Analysis of the Development of TPACK-Based High School Mathematics Learning Designs

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Abstract. This study aims to obtain a TPACK-based learning design that can improve high school students' numeracy literacy skills in Mathematics subjects that are valid, practised, and effective. Mathematics still needs to be considered a complex subject by some students. It is still conceivable to convey basic and center school science based on students' encounters with lifestyle. High school-level material requires a higher level of understanding. Consequently, creating learning experiences that offer students direct engagement is essential. Technological Pedagogical and Content Knowledge (TPACK) integrates various applications, focusing on the interplay of technology, pedagogy, and content. Research on developing TPACK- based Mathematics learning designs uses the Thiagarajan (4D) development type, but the research implementation is limited to the Definition, Design and Development stages. The trial was conducted using tests on 32 class XII students of SMAN 6 Madiun. Data collection was carried out by filling in validation sheets for learning tools by validators (validity test), observation sheets during learning (practicality test), student response questionnaires and learning outcomes tests (effectiveness test). Validity, practicality and effectiveness data were analyzed quantitatively. The analysis results showed that the validity of the TPACK-based learning on Mathematics design is 70,83%, which meets the valid criteria. The results of the practicality analysis of 72,37% indicated that practical criteria, and the effectiveness of 56,60% showed that the requirements are quite effective. The TPACK-based high school mathematics learning design is valid, practical, and quite effective.

Keywords: TPACK Mathematics, Learning Design, Literacy, numeracy.

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1 Introduction

The development of human life is currently experiencing rapid progress due to the impact of technology. Society and various fields of life will feel the impact, especially in education. All aspects of daily life impact teachers in the field of education. Teachers are faced with students who are very technologically literate, which is also the impact of the COVID-19 pandemic [1-3]. Through the independent curriculum, the government wants educational institutions to implement technology-based learning. This will trigger the increasing speed of instructive innovation in Indonesia. This certainly has a positive effect since instruction innovation is in line with the period of Mechanical Transformation 4.0, which proceeds to creep forward. The current circumstance is certainly not simple for the world of instruction [1, 4].

The learning outcomes students achieve after the learning process are still a measure of success. After the mathematics learning process is completed, students must grasp mathematical concepts, apply logical reasoning, solve problems effectively, and communicate their ideas, have curiosity and attention, and be interested in practicing mathematics. Academic success is intrinsically linked to the various learning processes underpinning it; therefore, it cannot be considered in isolation from how learning occurs. Factors that can influence the learning process and learning outcomes include internal factors of students, namely learning motivation, and external factors, namely learning patterns [2]. Motivation to succeed also plays an important role in personal development and achieving specific goals, such as academic success [5,6]. Several efforts have been made to improve the quality of Indonesian education, including improving the quality of teachers, increasing graduation standards, improving school facilities and infrastructure, and developing technology-based learning methods.

Therefore, thinking about appropriate and creative learning strategies is necessary without leaving behind educational science (pedagogy). Learning strategies are systematic steps educators use to create a learning atmosphere that allows learning to occur and specific skills to be acquired. Learning mathematics can be a fun experience for students. This depends on the teacher who presents mathematics as an interesting application. Currently, almost every social activity is centered on society and technology-based, as are learning activities. Until now, technology-based learning is still being carried out, so there needs to be continuous effort in innovative learning by applying technology. The development of information technology today is increasingly opening up opportunities for teachers to utilize technological facilities and the need for learning innovation to support the learning process. Of course, teachers are now starting to develop learning methods based on sophisticated technology [7], [8].

Given the current technological advances, student knowledge transfer needs to be adjusted. The approach is applied based on TPACK (Technological, Pedagogical, and Content Knowledge). TPACK is an integrated learning approach that challenges teachers to master knowledge about facilitating student learning from content material through pedagogy and technology [1]. In addition to mastering subject lessons and pedagogy, teachers must follow technological developments. Therefore, integrating material, pedagogy, and technology is necessary [3]. TPACK-based learning is a framework for understanding and describing the types of knowledge teachers need to carry out

practical teaching activities and conceptual understanding by integrating technology into learning practices. This research needs to be conducted because nowadays, students interact more with technology and school demands assignments after learning and the final grades obtained by students.

2 Research Method

The research conducted was classified as Research and Development (R&D) or development research. According to [4], development research aims to create a specific product, including test of validity, practicality, and effectiveness. The development model used in this study is the Four D (4D) model. According to Raysharie et al. (2023) and Sides & Cuevas (2020), this 4D model includes four stages of development: identification, design, development, and dissemination [5,6]. The first stage is the discovery stage (identification), which includes the content analysis and problem definition stages. The second phase is the design stage, which includes designing learning devices and compiling the product's initial form (prototype). The next stage is the development stage, which includes product validation, which is the product realization stage. The fourth phase is the dissemination phase, which aims to promote the developed product so that users can adopt it, whether individuals, groups, or systems.

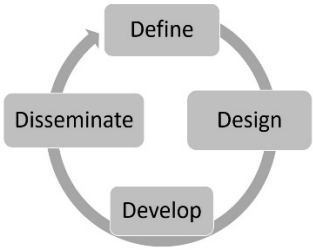

Fig. 1. Thiagarajan 4-D model

The mathematics learning design based on TPACK encourages students to work collaboratively in groups during class. They then present the outcomes of their discussions to the entire class. Students carry out learning using computers with MS Excel and questions that can be accessed via their respective gadgets to complete the concept of bivariate statistics. In the final phase, students complete questions to determine learning outcomes.

Mathematics teachers validated the teaching module as learning media and planning experts. The study subjects were grade XII students of SMA Negeri 6 Madiun. The data collected were: (1) data from the validation results of the teaching module from the learning planning expert and learning media expert and (2) data from the results of small group trial tests. Data for this developmental research was collected using a questionnaire. Specifically, a structured questionnaire sheet was employed to gather information from experts of content, learning media specialists, and students. Quantitative data were analyzed from the completed validation sheets by calculating the percentage

of scores obtained. Table 1 explains the criteria used to develop TPACK-based mathematics learning tools.

A data collection technique, a questionnaire with a Likert scale, was used to obtain validation and practical data. The effectiveness aspect was obtained by conducting a test on student learning outcomes. The non-test questionnaire for validation used a Likert scale, with answer choices of Very Good with a value of 4, Good with a value of 3, Quite Good with a value of 2, and Not Good with a value of 1. Next, determine the percentage of validation results using the formula

$$percentage\ (V) = \frac{Total\ score}{maximum\ score} \times 100\%$$

The following criteria are used to analyze the validation results.

Table 1. Validation criteria

Criteria (V)	Validation levels
$V \leq 25\%$	Unfit for use, cannot be utilized
$25\% < V \leq 50\%$	Acceptable, suitable for use but requires minor revisions
$50\% < V \leq 75\%$	Feasible, ready for use with some minor adjustments
$75\% < V \leq 100\%$	Highly feasible, can be used without revision

The data used to measure the practicality of the teaching module used a non-test questionnaire containing statements for teachers and students and arranged on a Likert scale with a score of 4 for strongly agree, a score of 3 for agree, a score of 2 for disagree, and a score of 1 for strongly disagreement. The teaching module's practicality level is measured through the criteria in Table 2.

Table 2. Practicality criteria

Criteria (V)	Level of practicality
$V \leq 25\%$	Very impractical
$25\% < V \leq 50\%$	Quite practical
$50\% < V \leq 75\%$	Practical
$75\% < V \leq 100\%$	Very practical

For effectiveness, it is analyzed based on students' mathematics learning outcomes. The analysis is carried out by comparing learning outcomes between the group that did not receive treatment (control group) and the class that received treatment (experimental group). The analysis is carried out from the results of classical completeness calculations with the formula

$$\text{Classical completeness} = \frac{completed\ score}{number\ of\ student} \times 100\%$$

The effectiveness criteria for the teaching modules used in learning are reviewed based on Table 3.

Table 3. Effectiveness criteria

Criteria	level of effectiveness (V)
$V \leq 25\%$	Very ineffective
$25\% < V \leq 50\%$	Quite effective
$50\% < V \leq 75\%$	Effective
$75\% < V \leq 100\%$	Very effective

The data collection method used was a questionnaire with a Likert scale to obtain data related to validity, practicality, and effectiveness. Effectiveness is known from the student learning outcome test. The teaching module's effectiveness is also measured by calculating the n-gain score. The n-gain test is carried out by calculating the difference between the pretest and posttest. The formula for calculating n-gain is

$$n - gain = \frac{posttest\ score - pretest\ score}{ideal\ score - pretest\ score}$$

The ideal score is the maximum value that can be obtained. The n-gain value category can be determined based on the n-gain value in the form of a percentage in Table 4.

Table 4. Category interpretation of n-gain effectiveness

Percentage	Interpretation Level
< 40	Ineffective
40 - 55	Somewhat effective
56 - 75	Moderately effective
> 76	Effective

3 Results and Discussion

The learning tools developed in this study consist of a TPACK-based teaching module for Bivariate Statistics material equipped with student worksheets (LKPD) and test questions. The stages in the development are as follows:

3.1 Define stage

At this stage of the study, an initial identification was first carried out through a preliminary study to obtain information by analyzing the phenomena and obstacles faced following the mathematics learning process. This activity was carried out through discussions and interviews with mathematics teachers. From the results of the preliminary study, it was concluded that teachers and students need learning development through innovative learning media. Currently, grade XII students' technological capabilities are quite advanced, so thinking about learning designs that utilize technology is necessary. This is in line with the results of the research by Legi et al. [9], which found

that education has changed in Society 5.0. In civilization 5.0, learning tools must coexist with technology. Digitalization helps learning and teaching. Education can prepare people for Society 5.0 and help advance society. Technological progress will continue.

3.2 Design stage

In selecting media, the researcher implemented TPACK-based learning using MS Excel and Word wall applications. Because the learning material is Bivariate Statistics, the MS Excel application is used to present the material, which can help students understand the completion steps and make it easier to complete their assignments. These results are in line with the recommendation that teachers prepare students' continuous assessment and exam records using MS Excel and teach them its contents to prepare them for its application in teaching, learning, and other personal uses [10,11].

3.3 Develop stage

In this stage, the researcher compiled a teaching module equipped with LKPD and test questions with TPACK-based learning. Validation was carried out to obtain a valid, practical, and effective teaching module product for learning. It is stated that instruments with indicators must be by the variables to be observed and declared valid and reliable before being used for research [12,13]. The teaching module validation test data was carried out through expert validator assessments covering the material and presentation of the teaching module. The following are the results of the questionnaire data analysis from the validated test. Two material experts carried out the teaching module validator. Three aspects of the teaching module assessment are the relevance aspect, the accuracy aspect, the learning content aspect, and the learning quality aspect. The results of the teaching module validation are given in Figure 2.

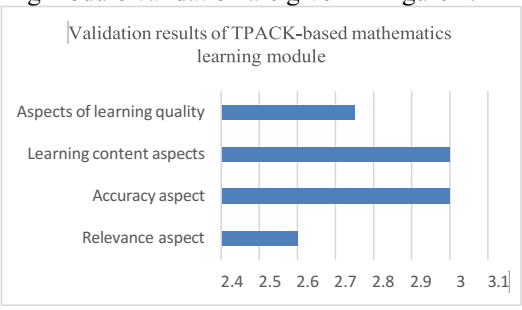

Fig. 2. Validation data from TPACK-based teaching modules

The data from the validation test of the TPACK-based learning module in Figure 2 shows the total validation value based on the learning quality, learning content, accuracy, and relevance aspects. After processing the value data, a percentage of 70.83% was obtained, indicating that the validation of the TPACK-based learning module was classified as feasible.

3.4 Disseminate stage

Next, in the dissemination stage, a limited trial was conducted. The purpose of this stage is to measure the level of practicality and effectiveness of the TPACK-based teaching module. The data obtained for the practicality test uses a questionnaire for teachers and students. Meanwhile, the effectiveness test is based on student test results. The practicality test of the TPACK-based teaching module is carried out by considering the following aspects: language, material, and format. The data on the practicality of the developed teaching module are given in the following figure.

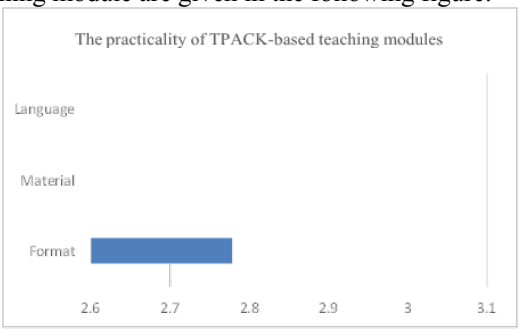

Fig. 3. Data on the results of the practicality of the TPACK-based teaching module

The practicality test data of the teaching module with TPACK-based learning was obtained based on the analysis of the questionnaire results on the practicality of the teaching module by teachers and students. This analysis obtained the practicality value with a percentage of 72.37%. It can be concluded that the developed TPACK-based teaching module is classified as practical.

An *effectiveness test* is a test conducted to measure the level of success of using the module in improving student learning outcomes. Therefore, the effectiveness of the teaching module in this study is measured by learning outcomes. Differences in learning outcomes can be seen from the completeness of student learning outcomes. The completeness of learning outcomes was obtained from the pretest and posttest assessments, followed by 32 students from class XIIC of SMA Negeri 6 Madiun who had carried out learning using the teaching module that had been tested. A normality test was carried out on the pretest and posttest value data as an initial step.

Ranks

	Kelompok	N	Mean Rank	Sum of Ranks
Pretes Postes	Pretes	32	25.17	805.50
	Postes	32	39.83	1274.50
	Total	64		

Fig. 4. Average pretest and posttest data

The results obtained through analysis using the SPSS application program from 32 students were that the average pretest was 8.34 and the average posttest was 9.25. The data was not normally distributed, as shown in Figure 5.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretes	.253	32	.000	.814	32	.000
Postes	.299	32	.000	.579	32	.000

a. Lilliefors Significance Correction

Fig. 5. Normality test of pretest and posttest means

The data is not normally distributed since the significance value (Sig. value) < 0.05 in the Kolmogorov- Smirnova column. Therefore, it is continued with the Mann-Whitney non-parametric statistical test, the results of which are given in Figure 6.

Test Statistics[a]

	Pretes Postes
Mann-Whitney U	277.500
Wilcoxon W	805.500
Z	-3.311
Asymp. Sig. (2-tailed)	.001

a. Grouping Variable: Kelompok

Fig. 6. Mann-Whitney test, average pretest and posttest

Based on the statistical test output in the Mann-Whitney test, the 2-tailed asymp sig value is 0.00. Because it is smaller than 0.05, there is a difference in learning outcomes before and after learning with the TPACK-based teaching module. This shows that the learning process influences learning outcomes. From the results of the n-gain test with SPSS, the n-gain percent result is 56.60. Based on the criteria of the n- gain interpretation table, it is included in the quite effective category. It can be concluded that the TPACK- based teaching module is practical for use in learning.

4 Conclusion

Based on the discussion results, it can be concluded that the development of TPACK-based teaching modules has a level of feasibility, practicality, and effectiveness—TPACK-based teaching modules used in learning impact student learning activities running well. Researchers also received good responses from teachers and students that using technology in learning creates a conducive atmosphere to help students understand the material.

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References

1. G. Ariyanti and F. G. I. Santoso, "Analysis of mathematics learning outcomes on senior high school students in Madiun City, Indonesia in COVID-19 pandemic," *J. Phys. Conf. Ser.*, vol. 1663, no. 1, 2020, doi: 10.1088/1742-6596/1663/1/012037.

2. G. Ariyanti and F. G. I. Santoso, “The effects of online mathematics learning in the Covid-19 pandemic period: A case study of senior High School students at Madiun City, Indonesia,” *Math. Teaching-Research J.*, vol. 12, no. 3, pp. 4–11, 2020.
3. D. S. Setiana, “Pengaruh Metode Pembelajaran CTL dan Open-ended Terhadap Minat Belajar Matematika dengan Memperhatikan Gaya Belajar” *J. Pendidik. Surya Edukasi*, vol. 3, no. November, pp. 66–74, 2017.
4. G. Ariyanti and F. G. I. Santoso, “The Effects of Online Mathematics Learning in the Covid-19 Pandemic Period : A Case study of Senior High School Students at Madiun City , Indonesia,” vol. 12, no. 3, pp. 4–11, 2020.
5. Puput Iswandyah Raysharie *et al.*, “The Effect of Student’s Motivation on Academic Achievement,” *J. Pendidik. Ilmu Pengetah. Sos.*, vol. 15, no. 1, pp. 168–175, 2023, doi: 10.37304/jpips.v15i1.9552.
6. J. D. Sides and J. A. Cuevas, “Effect of goal setting for motivation, self-efficacy, and performance in elementary mathematics,” *Int. J. Instr.*, vol. 13, no. 4, pp. 1–16, 2020, doi: 10.29333/iji.2020.1341a.
7. M. S. Kurniawan, “The Role of Information Technology in Improving the Effectiveness of Education Management,” *J. Educ.*, vol. 04, no. 04, pp. 1658–1665, 2022.
8. Fathan Syuhada Kurniawan, Sariyatun, and Herry Widyastono, “Analysis of Types of Technology Use as a Supporting Tool for Sociology Learning by High School Students,” *J. Educ. Technol.*, vol. 6, no. 4, pp. 722–732, 2022, doi: 10.23887/jet.v6i4.51619.
9. H. Legi, D. Damanik, and Y. Giban, “Transforming Education Through Technological Innovation In The Face Of The Era Of Society 5.0,” *Educenter J. Ilm. Pendidik.*, vol. 2, no. 2, pp. 102–108, 2023, doi: 10.55904/educenter.v2i2.822.
10. K. Bawa, S. Saminu, A. Rabiu, and I. Zubairu, “Application of Microsoft Office Suite in Teaching and Learning,” *Emerg. Trends Contemp. Educ. A B. Readings*, no. April, pp. 62–73, 2021, [Online]. Available: https://www.researchgate.net/publication/351811307_Application_of_Microsoft_Office_Suite_in_Teaching_and_Learning
11. N. S. Joli, A. Mohd Zahidi, K. Z. Hamzah, N. Simin, F. A. Badrol Hissam, and M. E. @ E. Mohd Matore, “Application of MS Excel Software in The Teaching and Learning of Anova Topic through Google Meet,” *J. Adv. Res. Comput. Appl.*, vol. 34, no. 1, pp. 19–27, 2024, doi: 10.37934/arca.34.1.1927.
12. R. D. Sugiarta, F. Arofiati, and E. M. Rosa, “Validity and Reliability of Research Instruments on the Effect of Motivation on Nurse Performance in Moderation with Nurse Credentials,” *JMMR (Jurnal Medicoeticolegal dan Manaj. Rumah Sakit)*, vol. 12, no. 1, pp. 46–55, 2023, doi: 10.18196/jmmr.v12i1.6.
13. G. Ariyanti, M. Dian, and C. D. Indrawati, “Implementation of Tpack-Based Learning Design on the Rotating Object Concept,” *Paedagog. J. Pendidik.*, vol. 13, no. 1, pp. 107–120, 2024, doi: 10.24239/pdg.vol13.iss1.514.