mastery of TPACK (Technological Pedagogical Content Knowledge) skills with all its dimensions by teachers greatly affects the quality of learning in the classroom. This is because teachers with quality content knowledge will be able to transmit content well through the pedagogical knowledge they have mastered which is then integrated with the use of technology.

The current education curriculum is also a curriculum designed to face today's challenges (Ulya & Syafei, 2022), so that the learning created is based on a student-centered learning pattern. The goal is to achieve quality national education goals. The development of learning approaches and models has long been developing and diverse in accordance with the demands of knowledge development and expertise needs in the 21st century. One approach that can be used is the STEAM approach.

The STEAM approach stands for Science, Technology, Engineering, Art and Mathematics which links the fields of Science, technology, engineering, art, and mathematics, so that students are given a holistic understanding of the relationship between the fields of science through 21st century learning experiences and improve high-order thinking skills. One of the characteristics of the STEAM approach is that learning is contextually based (Yakman, 2012), where students will be invited to understand the phenomena that occur in everyday life of them. The STEAM approach encourages students to learn to explore his interests and talents. STEAM will also produce different and unexpected works from each individual or group. Therefore, collaboration, cooperation and communication skills will emerge in the learning process that uses the STEAM approach. The other advantages of STEAM approach include preparing the next generation who are ready to face the development of the era 21st Century (Sanders, 2009), making learning more in line with life (Stolman, Moore, Roehrig, 2012), helping students to actively build their own concepts (Bybee, 2010), increasing students' interest in jobs in the STEAM field (White, 2014), and giving rise to various innovations in life (Eberle, 2010).

The implementation of TPACK in STEAM-based learning is very relevant and important. Both approaches have the same focus, namely how a teacher understands and teaches lesson content by applying and utilizing relevant technology. In addition, to encourage students to think creatively and critically, the application of TPACK in STEM Education is very suitable to

be adapted in the teaching methods or pedagogy of science teachers (Abdullah et al. 2024). Therefore, researchers are interested in studying research trends related to the implementation of TPACK and STEAM-based learning, especially chemistry learning in higher education.

Method

The research method used is systhematic literatire review. Systematic Literature Review (SLR) is a is a type of research that aims to identify, measure, and interpret the results of primary research findings [barriceli 2019]. This research was conducted on 7 Oktober-15 November 2024. The data collection technique was carried out by conducting research studies according to the keywords in the research titles for the last 9 years (2014-2024) based on the Google Schooler database. The data obtained were analyzed using a bibliometric analysis approach, namely an approach that can determine technology patterns or research orientation using keywords, title keywords, and plus keywords (Ismoyo *et al*., 2023; Sheikh, 2017). The inclusion and exclusion criteria for article search include TPACK, STEAM education, science, chemistry learning, etc. Bibliometric analysis was carried out using the VOSviewer program. Based on the author's search, 100 documents were found that matched the keywords.

Results and Discussion

This section presents the findings and discussion of findings to reflect the development and trends of research on the relationship between TPACK and the STEAM approach in chemistry learning in higher education. Based on the search results with the keywords "TPACK", "STEAM Education", "Science learning", "Chemistry learning" using Publish or Perish, citation metrics are obtained as in table 1

Tabel 1: Citations Metrics

Publication years:	2015-2024
Citation years:	9 (2015-2024)
Papers:	100
Citations:	2394
Cites/year:	266.00
Cites/paper:	23.94
Cites/author:	859.47
Papers/author:	43.19
Authors/paper:	2.92
h-index:	24
g-index:	47
hI,norm:	13
hI,annual:	1.44
hA-index:	13
Papers with ACC >= 1,2,5,10,20:	77,61,40,18,10

The data in Table 1 shows that based on the search results on the Google Scholar database, it shows that the development of research on the relationship between TPACK and the STEAM approach in chemistry learning in higher education over a period of 9 years (2014-

2024) there were 100 articles that matched the keywords of the related research title. Based on the number of citations over the past 9 years, there were 2394 with an average citation per year of 266,000. Citation is a reference or quotation that allows us to acknowledge the sources that have been cited (Bahriah, et al., 2024). Citation is useful for verifying the data obtained so that our writing can be accounted for and has accountability. This shows that research related to research on the relationship between TPACK and the STEAM approach in chemistry learning in higher education is still a trend and is widely studied, especially in science learning.

The results of the analysis using VOSViewer, which is a software that can be used to visualize bibliometric maps or data sets containing bibliographic fields such as title, author, writer, journal, and others, can be used to determine the number of clusters and keywords (Karim et al., 2021). The results of the analysis of the research area for the implementation of TPACK and the STEAM approach in chemistry learning in higher education show that there are 3 clusters with 12 keywords, this can be seen in Table 2 below.

Table 2: Frequently Appearing Clusters and Keywords

Cluster	Item	Keywords
1	6	Learning, STEM education, teacher, technological pedagogical content knowledge, technology, TPACK.
2	5	Chemistry, effect, science, STEAM education, student.
3	1	STEAM

Based on Table 2 representing number of clusters that appear is 3 clusters with the number of keyword items as many as 12 items. Cluster 1 (6 items), cluster 2 (5 items), cluster 3 (1 item). This shows that there is still an opportunity to study the research theme of TPACK and STEAM Education and the implementation of TPACK in STEAM-based chemistry learning in higher education.

The map of publication development and the relationship between terms based on search keywords on Google Scholar is depicted in Figure 2. In the visualization of the relationship between networks, the relationship between terms is represented by a network or line that connects one term to another (Al Husaini et al., 2023).

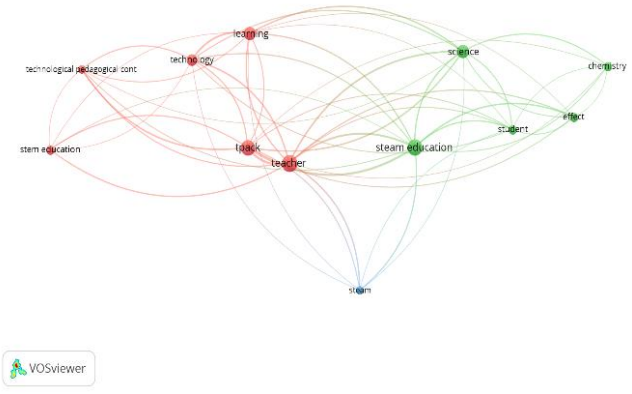

Figure 2: Visualization Network

Conclusion

The results of the study indicate that the TPACK Model is effective in improving high-level thinking skills and improving students' 21st-century skills. STEAM education is also widely associated with educational innovation, skills, teacher training, educational technology, and science teaching. STEAM-based learning is very effective in improving students' chemistry learning outcomes and 21st-century skills. Based on the results of the Google Scholar database analysis over a period of 9 years (2014-2024), article documents were obtained for the keywords TPACK and the STEAM approach in chemistry learning in higher education as many as 100 articles with 3 clusters and 12 appropriate items. This shows that research trends related to the implementation of TPACK in STEAM-based chemistry learning in higher education still have opportunities for further study.

References

Abdullah, Arifah and Siti Nur Diyana Mahmud.2024. Applying TPACK in STEM Education towards 21-st Century: Systematic Literature Review. International Journal of Academic Research in Progressive Education and Development. Vol. 1 3 , No. 1, 2024, E-ISSN: 2 2 2 6 -6348

Ariani. (2015). "Hubungan antara Technological Pedagogical Content Knowledge dengan Technology Integration Self Efficacy Guru Matematika di Sekolah Dasar. Muallimuna Jurnal Madrasah Ibtidaiyah Vol.1, No. 1 Oktober, 2015

Al Husaeni, D. F., Nandiyanto, A. B. D., & Maryanti, R. 2023. Bibliometric analysis of educational research in 2017 to 2021 using VOSviewer: Google scholar indexed research.

Belland, B. R. (2009). Using the theory of habitus to move beyond the study of barriers to technology integration. Journal Computers &Education, 52(1), 353-364

Bybee, R. W. (2010). Advancing STEM Education: A 2020 Vision. Technology & Engineering Teacher. 70 (1), 30-35.

Barricelli, B. R., Cassano, F., Fogli, D. & Piccino, A., 2019. End-user development, enduser programming, and end-user software engineering: A systematic mapping study. Journal of System Software.

Depdiknas .2003. Undang-undang RI No.20 tahun 2003.tentang sistem pendidikan nasional.

Ersanli, C. Y. (2016). Improving technological pedagogical content knowledge (TPACK) of pre-service english language teachers. International Education Studies, 9(5), 18-27. http://dx.doi.org/10.5539/ies.v9n5p18

ES Bahriah et al., 2024. Proceedings of the 7th International Conference on Learning Innovation and Quality Education (ICLIQE 2023), Advances in Social Science, Education and Humanities Research 873, https://doi.org/10.2991/978-2-38476-301-6_71

Eberle, L., & Reh, A. (2014). The slogan as part of the corporate visual identity (CVI) of multinational firms: Associations between industry, market and country of brand in terms of the slogan usage and adjustments in foreign markets.

Harris, J., Mishra, P. & Koehler, M., 2009. Teachers ' Technological Pedagogical Content Knowledge and Learning Activity Types : Curriculum-based Technology Integration Reframed. Journal of Research on Technology in Education, 41(4), pp.393–416.

Ismoyo T, Wibawa B, Sutiyono, Gautama, SA., Poniman. 2023. Research trend of smart learning environment: Bibliometric analysis. LIGHTHOUSE INTERNATIONAL CONFERENCE PROCEEDING 2023, VOLUME 1, 266 – 270

Karim, A., Soebagyo, J., Nuranti, R. P., & Uljanah, A. L., 2021. Analisis Bibliometrik Menggunakan Vosviewer Terhadap Trend Riset Matematika Terapan Di Google Scholar. Jurnal Riset Pendidikan Matematika Jakarta. 3(2). 23-33. https://doi.org/10.21009/jrpmj.v3i2.22264 Indonesian Journal of Teaching in Science, 3(1), 1–8.

Keengwe, J., Onchwari, G. & Onchwari, J., 2009. Technology and Student Learning : Toward a Learner- Centered Teaching Model. Technology, 17(1), pp.11–22. Available at: http://www.editlib.org/p/26258.

Lim, C. P., & Khine. M. (2006). Managing teachers' barriers to ICT integration in Singapore schools. Journal of Technology and Teacher Education, 14(1), 97-125.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: a framework for teacher knowledge. Teachers College Record. 108(6), 1017-1054.

Sen, S., & Temel, S.(2016). An analysis of prospective chemistry teacher's attitudes towards information and communication technologies, and of their confidence in technological and pedagogical content knowledge. Participatory Educational Research (PER), 1-10. http://dx.doi.org/10.17275/per.16.spi.2.1

Shulman, L. S. (1986). "Those who understand: knowledge growth in teaching". Educational Researcher, 15(2), 4–14.

Sanders, M. E. (2009). Integrative STEM: Primer [in some places titled STEM, STEM Education, STEMmania]. The Technology Teacher, 68 (4), 20-26).

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. Journal of Pre-College Engineering Education Research (J-PEER). 2 (1), 4.

Schmidt, D.A. et al., 2009. Technological Pedagogical Content Knowledge. (TPACK). Journal of Research on Technology in Education, 42(2), pp.123–. 149

Sheikh, N. J., & Sheikh, O. (2017). Forecasting of biosensor technologies for emerging point of care and medical IoT applications using bibliometrics and patent analysis. PICMET 2016 - Portland International Conference on Management of Engineering and Technology: Technology Management for Social Innovation, Proceedings, 3082–3093. https://doi.org/10.1109/PICMET.2016.7806585.

Undang-Undang No 14 Tahun 2005 Tentang Guru dan Dosen, Pasal 1 ayat 1

Ulya, N., & Syafei, M. M. (2022). Evaluasi Kebijakan Kurikulum Pendidikan Islam di Indonesia. Jurnal Pendidikan Tambusai, 6(2), 9412-9420

Wilcox, D., Liu, J. C., Thall, J., & Howley, T. (2017). Integration of Teaching Practice for Students' 21st Century Skills: Faculty Practice and Perception. International Journal of Technology in Teaching and Learning, 13(2), 55–77

White, M. C. et al. (2014) "Disparities in cancer mortality and incidence among American Indians and Alaska natives in the United States," American Journal of Public Health, 104(SUPPL. 3). doi: 10.2105/AJPH.2013.301673.

Yakman, Georgette., Hyongyong, Lee. Exploring The Exemplary STEAM Education in the U.S. as a Practical Educational Framework for Korea. J Korea Assoc. Sci. Edu. Vol. 32, No. 6, 2012 Evi_nunun9$5