JURNAL EDUSCIENCE (JES)
p-ISSN : 2303 - 355X | e-ISSN : 2685 - 2217
PUBLISHED BY : LPPM of UNIVERSITAS LABUHANBATU

Teacher Professionalism in Moderating the Influence of Ethno-based Augmented Reality on TPACK

Wilda Yulia Rusyida[1], Nurul Husnah Mustika Sari[2], Zaki Dia Ulhak[3], Susilo Adi Prayoga[4], Veranda Ardiyan Putra Pratama[5]

[1,5]Department of Data Science, UIN K.H. Abdurrahman Wahid Pekalongan, Indonesia
[2,3,4] Department of Mathematics Education, UIN K.H. Abdurrahman Wahid Pekalongan, Indonesia
*Email: wilda.yulia.rusyida@uingusdur.ac.id

ARTICLE INFO

Keywords:
Teacher professionalism
ethnomathematics
Augmented Reality

ABSTRACT

Purpose- This study aims to determine: (1) the effect of Augmented Reality (AR) on teachers' Technological Pedagogical and Content Knowledge (TPACK); and (2) whether teacher professionalism strengthens the effect of Augmented Reality on TPACK.

Methodology- This research employed a quantitative approach using moderated regression analysis (MRA) as the data analysis technique. Data were collected through questionnaires measuring teachers' ability to use ethnomathematics-based Augmented Reality and their TPACK levels.

Findings-The results showed that ethnomathematics-based augmented Reality significantly influenced teachers' TPACK, with a significance value of 0.000 < 0.05 in the partial test (t-test). However, teacher professionalism did not have a significant moderating effect, as indicated by a significance value of 0.508 > 0.05 in the moderation test.

Significance- This study reinforces the theoretical framework that integrating augmented Reality with culturally relevant content (ethnomathematics) can effectively enhance teachers' competence in integrating technology, pedagogy, and subject matter.

Received 12 February 2025; Received in revised form 25 February 2025; Accepted 10 September 2025
Jurnal Eduscience (JES) Volume 12 No. 5 (2025)
Available online 30 October 2025

INTRODUCTION

The global transformation driven by technological advances, such as the Industrial Revolution 4.0 and the emergence of Society 5.0, emphasizes the integration of human-centered innovation and digital technologies in various sectors, including education (Puspita, 2020; Saskirana & Herlambang, 2020). These changes have necessitated a shift in education systems to prepare learners with competencies relevant to the 21st century. Education today must foster students who are critical thinkers, creative, ethical, collaborative, and capable of solving problems (Abidin, 2015; Mongkau & Pangkey, 2024). Technological Pedagogical and Content Knowledge (TPACK) is a conceptual framework introduced by Mishra and Koehler to describe the knowledge teachers need to effectively integrate technology into teaching and learning (Rosenberg & Koehler, 2015; Koehler & Mishra, 2016). TPACK consists of three core knowledge domains—Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK)—and four intersecting domains: Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and the integrated domain of TPACK itself. In the context of 21st-century education, mastering TPACK is essential as teachers are expected to design learning experiences that are not only content-rich but also pedagogically sound and technologically enhanced (Wang, 2018). Ritonga (2023) emphasized that professional teachers—those who have completed the Teacher Professional Program (PPG)—are expected to have a firm grasp of TPACK to implement innovative and meaningful learning practices.

In response to these demands, teachers are required to possess Technological Pedagogical and Content Knowledge (TPACK), a framework introduced by Mishra and Koehler that integrates knowledge of technology, pedagogy, and subject content into teaching practices (Rosenberg & Koehler, 2015; Koehler & Mishra, 2016). Mastery of TPACK is essential for professional teachers who have received certification through programs such as the Teacher Professional Program (Ritonga, 2023). However, many teachers still struggle to fully utilize available technologies beyond basic tools like laptops and projectors (Nento & Manto, 2023).

One promising innovation that can help teachers enhance their TPACK is augmented Reality (AR). AR technology merges digital content with the physical environment in real time, making learning more interactive and engaging (Arena, 2022; Carmigniani & Furht, 2011). AR can be used to create educational content with only a laptop and smartphone, using platforms like Unity 3D and Vuforia. This makes AR relatively accessible for teachers. Augmented Reality (AR) is a technology that overlays digital content—such as images, videos, or 3D models—onto the physical environment in real time (Arena, 2022). It enhances user experience by making learning more interactive and immersive, improving student engagement and understanding of complex concepts (Carmigniani & Furht, 2011; Vertucci, 2023). AR can be implemented using widely accessible devices like smartphones and laptops with webcams. AR-based teaching materials can be developed using free software such as Unity 3D and Vuforia, making it feasible even for teachers with basic technical skills (Abdullah, 2022). Previous studies have demonstrated that AR can positively impact students' motivation and conceptual understanding, especially in abstract subjects like geometry (Uriarte-Portillo et al., 2023). Ethnomathematics is a pedagogical approach that links mathematical concepts to local culture, making the content more contextual and meaningful to students (Sudirman, 2020). Integrating AR with ethnomathematics leads to the development of instructional media that is not only interactive but also rooted in cultural relevance. This approach enhances conceptual understanding and contributes to cultural heritage preservation. Teacher professionalism is often associated with attaining professional certification, which signifies that a teacher has undergone formal training and met specific competency standards. Professional teachers are expected to be ready and capable of integrating technology into their classrooms (Nento & Manto, 2023). However, the extent to which professionalism strengthens the impact of technological tools like AR on enhancing teachers' TPACK remains underexplored and warrants empirical investigation.

In mathematics education, particularly geometry, AR can help visualize complex shapes, thus supporting student understanding. When this technology incorporates cultural elements, it becomes ethnomathematics-based AR, which not only aids learning but also preserves local culture (Uriarte-Portillo et al., 2023; Sudirman, 2020). Previous studies have indicated that AR can improve teachers' TPACK in various subjects (Imadudin & Astuti, 2022; Mustika & Temarwut, 2022). Despite the growing interest in TPACK and AR, research that specifically investigates the impact of ethnomathematics-based AR on TPACK—particularly within the context of local culture and teacher professionalism—is still limited. There remains a gap in understanding how AR can enhance teacher competencies and whether professional certification moderates this relationship.

Therefore, this study aims to examine the effect of ethnomathematics-based augmented Reality on teachers' TPACK and analyze whether teacher professionalism moderates the effect of augmented Reality on teachers' TPACK. By addressing this gap, the study contributes theoretically and practically to the discourse on educational technology integration, particularly in supporting teacher development in the digital era.

METHODOLOGY

Research Design

This study is an ex-post facto research design that investigates causal relationships without directly manipulating variables. Specifically, this study examines whether ethnomathematics-based Augmented Reality (AR) affects mathematics teachers' Technological Pedagogical and Content Knowledge (TPACK). Furthermore, it explores whether teacher professionalism, operationalized by certification status (PPG or non-PPG), is a moderating variable in this relationship.

The research employs a quantitative approach suitable for identifying patterns and testing hypotheses through statistical analysis. Quantitative research is conclusive, as it aims to derive findings generalizable to a broader population.

Population and Sampling

The population in this study includes Indonesian junior high school mathematics teachers familiar with Augmented Reality (AR). The criterion for "familiarity" was determined based on teachers' previous involvement in workshops, training, or classroom implementation of AR-based teaching tools. This information was collected through preliminary screening questions included in the research questionnaire.

Due to time, access, and resource constraints, a purposive sampling technique was used. Sugiyono (2017) states that purposive sampling involves selecting individuals based on specific characteristics that align with the research objectives. The sample consisted of 30 mathematics teachers from five provinces in Indonesia: 1 from Aceh, three from the Special Region of Yogyakarta (DIY), two from West Java, 23 from Central Java, and one from East Java. Although the sample size is relatively small, it meets the minimum standard for correlational research, which, according to Gay and Diehl in Sari and Rahayu (2020), requires at least 30 participants. The limited number of respondents is acknowledged as a limitation of the study and is recommended for future research to expand the participant pool to increase generalizability.

Instrument and Data Collection

The researcher developed the questionnaire based on a synthesis of prior studies and validated it through expert judgment by specialists in educational technology and mathematics education. A pilot test was conducted to assess the instrument's reliability, with internal consistency measured using Cronbach's Alpha, which indicated satisfactory levels (>0.70) for all subscales. Before responding to the full questionnaire, participants were given access to example AR teaching materials based on ethnomathematics, developed using Unity 3D and Vuforia, and accessed via smartphones and laptops. These materials were used to ensure that all respondents had a minimum level of exposure and understanding of how AR is applied in the learning process. However, the study did not include a training intervention, as it focuses on teachers' existing familiarity and independent use of AR tools.

Table 1. Research Variables and Instrument Descriptions

No.	Variable	Indicator	Measurement Method	Scale
1	Use of Ethnomathematics-Based AR	Frequency of AR usage Type of AR used Integration in lesson plans	Self-reported questionnaire	Likert Scale (1–5)
2	Technological Pedagogical and Content Knowledge (TPACK)	TK (Technological Knowledge) PK (Pedagogical Knowledge) CK (Content Knowledge) PCK, TCK, TPK, TPACK	Adapted from the validated TPACK framework (e.g., Schmidt et al.)	Likert Scale (1–5)
3	Teacher Professionalism	Participation in Teacher Professional Program (PPG)	Dichotomous (Yes/No)	Nominal

Data Analysis

Data analysis in this study was conducted using Moderated Regression Analysis (MRA) to test both direct and moderating effects and a t-test for partial significance. The research was conducted between April and May 2024. The collected data were analyzed using Moderated Regression Analysis (MRA) to test the research hypothesis regarding the influence of AR on TPACK and the moderating role of teacher professionalism. Statistical analysis was conducted using SPSS software, and significance levels were set at $p < 0.05$.

FINDINGS

The research instrument for this study was questionnaires. 2 experts with valid results have validated the questionnaires. Then, the instrument was tested for validity using SPSS, and the results showed that all items were valid. The validated instrument is then tested for reliability. Assessing instrument reliability ensures the dependability and trustworthiness of a measuring tool. Testing the level of instrument reliability uses Cronbach's Alpha—the reliability test results are displayed in Table 2.

Table 2. Result of Reliability Statistics

Instruments	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Augmented reality implementation questionnaire based on ethnomathematics	.822	.833	13
TPACK questionnaire	.967	.968	44

From Table 1, it can be inferred that overall, the research instrument items, both implementation variables and TPACK, are reliable because the Cronbach alpha coefficient value is > 0.70, so all valid items of this research instrument are said to be suitable for further testing.

After the instrument is valid and the data are obtained, a test of the normality, multicollinearity, and heteroscedasticity assumptions is carried out. The purpose of the normality test is to determine whether the residuals studied are normally distributed or not. The Kolmogorov-Smirnov test is a procedure used to determine normality. The normality test using SPPS obtained a sig value = 0.169 > 0.05, and H0 was accepted. This means that the residuals are normally distributed. Below, we also show the normality test results with a histogram and a P-P Plot.

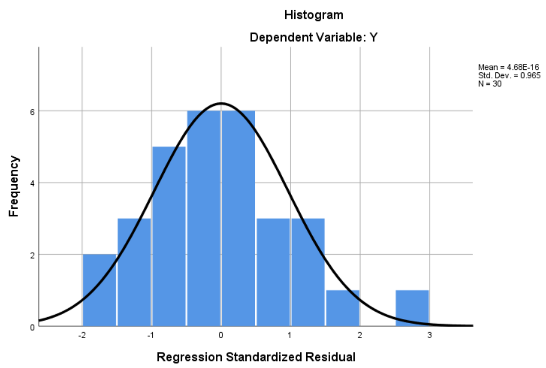

Figure 1. Histogram of Normality Test

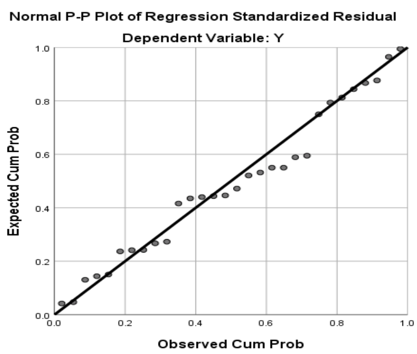

Figure 2. P-P Plot

The multicollinearity test aims to identify any correlations between the independent variables in the regression model. Ideally, a good regression model should show no correlation between its independent variables. The results of the test are presented in Table 3.

Table 3. Multicollinearity Test Results

Model		Collinearity Statistics	
		Tolerance	VIF
1	(Constant)		
	X	.985	1.015
	Z	.985	1.015

Based on the multicollinearity test output, both variables X (AR Etno implementation) and Z (educator certification) obtained a tolerance value of 0.985 > 0.1 and the VIF value of 1.015 < 10. This indicates that the data does not exhibit any signs of multicollinearity.

The heteroscedasticity test is used to see if there is an inequality of variance in each variable. A good regression equation does not have heteroscedasticity but contains homoscedasticity. The Glejser test determines the presence or absence of heteroscedasticity symptoms. This involves examining the regression results of the absolute residual value against other independent variables. The results are illustrated in Table 4.

Table 4. Heteroscedasticity Test Results

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-18.495	27.748		-.667	.511
	X	.477	.508	.298	.940	.356
	Z	21.947	34.586	1.485	.635	.531
	X_Z	-.357	.637	-1.302	-.560	.580
a. Dependent Variable: ABS_RES						

Based on the test results presented in Table 3, it can be concluded that the regression analysis shows no signs of heteroscedasticity. This is because the X variable has a sig value of 0.356, the Z variable has a sig value of 0.531, and the X_Z variable has a sig value of 0.580, where the overall significance value is > 0.05.

Table 5. Multiple Linear Regression Test Results

Model		Unstandardized Coefficients		Sig.
		B	Std. Error	
1	(Constant)	61.552	26.107	.026
	X	2.242	.480	.000
	Z	10.576	13.584	.443
	X_Z	-.169	.251	.508

The constant value of 61.552 indicates that if the AR Implementation and Educator Certificate variables are 0, then the Teacher's TPACK Ability is 61.552 units. The calculation result of the coefficient value of the AR implementation variable based on ethnomathematics is 2.242, meaning that if the implementation of AR based on ethnomathematics is one or increased by 1 level, then the TPACK Ability will increase by 2.242 units, assuming that the other independent variables remain the same. The calculation result of the coefficient value of the educator certificate variable is 10.576. If the educator has an educator certificate, the teacher's TPACK ability will increase by 10.576 units, assuming the other independent variables remain the same.

A moderating variable influences the characteristics or direction of the relationship between variables. The relationship between independent and dependent variables can be positive or negative, depending on the moderating variable. The output results from SPSS are as follows:

Table 6. Partial Test Results (t)

Model		t	Sig.
1	(Constant)	2.358	.026
	X	4.673	.000
	Z	.779	.443
	X_Z	-.671	.508

Based on Table 6, the significance for Z is 0.443>0.05 and the significance for XZ is 0.508>005. This means that certified teachers cannot influence or moderate the effect of ethno-based AR implementation on educators' TPACK ability. Based on the partial test output (t-test), it can be seen that the calculated t value of variable X is 4.673 > t table (1.699) and the significance is 0.000 <0.05. This means that variable X is significant. In other words, implementing AR based on Etno can influence educators' TPACK abilities.

Table 7. R Square 1st Model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.672[a]	.452	.432	11.826
a. Predictors: (Constant), X				

From the R Square value of 0.452 or 45.2%, this table shows that the implementation variable of AR based on ethnomathematics (X) contributes to TPACK ability (Y) by 45.2%. At the same time, the remaining 54.8% is influenced by other causes that were not studied.

Table 8. R Square 2nd Model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.682[a]	.465	.403	12.123
a. Predictors: (Constant), X_Z, X, Z				

From the Adjusted R Square value of 0.403 or 40.3%, this table shows that the implementation variable of AR based on ethnomathematics (X) with educator certification as a moderating variable contributes to TPACK ability (Y) by 40.3%. At the same time, the remaining 59.7% is influenced by other causes that were not studied. From the results above, it can be concluded that the presence of a moderating variable reduces the Adjusted R Square value in model II, which is 0.403 (40.3%), from the R Square value of model I, which is 0.452 (45.2%). Of the two models, there was a decrease of 4.9%. This means that model I, without moderating variables, is better than model II.

DISCUSSION

The Influence of Ethnomathematics-Based Augmented Reality on TPACK

Based on the partial test in Table 5, this study finds that implementing Augmented Reality (AR) based on ethnomathematics significantly influences educators' TPACK abilities. This result aligns with previous studies showing the benefits of AR in mathematics education. For example, AR has been found to improve mathematics learning outcomes (Buchori et al., 2021), enhance spatial ability (Rohendi & Wihardi, 2020), and increase student engagement (Wirawan et al., 2021). Integrating ethnomathematics into AR allows cultural contextualization, making mathematical concepts more relatable. This alignment between content and context likely strengthens the technological component of teachers' TPACK.

Influence on Technological Knowledge (TK)

Augmented Reality is categorized as modern technology within the broader framework of Technological Knowledge (TK). Teachers must possess foundational knowledge of AR tools to implement AR in the classroom. Teachers unfamiliar with AR technology may struggle to incorporate it effectively, while those who use AR gain direct experience applying digital tools for pedagogical purposes. This experience inherently improves their TK. Bower et al. (2014) emphasize that technological knowledge encompasses understanding how to operate and apply digital tools such as AR, which are essential for meaningful classroom integration. Ibáñez & Delgado-Kloos (2018) further argue that direct interaction with AR technology enhances teachers' familiarity and confidence in utilizing such tools, thus strengthening their TK.

Influence on Technological Content Knowledge (TCK)

Not all mathematical topics are suited for AR. Geometry, for instance, is more compatible due to its visual and spatial nature. Teachers must be able to analyze content and determine whether it aligns with AR features. Those who successfully integrate AR with appropriate mathematical content demonstrate a strong understanding of Technological Content Knowledge (TCK). According to Wu et al. (2013), the visual affordances of AR make it particularly useful for subjects that require spatial understanding, such as geometry. Kohen & Kramarski (2012) highlight that TCK involves selecting appropriate technology based on content characteristics, reinforcing the importance of content-technology alignment in effective AR use.

Influence on Technological Pedagogical Knowledge (TPK)

The process of choosing AR as an instructional medium also requires pedagogical considerations. Teachers must assess whether AR supports the desired learning outcomes and fits the instructional strategy. For instance, AR may not be the most effective medium in some cases. Teachers who engage in such evaluative processes exercise their Technological Pedagogical Knowledge (TPK), especially when adjusting their teaching approaches based on technological affordances. Mishra & Koehler (2006) conceptualize TPK as understanding how teaching and learning can change when technologies are used in particular ways. Cheng & Tsai (2013) found that when teachers evaluate the pedagogical implications of using AR, they demonstrate adaptive expertise, a core aspect of TPK.

Influence on Technological Pedagogical Content Knowledge (TPACK)

Ultimately, integrating AR involves selecting suitable content, aligning it with appropriate pedagogy, and utilizing compatible technology. Therefore, teachers who successfully implement AR are integrating all components of the TPACK framework. This combination enhances their capacity to deliver effective, engaging, and contextually meaningful instruction. Koehler & Mishra (2009) define TPACK as the basis of effective teaching with technology, where pedagogy, content, and technology intersect. Studies like Çetin-Berber & Erdem (2021) show that AR integration requires a profound interplay between content knowledge, pedagogical strategies, and technological expertise, thus exemplifying the TPACK model in action.

Limitations of the Moderating Role of Teacher Professionalism

While AR significantly influences TPACK, the moderating variable—teacher professionalism, defined by PPG certification—was statistically insignificant. One plausible explanation is that teacher certification does not automatically correlate with technological proficiency. Younger, uncertified teachers may have greater digital literacy and enthusiasm for new technologies such as AR. However, this conclusion must be treated with caution. Although the hypothesis aligns with prior studies (Lumban Gaol & Simanjuntak, 2023; Fahmiyah et al., 2023), the current study does not include data on the age distribution of participants. Therefore, without further empirical support, no definitive claims can be made about the relationship between teacher age, certification status, and TPACK. Future research should include demographic variables such as age and teaching experience to clarify this relationship. Moreover, external factors such as school facilities, availability of AR-supportive devices, and institutional support may also influence a teacher's ability to use AR effectively. Teachers working in well-resourced schools may have more opportunities to experiment with AR than those in under-resourced environments. Motivation, training, and support systems could also be important mediators not considered in this study.

Methodological Limitations and Future Directions

This study is limited by its relatively small sample size (n = 30), which may restrict the generalizability of the findings. Additionally, the study only involved teachers already familiar with AR but did not explicitly assess the extent or depth of that familiarity. Another limitation is the reliance on self-reported questionnaire data without triangulation from classroom observation or performance-based assessment. Future research should consider: Including larger, more diverse samples across different regions, collecting data on teacher age and years of experience, using mixed methods to triangulate data, and exploring the institutional and motivational factors affecting AR adoption.

CONCLUSION

Based on the results and discussion, this study concludes that using ethnomathematics-based Augmented Reality (AR) significantly improves teachers' Technological Pedagogical Content Knowledge (TPACK). The integration of AR in mathematics instruction enhances teachers' technological competence and supports culturally contextualized teaching through ethnomathematics. This suggests that AR can be an effective strategy to strengthen teachers' ability to merge technology, pedagogy, and content in the classroom. However, the study also finds that teacher professionalism, defined in this context as possessing a professional teacher certification (PPG), does not significantly moderate the relationship between AR implementation and teachers' TPACK. This indicates that professional certification alone may not reflect teachers' readiness or capacity to adopt emerging technologies like AR. Age, technological literacy, and exposure to digital tools could play a more decisive role, although this study did not examine such variables.

These findings have practical implications for teacher training and professional development programs. Specifically, AR-based learning tools can be incorporated into teacher education curricula to enhance TPACK, especially among pre-service and early-career teachers. Furthermore, integrating local cultural elements through ethnomathematics may offer a valuable framework for contextualizing mathematics education, making it more meaningful and engaging for students. Despite its contributions, this study has several limitations. The small sample size and limited regional representation may affect the generalizability of the findings. Additionally, the study did not include key demographic data such as teacher age, years of teaching experience, or access to technological infrastructure—all of which may influence teachers’ TPACK development.

Future research should address these limitations by expanding the sample size, incorporating qualitative data (e.g., classroom observations), and examining additional variables such as motivation, institutional support, and access to digital resources. Such studies could offer a more comprehensive understanding of how technology, teacher characteristics, and contextual factors influence effective teaching in the digital era.

ACKNOWLEDGMENT

Thank you to UIN K.H. Abdurrahman Wahid Pekalongan for providing financial assistance and support and ensuring the smooth execution of this research.

REFERENCES

Abdullah, N., Baskaran, V. L., Mustafa, Z., Ali, S. R., & Zaini, S. H. (2022). Augmented Reality: The Effect on Students' Achievement, Ability, and Interest in Science Education. *International Journal of Learning, Teaching and Educational Research*, *21*(5), 326–350. https://doi.org/10.26803/ijlter.21.5.17

Abidin, Y. (2015). Pembelajaran Multiterasi. In *Refika Aditama*. Refika Aditama.

Arena, F., Collotta, M., Pau, G., & Termine, F. (2022). An Overview of Augmented Reality. *Computers*, *11*(28). https://doi.org/10.3390/computers11020028

Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented Reality in education – cases, places and potentials. Educational Media International, 51(1), 1–15. https://doi.org/10.1080/09523987.2014.889400

Buchori, A., Prasetyowati, D., & Wijayanto, W. (2021). Implementing the Magic Book Math Media Based on Augmented Reality in UPGRIS Senior High School. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3865862

Carmigniani, J., & Furht, B. (2011). Handbook of Augmented Reality. In *Handbook of Augmented Reality* (Issue July 2011). https://doi.org/10.1007/978-1-4614-0064-6

Çetin-Berber, D., & Erdem, C. (2021). Examining pre-service teachers' experiences of using augmented reality applications within the scope of the TPACK framework. Education and Information Technologies, 26(3), 3075–3096. https://doi.org/10.1007/s10639-020-10392-0

Cheng, K.-H., & Tsai, C.-C. (2013). Affordances of Augmented Reality in science learning: Suggestions for future research. Journal of Science Education and Technology, 22(4), 449–462. https://doi.org/10.1007/s10956-012-9405-9

Escuenta, M., Quan, V., Nickow, A. J., & Oreopoulos, P. (2017). *Education Technology: An Evidence-Based Review. NBER Working Paper No. 23744*. 1–102.

Fahmiyah, I., Utami, I. Q., Ningrum, R. A., Fakhruzzaman, M. N., Pratama, A. I., & Triangga, Y. M. (2023). Examining the Effect of Teachers' Age Difference on Learning Technology Adoption Using the Technology Acceptance Model. *AIP Conference Proceedings*, *2536*(May). https://doi.org/10.1063/5.0123943

Ibáñez, M.-B., & Delgado-Kloos, C. (2018). Augmented Reality for STEM learning: A systematic review. Computers & Education, 123, 109–123. https://doi.org/10.1016/j.compedu.2018.05.002

Imaduddin, M., & Astuti, A. P. (2022). Strengthening Chemistry Teachers' Technological Pedagogical Content Knowledge through the Introduction of Augmented Reality and Learning Management Systems. *Bulletin of Community Engagement*, *2*(1), 21–31. https://doi.org/10.51278/bce.v2i1.299

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? Contemporary Issues in Technology and Teacher Education, 9(1), 60–70. https://citejournal.org/volume-9/issue-1-09/general/what-is-technological-pedagogicalcontent-knowledge/

Koehler, M. J., & Mishra, P. (2016). *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators*. Taylor & Francis. https://books.google.co.id/books?id=CUh-CwAAQBAJ

Kohen, Z., & Kramarski, B. (2012). Developing a TPCK-SRL model for designing digital mathematical tasks. Instructional Science, 40, 261–282. https://doi.org/10.1007/s11251-011-9171-5

Lumban Gaol, C. A., & Simanjuntak, S. (2023). Analisis Kesulitan Guru Menerapkan Teknologi Dalam Proses Pembelajaran di SD Negeri 08 Bilah Hilir Labuhan Batu T.A 2022/2023. *Journal on Education*, *6*(1), 2441–2448. https://doi.org/10.31004/joe.v6i1.3267

Michael Onyema, E. (2019). Opportunities and challenges of using mobile phone technology in teaching and learning in Nigeria- A Review. *International Journal of Research in Engineering and Innovation*, *3*(6), 352–358. https://doi.org/10.36037/ijrei.2019.3601

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. Teachers College Record, 108(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Mongkau, J. G., & Pangkey, R. D. H. (2024). Kurikulum Merdeka: Memperkuat Keterampilan Abad 21 untuk Generasi Emas. *Journal on Education*, *6*(4), 22018–22030. https://doi.org/10.31004/joe.v6i4.6323

Muhammadiah, M., Hamsiah, A., Muzakki, A., Nuramila, N., & Fauzi, Z. A. (2022). The Role of the Professional Teacher as the Agent of Change for Students. *AL-ISHLAH: Jurnal Pendidikan*, *14*(4), 6887–6896. https://doi.org/10.35445/alishlah.v14i4.1372

Mustika, M., & Temarwut, R. (2022). Membangun TPACK Guru IPS Melalui Moodle berbasis Blended Learning dalam Pembelajaran Tatap Muka Terbatas. *Jurnal Jendela Pendidikan*, *2*(02), 313–323. https://doi.org/10.57008/jjp.v2i02.215

Nento, F., & Manto, R. (2023). Peran Teknologi dalam Dunia Pendidikan. *E-Tech*, *11*(01), 1–5. https://doi.org/10.1007/XXXXXX-XX-0000-00

Prayogi, R. D. (2020). Kecakapan Abad 21: Kompetensi Digital Pendidik Masa Depan. *Manajemen Pendidikan*, *14*(2), 144–151. https://doi.org/10.23917/jmp.v14i2.9486

Puspita, Y., Fitriani, Y., Astuti, S., & Novianti, S. (2020). Selamat Tinggal Revolusi Industri 4.0, Selamat Datang Revolusi Industri 5.0. *Prosiding Seminar Nasional Pendidikan Program Pascasarjana Universitas Pgri Palembang*, 122–130. https://jurnal.univpgri-palembang.ac.id/index.php/Prosidingpps/article/view/3794/3565

Ritonga, M. S., Sumanti, S. T., & Anas, N. (2023). Analisis kemampuan guru pendidikan agama Islam (PAI) dalam mengimplementasikan technological pedagogical and content knowledge (TPACK) di sekolah dasar. *Jurnal EDUCATIO: Jurnal Pendidikan Indonesia*, *9*(2), 722. https://doi.org/10.29210/1202323203

Rohendi, D., & Wihardi, Y. (2020). Learning three-dimensional shapes in geometry using mobile-based augmented Reality. *International Journal of Interactive Mobile Technologies*. https://doi.org/10.3991/ijim.v14i09.13035

Rosenberg, J. M., & Koehler, M. J. (2015). Context and technological pedagogical content knowledge (TPACK): A systematic review. *Journal of Research on Technology in Education*, *47*(3), 186–210. https://doi.org/10.1080/15391523.2015.1052663

Sari, B., & Rahayu, M. (2020). Pengaruh Lingkungan Pendidikan Kewrirausahaan Dan Penggunaan E-Commerce Pada Peningkatan Minat Berwirausaha Mahasiswa FEB UPI YAI. *Jurnal Ikra-Ith Ekonomika*, *2*(3), 20–29. http://repository.upi-yai.ac.id/2671/%0Ahttp://repository.upi-yai.ac.id/2671/1/Ikraith minat berwirausaha.pdf

Sasikirana, V., & Herlambang, Y. T. (2020). Urgensi Merdeka Belajar di Era Revolusi Industri 4.0 dan Tantangan Society 5.0. *E-Tech*, *08*(02), 1–8.

Setya Wismoko Putri, R., & Saliman, S. (2022). Information Technology-Based Learning to Increase Secondary School Students' Learning Interest. *AL-ISHLAH: Jurnal Pendidikan*, *14*(4), 6285–6296. https://doi.org/10.35445/alishlah.v14i4.1643

Sudirman, Mellawaty, Yaniwati, R. P., & Indrawan, R. (2020). Integrating local wisdom forms in augmented reality application: Impact attitudes, motivations, and understanding of geometry of pre-service mathematics teachers. *International Journal of Interactive Mobile Technologies*, *14*(11), 91–106. https://doi.org/10.3991/ijim.v14i11.12183

Sugiyono. (2017). *Metode Penelitian Kuantitatif Kualitatif dan R&D*. Alfabeta.

Uriarte-Portillo, A., Zatarain-Cabada, R., Barrón-Estrada, M. L., Ibáñez, M. B., & González-Barrón, L. M. (2023). Intelligent Augmented Reality for Learning Geometry. *Information (Switzerland)*, *14*(4), 245–262. https://doi.org/10.3390/info14040245

Vertucci, R., D'Onofrio, S., Ricciardi, S., & De Nino, M. (2023). History of Augmented Reality. In A. Y. C. Nee & S. K. Ong (Eds.), *Springer Handbook of Augmented Reality* (pp. 1–919). Springer. https://link.springer.com/10.1007/978-3-030-67822-7

Wang, W., Schmidt-Crawford, D., & Jin, Y. (2018). Pre-service Teachers' TPACK Development: A Review of Literature. *Journal of Digital Learning in Teacher Education*, *34*(4), 234–258. https://doi.org/10.1080/21532974.2018.1498039

Wirawan, R., Faizah, A. N., & Wahyuningsih. (2021). Implementasi Augmented Reality 3 Dimensi Pada Pembelajaran Matematika Di Sdn 134 Kalumpang. *Jtriste*, *8*(2), 32–40.

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities, and challenges of augmented Reality in education. Computers & Education, 62, 41–49. https://doi.org/10.1016/j.compedu.2012.10.024