ICMSE (2024): 214-224
International Conference on Mathematics, Science, and Education
QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

TPACK ABILITY PROFILE OF HIGH SCHOOL BIOLOGY TEACHERS IN SEMARANG CITY

Atip Nurwahyunani[1,2, a)] Wiwi Isnaeni[3,b)], Siti Alimah[4,c)], Aditya Marianti[5,d)]

Author Affiliations
[1]*Program Studi Pendidikan Biologi, FPMIPATI, Universitas PGRI Semarang (UPGRIS Jl. Sidodadi Timur 24 Kota Semarang).*
[2,3,4,5]*Program Doktor IPA Pascasarjana Universitas Negeri Semarang (UNNES Sekaran Campus Gunungpati Semarang 50229 Central Java, Indonesia).*

Author Emails
[a)]*Corresponding author: atipnurwahyunani@gmail.com*
[b)]*wiwiisna@mail.unnes.ac.id*
[c)]*siti_alimah@mail.unnes.ac.id*
[d)]*aditya.marianti.am@mail.unnes.ac.id*

Abstract. This study aims to assess the Technological Pedagogical Content Knowledge (TPACK) profile of high school biology teachers in Semarang, Indonesia. Using a descriptive quantitative approach, data were collected through a survey involving 55 respondents from a population of 105 biology teachers who are members of the Biology Subject Teachers' Forum (MGMP) in Semarang. The instrument used was a closed-ended questionnaire with 30 items to evaluate the seven TPACK components. The results showed that the Technological Knowledge (TK) component had the highest average score of 3.60, followed by Content Knowledge (CK) and Technological Content Knowledge (TCK), both with a score of 3.32. Pedagogical Knowledge (PK) scored 3.22, Technological Pedagogical Knowledge (TPK) scored 3.28, Pedagogical Content Knowledge (PCK) scored 3.33, and the overall TPACK score was 3.23. These results indicate that biology teachers in Semarang generally have a good understanding of integrating technology, pedagogy, and content in their teaching practices. The study suggests the need for targeted professional development to enhance pedagogical strategies that effectively integrate technology in biology education.

Keywords: TPACK; biology education; teacher competency; technology integration; Semarang

INTRODUCTION

Teachers' ability to integrate technology with pedagogy and content commonly referred to as TPACK (Technological Pedagogical Content Knowledge) has become increasingly recognized as a crucial factor in enhancing teaching effectiveness in the digital age. TPACK enables teachers to design more relevant and effective learning experiences tailored to the diverse needs of students. In biology education, mastery of TPACK is particularly important due to the complexity and dynamic nature of the subject matter. Previous studies have shown that teachers with strong TPACK skills are more successful in implementing technology-based learning and in delivering biological concepts more clearly and engagingly (Mishra & Koehler, 2006).

However, challenges persist in the development and application of TPACK, especially among biology teachers. Studies have indicated variations in TPACK proficiency influenced by factors such as teaching experience, access to technology, and professional support (Koehler et al., 2013). Therefore, it is essential to conduct in-depth research on TPACK ability profiles, particularly in specific regions such as Semarang City, to understand the extent to which teachers have mastered TPACK and how it affects the teaching process.

The main issue is the lack of a detailed profile of TPACK competencies among high school biology teachers in Semarang City. Limited data on their mastery of TPACK makes it difficult to design appropriate professional development programs. A comprehensive study that maps out biology teachers' TPACK skills—not only in terms of technical knowledge but also pedagogical abilities and biological content mastery—is urgently needed.

Efforts to improve TPACK include various strategies, such as targeted professional training in technology skills and mentoring programs that connect teachers with TPACK experts. Active use of technology in biology classrooms

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

is also considered an effective way to sharpen teachers' TPACK. However, implementing these solutions effectively requires empirical data that reflect the actual conditions in the field in this case, the TPACK ability profile of biology teachers in Semarang City.

Previous studies have emphasized that TPACK development should begin with increasing teachers' understanding of how technology can support effective pedagogical strategies for teaching specific content (Chai et al., 2010). In biology, this includes using digital tools to visualize complex concepts and employing virtual simulations for experiments that are difficult to conduct in school labs. Additionally, curriculum development that systematically integrates technology into biology instruction is a promising solution (Angeli & Valanides, 2009).

Collaboration among teachers is also essential to share best practices in classroom technology use. For example, Voogt et al. (2013) found that professional learning communities (PLCs) are effective for developing TPACK skills by allowing teachers to learn from peers who have successfully integrated technology into their teaching. In this context, subject teacher forums (MGMPs) can play a crucial role in facilitating information and experience sharing among biology teachers.

Comprehensive TPACK assessments are also needed to identify areas requiring further development. Specially designed questionnaires to evaluate TPACK components have proven effective in highlighting teachers' strengths and weaknesses in technology integration (Schmidt et al., 2009). Data obtained from these assessments can guide the creation of more targeted training programs to enhance teachers' TPACK skills.

Although some studies have examined TPACK ability profiles among teachers, few have focused specifically on high school biology teachers in urban areas like Semarang. For instance, Harris and Hofer (2011) found that teachers often struggle to integrate TPACK effectively without adequate support in training and resources. While some studies have explored these challenges, few empirical investigations have been conducted on the TPACK proficiency of high school biology teachers in Semarang City. Given the vital role of TPACK in ensuring effective and technology-supported biology instruction, this study seeks to fill that gap by providing data that can inform future policy and training program development.

The objective of this research is to outline the TPACK ability profile among high school biology teachers in Semarang City. By understanding this profile, the study aims to present a clear picture of the extent to which teachers have mastered TPACK and how this affects the effectiveness of biology teaching. The findings are expected to contribute new insights to the literature on teacher professional development in Indonesia, particularly in the context of biology education. This study includes all biology teachers registered in the MGMP of Semarang City, with a randomly selected sample. The results will serve as a reference for policymakers to design more effective and data-driven teacher competence improvement programs.

RESEARCH METHOD

This study uses a quantitative descriptive method to explain a phenomenon using numbers to create a picture of a group (Schreiber, 2011). This study involved a population of 105 biology teachers who were members of the Biology Subject Teachers' Council (MGMP) in Semarang City. Purposive sampling technique was used to ensure that the sample was representative of the population. Of the 105 teachers, 55 respondents were willing. This sample size is considered sufficient to provide reliable data for research purposes (Creswell, 2014).

The instruments used in this study included a structured closed questionnaire designed to assess the TPACK profile of high school biology teachers. This questionnaire was developed based on validated and commonly used instruments to measure the seven components of TPACK: Technology Knowledge (TK), Content Knowledge (CK), Pedagogy Knowledge (PK), Content Technology Knowledge (TCK), Pedagogy Technology Knowledge (TPK), Content Pedagogy Knowledge (PCK), and overall TPACK. Each item in the questionnaire was carefully designed to reflect indicators for each component of TPACK, ensuring comprehensive coverage of teacher competencies (Mishra & Koehler, 2006; Chai, Koh, & Tsai, 2013). The questionnaire was administered during the MGMP meeting to ensure maximum participation. Teachers were briefed on the purpose of the study and the importance of providing accurate responses. The data collection process was carefully supervised to avoid bias and ensure the validity of responses. The questionnaire was divided into sections corresponding to each component of TPACK, and teachers were given sufficient time to complete the survey. The survey data were then coded and entered into a statistical software program for further analysis (Bryman, 2012). The questionnaire instrument was structured based on indicators in dimensions 1(a), 2, 3 and 4 using a 4-rank Likert scale, namely (SS/SB) strongly agree/very good, (S/B) agree/good, (C) sufficient, (TS/K) disagree, and (K/TS) Less/Disagree.

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

RESULTS AND DISCUSSION

General Description of Overall TPACK Ability Profile

The TPACK ability profile of Biology Teachers in Semarang City generally shows an overall average value and an average of each aspect illustrated in Figure 1.

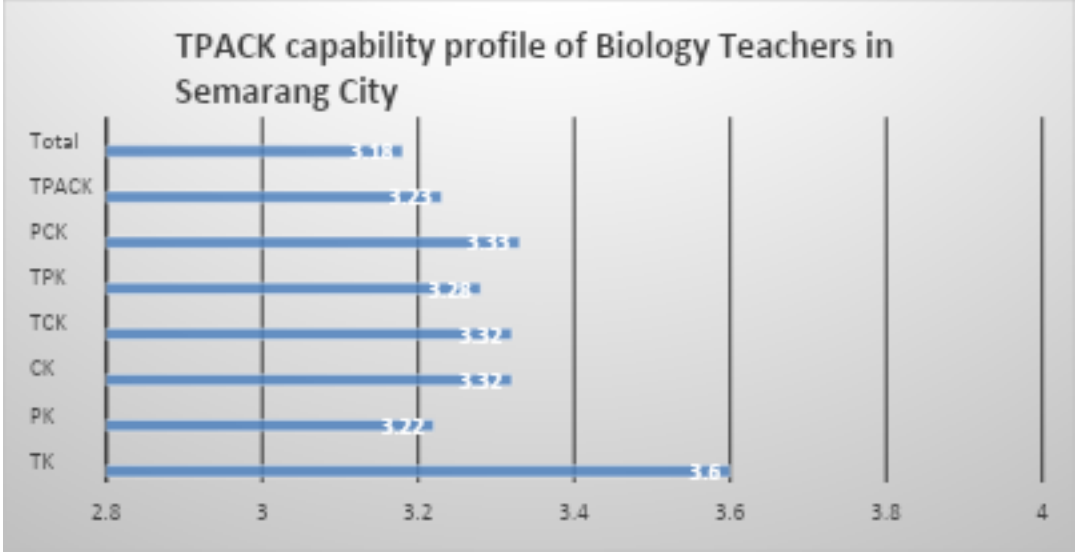

Figure 1. Average TPACK ability profile of teachers in each aspect

Based on Figure 1, the total average score is 3.18 out of a maximum score of 4.00. This means that the overall TPACK capability profile of Biology Teachers in Semarang City is good.

Specific Description of TPACK Capability Profile in Each Aspect

This section specifically discusses the data and findings displayed in each aspect

• Technological Knowledge (TK) Aspect

The results of the questionnaire in this aspect are shown in Table 1.

Table 1. Technological Knowledge (TK) Indicators

No	Observed Indicator	Average Percentage Obtained	Category
1	Mastering the technology used in teaching well	80%	GOOD
2	The technology I use is appealing to students	80.83%	GOOD
3	The technology used successfully increases students' interest and motivation	83%	GOOD
4	The technology used in teaching is easy to operate	82.5%	GOOD
5	The technology used is appropriate for students' understanding	81.6%	GOOD
6	The technology used is in line with current technological developments	81.6%	GOOD
7	The technology used helps solve problems/challenges students face in learning	83%	GOOD

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

	Average	81.79%	GOOD

Overall, for the learning analysis in the aspect of Technological Knowledge (TK), the highest average results were obtained in aspects (3) and (7) of 83% with good criteria. while the indicator of mastering the technology used in learning received the lowest value, namely 80%.

Table 2. Average Percentage Pedagogical Knowledge (PK)

No	Observed Indicator	Average Percentage Achieved	Criteria
1	Has varied strategies/approaches in delivering concepts to students	80.83%	GOOD
2	Uses varied methods and models in teaching	79%	GOOD
3	Demonstrates good classroom management and control	81.67%	GOOD
4	Engages in reflective practices to improve teaching quality	81.67%	GOOD
	Average	**80.79%**	**GOOD**

Overall, the analysis of learning in the aspect of Pedagogical Knowledge (PK) yielded an average score of 80.79%, which falls into the "Good" category. The highest score, 81.67%, was obtained on the indicator of effectively managing the classroom and engaging in reflective practices to improve the quality of learning.

Content Knowledge (CK)

The results of the observation in the aspect of Content Knowledge (CK) cover five indicators as shown in the table below:

Table 3. Average Percentage in the Content Knowledge (CK) Aspect

No	Observed Indicator	Average Percentage	Criteria
1	Mastery of the subject matter	89.16%	Very Good
2	Providing relevant examples to enhance student understanding	86.67%	Very Good
3	Delivering material logically, clearly, and in accordance with the lesson plan/module	81.67%	Good
4	Accurately answering student questions	83.00%	Good
5	Utilizing up-to-date learning resources to teach students	81.67%	Good
	Average	**84.43%**	**Good**

Overall, the analysis of TPACK competence in the aspect of Content Knowledge (CK) showed an average score of 84.43%, which is categorized as "Good." The highest average score was found in the indicator of mastery of the subject matter (89.16%), while the lowest score was in the indicator of delivering material logically, clearly, and in accordance with the lesson plan/module, which was 81.67%.

Technological Pedagogical Knowledge (TPK)

The observation results for the aspect of Technological Pedagogical Knowledge (TPK) include three observed indicators, as presented in the following table:

Table 4. Average Percentage in the Aspect of Technological Pedagogical Knowledge (TPK)

No	Observed Indicator	Average Percentage	Criteria
1	Using computer applications in teaching	85.0%	Very Good

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

No	Observed Indicator	Average Percentage	Criteria
2	Selecting technology that aligns with teaching approaches and strategies	83.0%	Good
3	Using internet facilities to communicate with students, such as for submitting assignments or performance tasks	85.8%	Very Good
	Average	**84.6%**	**Very Good**

Overall, the analysis of TPACK competence in the TPK aspect yielded an average score of 84.6%, categorized as Very Good. The highest score, 85.8%, was recorded for the indicator "using internet facilities to communicate with students, such as for submitting assignments or performance tasks." Meanwhile, the lowest score, 83%, was for the indicator "selecting technology that aligns with teaching approaches and strategies."

Technological Content Knowledge (TCK)

The observation results for the Technological Content Knowledge (TCK) aspect are based on the three indicators shown in the table below:

Table 5. Average Percentage in the Aspect of Technological Content Knowledge (TCK)

No	Observed Indicator	Average Percentage	Criteria
1	The technology used is relevant to the material being taught	84.16%	Good
2	The technology used enhances student understanding	83.00%	Good
3	Developing student activities and assignments involving technology	81.67%	Good
	Average	**83.34%**	**Good**

Pedagogical Content Knowledge (PCK)

The analysis results of the TPACK competence in the Pedagogical Content Knowledge (PCK) aspect consist of three observation indicators presented in the table below:

Table 6. Observation Results for the Pedagogical Content Knowledge (PCK) Aspect

No	Observed Indicator	Average Percentage	Criteria
1	Selecting teaching approaches and strategies that align with the material	93.00%	Very Good
2	Providing assessment/evaluation to measure student understanding/mastery	87.50%	Very Good
3	Applying appropriate teaching strategies and utilizing a variety of computer applications during learning	82.16%	Good
	Average	**87.55%**	**Good**

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

Technological Pedagogical and Content Knowledge (TPACK)

The observation results for the Technological Pedagogical and Content Knowledge (TPACK) aspect consist of three indicators as shown in the following table:

Table 7. Observation Results for the TPACK Aspect

No	Observed Indicator	Average Percentage	Criteria
1	Selecting teaching strategies and technology appropriate for the material to be taught	93.00%	Very Good
2	Integrating biological content knowledge, pedagogical knowledge, and technological knowledge to achieve effective learning	82.50%	Good
3	Applying appropriate strategies and using various computer applications during the learning process	75.80%	Good
	Average	**83.76%**	**Good**

Overall, the analysis of the TPACK aspect in classroom teaching resulted in an average score of 75.40%, categorized as Good. Based on the observation results, it can be concluded that teachers have implemented teaching using the Technological Pedagogical and Content Knowledge (TPACK) framework in classroom learning. The role of teachers is already evident in utilizing technology as a learning aid. Despite some specific challenges, learning objectives were still achieved.

These research findings indicate that biology teachers in Semarang City demonstrate a relatively good ability to integrate technology into the teaching process, as reflected in the high scores in the Technological Knowledge (TK) component. This high score indicates that teachers are already familiar with using technology and can apply it effectively in biology instruction. This aligns with the literature, which states that technological mastery is crucial to support learning effectiveness, especially in complex subjects like biology.

The study shows relatively high TPACK mastery, with an overall average score of 3.18 out of a maximum scale of 4. These findings are consistent with the study by Mishra and Koehler (2006), which stated that good TPACK competence is marked by a teacher's ability to integrate technology into instruction in a relevant, effective, and contextual manner.

However, the lower score in Pedagogical Knowledge (PK) suggests that there are still challenges in applying effective pedagogical strategies. Although teachers demonstrate strong content knowledge, their ability to integrate pedagogy with technology needs further improvement. This is consistent with prior research, which emphasizes that effective TPACK implementation requires a balanced integration of content, pedagogy, and technology (Koehler et al., 2013).

Dominance of Technological and Content Aspects, Challenges in Pedagogical Aspects

The highest improvements were found in the Content Knowledge (CK) and Technological Knowledge (TK) components. This indicates that teachers are relatively confident in their mastery of Biology content and in using technology to support the learning process. High scores in the indicators "mastery of the subject matter taught" (89.16%) and "technology increases student interest" (83%) reflect teachers' readiness in terms of both substance and technical skills. However, the Pedagogical Knowledge (PK) aspect received comparatively lower scores than other components, indicating that although teachers have a solid grasp of the subject and technology, they are not yet fully optimal in applying varied instructional strategies tailored to students' characteristics.

These findings reinforce the perspective of Graham et al. (2019), who argue that technology integration in education can only be effective when supported by appropriate pedagogical approaches. A lack of variation in teaching strategies and reflective practices may result in technology integration being merely cosmetic rather than transformative.

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

Fragmented TPACK Integration

Components such as Pedagogical Content Knowledge (PCK) and Technological Pedagogical Knowledge (TPK) showed high average scores of 87.53% and 84.6% respectively. However, the overall average score for the Technological Pedagogical and Content Knowledge (TPACK) component dropped to 83.76%, with the indicator "integrating biological content knowledge, pedagogy, and technology" scoring only 82.5%. This suggests that integration across domains has not yet been fully internalized in classroom practices. Teachers tend to use technology as a supplementary tool rather than as an integral part of instructional strategies.

This aligns with Koh and Chai (2016), who emphasized that developing TPACK requires deep understanding and critical reflection on the interconnection between the three domains. Teachers need to be empowered to understand that TPACK is not merely the sum of its parts, but a dynamic and contextual integration of knowledge.

Institutional Context and Community Support

The role of professional communities such as MGMP Biologi (Biology Teachers' Working Group) has proven significant in supporting the development of teacher competencies. However, diversity in teaching practices, limited technological facilities, and school-level managerial policies are contextual factors that influence the level of TPACK mastery. This is consistent with the findings of Wang and Zhao (2020), who stated that technology leadership and school culture play a crucial role in determining the effectiveness of TPACK integration in the classroom.

Therefore, teacher training through Professional Learning Communities (PLCs) should be strengthened as a collaborative space to design, implement, and reflect on TPACK-based learning. Strategies such as lesson study and video-based coaching can be utilized to improve teachers' integrative skills.

Implications and Recommendations

Based on the findings, it can be concluded that Biology teachers in Semarang City have demonstrated good competence in TPACK, especially in content and technological knowledge. However, development in pedagogical aspects and the integration of all three domains remains a key area for improvement. Thus, professional development programs should focus on enhancing the integration of technology, pedagogy, and content.

The training programs should be continuous and grounded in reflective practice, including problem-based learning, peer feedback during teaching practice, and the development of digital lesson plans based on TPACK. In addition, policy support from schools and education authorities is essential to ensure the availability of infrastructure and the sustainability of training efforts.

Furthermore, the results of this study highlight the importance of professional development focused on pedagogical strategies that effectively integrate technology in learning. With well-directed training programs, it is expected that teachers' pedagogical abilities will improve, leading to more comprehensive and effective integration of technology in Biology education.

This study provides important contributions to the literature on teacher professional development, particularly within the local context of Semarang City. The findings can serve as a reference for policymakers in designing more effective, data-driven teacher competency development programs to improve the quality of Biology teaching in schools.

Additionally, the study lays the groundwork for future research to explore contextual factors that influence TPACK mastery, as well as the long-term impact of professional development initiatives on enhancing teachers' TPACK competencies. As such, the study not only provides a snapshot of the current TPACK profile but also points to potential directions for further development.

CONCLUSION

This study has provided a comprehensive assessment of the TPACK profile of high school Biology teachers in Semarang, showing generally high levels of competence across the various components of the TPACK framework.

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

The findings reveal that while teachers demonstrate strong Technological Knowledge (TK), Content Knowledge (CK), and Technological Content Knowledge (TCK), there is still room for improvement in Pedagogical Knowledge (PK) and in the overall integration of these elements, as reflected in the slightly lower TPACK score.

These results highlight the need for targeted professional development programs aimed at enhancing pedagogical strategies that effectively integrate technology into Biology instruction. The insights gained from this study contribute to our understanding of TPACK in a regional context, emphasizing the importance of local interventions to ensure that educators are prepared to meet the demands of modern teaching practices.

Future research should explore contextual factors affecting TPACK development and investigate the long-term effects of professional development initiatives in improving TPACK competence. This way, the study not only provides a picture of the current TPACK status but also offers directions for future improvement.

References

Baran, E., Canbazoglu Bilici, S., Mesutoglu, C., & Ocak, C. (2019). Moving beyond readiness: An investigation of the integration of ICT in science classrooms in a professional development context. *International Journal of STEM Education*, 6(1), 1-15.

Baser, D., Kopcha, T. J., & Ozden, M. Y. (2016). Developing a technology integration course for secondary preservice teachers: *A design-based research study*. Computers & Education 102, 1-19.

Chuang, H. H., & Tsai, C. C. (2019) Enhancing TPACK in K-12 teachers through online professional development in technology-enhanced inquiry-based learning. *Journal of Educational Technology & Society,* 22(2), 45-56.

Dong, Y., Xu, C., Liu, Z., & Wang, X. (2020). Analyzing the factors influencing technology integration among university teachers based on the TAM model. *Educational Technology Research and Development,* 68(2), 691-708.

Foulger, T. S., Graziano, K. J., Schmidt-Crawford, D., & Slykhuis, D. A. (2017). Teacher educator technology competencies. *Journal of Technology and Teacher Education,* 25(4), 413-448.

Graham, C. R., Borup, J., & Smith, N. (2019). Using TPACK as a framework to understand teacher candidates' technology integration decisions. *Journal of Computer Assisted Learning*, 35(3), 276-287.

Hsu, P. S., & McLean, L. (2020). Exploring preschool teachers' TPACK and the impact of a professional development model on their TPACK development. Journal of Research in Childhood Education 34(1), 36-51.

Huang, R., Spector, J. M., & Yang, J. (2019).Design and development of technology-enhanced learning: *Integrating TPACK and instructional design. Educational Technology Research and Development*, 67(3), 663-678.

Kimmons, R., & Hall, C. (2018). *The predictive validity of TPACK on technology integration in K-12 classrooms*. Computers & Education, 129, 1-13.

Koh, J. H. L., & Chai, C. S. (2016). *Seven design frames that teachers use when considering technological pedagogical content knowledge (TPACK)*. Computers & Education, 102, 244-257.

Li, S., & Jeong, S. (2020) Teachers' professional development in fostering TPACK: The role of technological pedagogical content knowledge-in-practice. *Journal of Educational Computing Research*, 58(4), 677-701.

Liao, Y. C., Chen, L. K., & Lin, S. S. (2020). Analyzing the influence of TPACK on teacher self-efficacy in the context of STEM education. *Journal of Research on Technology in Education*, 52(2), 243-258.

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

McGrail, E., & Davis, A. (2021) TPACK and teacher collaboration: An exploration of teacher knowledge and technology integration. *Education and Information Technologies*, 26, 3713-3730.

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

Mouza, C., Karchmer-Klein, R., Nandakumar, R., Ozden, S. Y., & Hu, L. (2014) Investigating the impact of an integrated approach to the development of preservice teachers' technological pedagogical content knowledge (TPACK). Computers & Education, 71, 206-221.

Nouri, J. (2019). Students' multimodal literacy and design of learning during self-studies in higher education. Technology, Pedagogy and Education, 28(5), 609-623.

Ottenbreit-Leftwich, A. T., Liao, J. Y. C., Sadik, O., & Ertmer, P. A. (2018).Evolution of technology integration in schools: Teachers' perspectives on professional development. Journal of Educational Computing Research, 56(7), 1034-1061.

Phillips, M., & Harris, J. (2018) Frameworks for K-12 online learning: A literature review. *Journal of Online Learning Research,* 4(2), 109-134.

Sahin, I., & Thompson, A. (2019).Understanding faculty use of learning management systems in online education: A technology acceptance model perspective. *Journal of Educational Technology Development and Exchange, 12(1), 1-16.*

Schmidt-Crawford, D., Thompson, A., & Lindstrom, D. (2018) Exploring factors that influence TPACK adoption among university faculty. *Journal of Research on Technology in Education*, 50(2), 87-104.

Scherer, R., Tondeur, J., Siddiq, F., & Baran, E. (2018). The importance of attitudes toward technology for pre-service teachers' technological, pedagogical, and content knowledge: Comparing structural equation modeling approaches. *Computers in Human Behavior*, 80, 67-80.

Scherer, R., Tondeur, J., & Siddiq, F. (2021). Technology acceptance in education: A meta-analysis of the relationship between perceived usefulness and perceived ease of use. *Journal of Educational Psychology*, 113(4), 756-775.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14.

Tondeur, J., Scherer, R., Siddiq, F., & Baran, E. (2020) Enhancing pre-service teachers' technological pedagogical content knowledge (TPACK): A meta-analysis of the effectiveness of intervention programs. *Educational Research Review*, 29, 100312.

Voogt, J., & McKenney, S. (2017) *TPACK in teacher education: Are we preparing teachers to use technology for early literacy,Technology, Pedagogy and Education*, 26(1), 69-83.

Wang, J., & Zhao, G. (2020) Exploring the relationships among TPACK, technology leadership, and teachers' technology integration efficacy: Evidence from elementary schools in China. *Educational Technology Research and Development*, 68, 383-399.

Wang, P., & Cheng, J. (2021) Examining the relationships between teachers' TPACK, intentions to use ICT and use of ICT: A structural equation modeling approach. *Computers & Educatio***n**, 163, 104105.

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

Wu, W. H., Kao, H. Y., Wu, S. H., & Wei, S. M. (2019) Development and evaluation of affective domain using mobile applications for ubiquitous learning in physical education. Interactive Learning *Environments*, 27(2), 221-234.

Yigit, E. O., & Bagci, H. (2019) Understanding teachers' TPACK in middle school mathematics classroom. *Journal of Educational Computing Research57*(6), 1441-1468.

Zinger, D., Tate, T., & Warschauer, M. (2017). Learning to integrate technology in teacher education: A TPACK framework. *Contemporary Issues in Technology and Teacher Education*, 17(4), 456-479.