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THE DEVELOPMENT OF PROBLEM-BASED LEARNING INTERACTIVE TEACHING MATERIAL TO IMPROVE MATHEMATICAL COMMUNICATION SKILLS AND LEARNING RESILIENCE

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ABSTRACT

Mathematical communication skills and learning resilience are essential competencies for success in mathematics learning in the 21st century. However, Indonesian students still show low achievement in these aspects, as reflected in PISA results and classroom learning practices. This study aimed to develop and examine the effectiveness of Problem-Based Learning (PBL)-based teaching materials assisted by the Canva interactive web platform to improve students' mathematical communication skills and learning resilience. This research employed a Research and Development (R&D) approach using the ADDIE model, which consists of Analysis, Design, Development, Implementation, and Evaluation stages. The study involved 60 tenth-grade students of MAN 4 Sukabumi, divided into an experimental group and a control group. The experimental group learned using PBL-based teaching materials assisted by Canva, while the control group received conventional instruction. The research instruments included expert validation sheets, student and teacher response questionnaires, a mathematical communication test consisting of four essay items, and a learning resilience scale with 30 statements. Data were analyzed using descriptive statistics and inferential statistical tests. The results showed that the developed teaching materials were categorized as very valid and highly practical. Students in the experimental group achieved higher mathematical communication scores and learning resilience compared to the control group, with moderate N-Gain improvements. Statistical analysis confirmed a significant difference between the two groups ($p < 0.05$). It can be concluded that PBL-based teaching materials assisted by the Canva interactive web platform are effective in improving students' mathematical communication skills and learning resilience.

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INTRODUCTION

Mathematical communication skills and learning resilience are two essential competencies that support students' success in mathematics learning. Mathematical communication enables students to express ideas, explain solution strategies, construct arguments logically, and interpret various representations such as symbols, graphs, tables, and verbal explanations. These skills help students build deep conceptual understanding rather than merely obtaining correct answers. *The National Council of Teachers of Mathematics* (NCTM) positions communication as one of the five core process standards in mathematics learning. In the Indonesian context, the importance of mathematical communication is consistently emphasized through curriculum reforms, from the 2006 Curriculum (KTSP), the 2013 Curriculum, to the Merdeka Curriculum, which explicitly promotes critical reasoning and effective communication as part of the Pancasila Student Profile. In addition, learning resilience plays a crucial role in enabling students to persist, adapt, and remain motivated when facing mathematical difficulties, failures, and cognitive challenges.

However, various national and international studies reveal that Indonesian students' mathematical communication skills and learning resilience remain at a low level. Research by Putra et al. (2023) shows that students experience difficulties in expressing mathematical ideas both orally and in writing, explaining solution steps logically, and using appropriate representations. Dakhi (2020) also found that students tend to focus only on final answers without presenting structured reasoning. These conditions are reinforced by the results of PISA 2018, which place Indonesian students below the OECD average in mathematical literacy, including communication aspects. Furthermore, low mathematical communication is closely related to weak learning resilience, where students easily give up, lack confidence, and struggle to maintain learning motivation when facing complex mathematical problems.

One promising solution to overcome these problems is the development of innovative teaching materials that integrate active learning models and digital technology. Problem-Based Learning (PBL) is widely recognized as an effective model to train communication, reasoning, and problem-solving through authentic and contextual problems. Several studies have proven the effectiveness of PBL and digital-based teaching materials, such as Haluti et al. (2024) on problem-based teaching materials, Sari (2018) on interactive web-based materials, and recent studies on Canva-based digital modules that successfully increase student participation and mathematical communication. The use of Canva interactive web provides visual, interactive, and flexible learning features that support students in constructing ideas and communicating mathematical solutions more effectively.

Based on these considerations, this study aims to develop and test the effectiveness of Problem-Based Learning teaching materials assisted by the Canva interactive web platform on trigonometric ratio material to improve mathematical communication skills and learning resilience of Grade X students at MAN 4 Sukabumi. This study is expected to provide both theoretical contributions to mathematics education and practical benefits for teachers in designing digital and student-centered learning environments.

METHOD

This study employed a Research and Development (R&D) design following the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) to develop and evaluate Problem-Based Learning (PBL) teaching materials assisted by the Canva interactive web platform. The development phase produced instructional modules and digital resources which were validated and revised before field testing.

Participants were 60 Grade X students from MAN 4 Sukabumi. They were divided into two intact groups of 30: an experimental group that received PBL-based instruction with Canva

interactive web materials and a control group that received conventional instruction. Teachers and two subject-matter experts also participated in validation and practicality evaluation.

Data were collected using: (1) expert validation sheets for content and ICT aspects; (2) student and teacher response questionnaires for practicality and usability; (3) a mathematical communication test comprising four essay items; and (4) a 30-item learning resilience scale. Additional instruments included lesson observation checklists and documentation of student work.

1. *Analysis*: Needs analysis was conducted through curriculum review, teacher interviews, and students' pretest to determine learning gaps in trigonometric ratio topics.
2. *Design*: Learning objectives, PBL scenarios, module structure, and Canva interactive activities were designed.
3. *Development*: Draft materials were produced and subjected to expert validation (content & ICT). Revisions were made based on expert feedback. A small-scale practicality trial (pilot) was conducted and refined.
4. *Implementation*: The finalized materials were implemented in the experimental class over the instructional unit while the control class followed the regular curriculum. Pretest and posttest (mathematical communication) and resilience questionnaires were administered before and after the intervention. Teacher and student responses and classroom observations were recorded.
5. *Evaluation*: Validity, practicality, learning outcomes, and implementation fidelity were evaluated using instrument results and observation data.

Validity and practicality data were reported as percentage scores and categorized by established criteria. Item reliability (where applicable) was computed using Cronbach's alpha. Student outcomes were analyzed descriptively (means, standard deviations) and using gain scores (N-Gain). Inferential statistics (independent-samples t-test or Mann–Whitney U test depending on normality and homogeneity) were used to compare experimental and control groups; significance level was set at $p < 0.05$. Normality (Shapiro–Wilk) and homogeneity (Levene) tests were performed before parametric analyses. Qualitative data from observations and open responses were analyzed thematically to support quantitative findings.

RESULTS AND DISCUSSION

Results

This study aims to develop and validate PBL-based teaching materials in the form of LKPD and Canva interactive web-based media to improve students' mathematical communication skills and learning resilience on trigonometric comparison material. The results of this research directly answer the research objectives, namely the validity, practicality, and effectiveness of the developed product.

At the analysis stage, the results of teacher interviews and classroom observations confirmed that students experienced difficulties in understanding trigonometric comparison concepts, showed low mathematical communication skills, and tended to be passive during learning. In addition, students' learning resilience was low, as indicated by their quick tendency to give up when facing non-routine problems. These findings justify the need for innovative, technology-based teaching materials that support independent learning and active student involvement.

At the design stage, the teaching materials were systematically structured according to the PBL model. The Canva-based interactive web media consists of clear learning objectives, contextual problem-based stimuli, step-by-step activity guides following the PBL syntax, discussion

spaces, and evaluation sections. The LKPD was designed with attractive visuals, readable typography (Times New Roman, Simsun, and Calibri, size 14–26), and structured learning flow to support students' conceptual understanding and communication processes.

At the development and validation stage, the product was evaluated by material experts and ICT experts. The material expert validation conducted in two stages showed a substantial improvement from the limited trial to the large trial. The average validity score increased from 73.625% (valid) to 92.25% (very valid), indicating that the content, presentation, language, and alignment with the PBL model were highly appropriate. Meanwhile, ICT expert validation also increased from 75.33% (valid) to 85% (very valid), indicating that the media design, interactivity, navigation, and technical quality of the Canva-based web media were of very high quality.

The practicality test results further support the feasibility of the product. In the limited trial involving 10 students, the practicality score reached 77.86% (practical), indicating that students found the material easy to use and helpful for learning. After revisions to layout clarity, instruction wording, and navigation flow, the large-scale practicality test involving 30 students showed a significant increase to 95.48% (very practical). Students reported that the teaching materials were interesting, easy to understand, encouraged active participation, and helped them explain trigonometric concepts more clearly.

The effectiveness test demonstrates that the developed teaching materials successfully achieved the learning objectives. As many as 87% of students achieved the Minimum Mastery Criterion (KKM), with an overall effectiveness percentage reaching 95% (very effective). These results indicate that the integration of PBL with Canva-based interactive media is highly effective in improving students' understanding of trigonometric comparisons. Moreover, classroom observations and student responses showed improvements in students' ability to express mathematical ideas verbally and in writing, as well as increased persistence in solving challenging problems—indicating positive growth in both mathematical communication skills and learning resilience.

Overall, these results confirm that the developed LKPD and Canva interactive web-based teaching materials are highly valid, very practical, and very effective, thus successfully answering the research objective and demonstrating their feasibility for use in trigonometry learning.

Table 1. Recapitulation of Expert Validation Assessment of Limited Trial Materials and Extensive Trials Based on Observed Aspects

Observed Aspects	Item Number	Limited Trial Percentage	Broad Trial Percentage
Material Suitability	1,2,3,4	75,00%	93%
Suitability of didactic conditions	5,6,7,8,9,10,11,12	72,50%	90%
Conformity of Construction conditions	13,14,15,16,17,18,19,20	67,00%	93%
Conformity of technical requirements	21,22,23,24,25,26,27,28,29,30	80,00%	93%
Average Presentation		73,63%	92,25%
Validation Test Criteria		Valid	Highly Valid

The implementation of learning was carried out in two classes: classes X-A as experiments using Canva's interactive web-assisted PBL and control classes using conventional learning.

The experimental learning scenario includes five stages: introductory activities by understanding contextual problems, using Canva's interactive web for problem solving, execution of plans with group discussions, learning reflections to conclude concepts, and evaluations to measure student understanding.

Figure 1. Canva Learning Interactive Web Cover

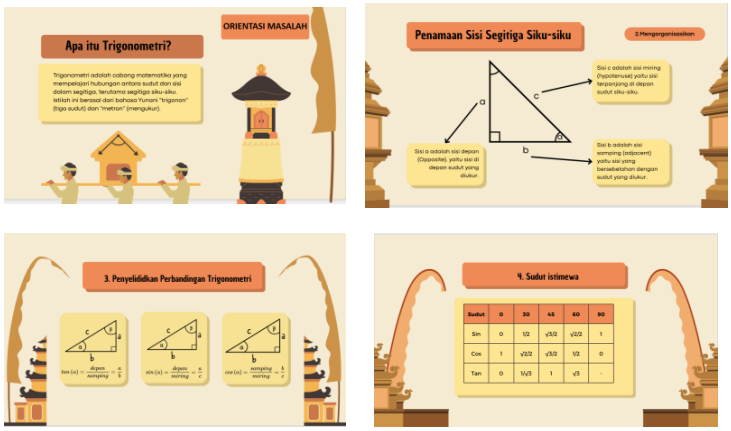

Figure 2. Canva Learning Interactive Web Materials

Figure 3. Introductory Activities

The students' response to the developed teaching materials was very positive with an average percentage of 88%. The aspects of interest and enthusiasm for learning reached 87%, ability to

overcome difficulties 90%, material understanding 88%, and ease of use 87%. The teacher's response was also very good with an average of 92%, including the quality and completeness of teaching materials 91%, effectiveness and attractiveness 93%, and accessibility and ease of use 92%.

Descriptive statistical analysis showed significant differences between the experimental and control classes. The average value of mathematical communication ability in the experimental class reached 81.2 with a standard deviation of 7.9, while the control class was only 67.4 with a standard deviation of 9.5. The results *of the pretest* using Mann-Whitney showed no significant difference in initial ability (Sig. 0.512), confirming that the two groups had equivalent conditions prior to treatment.

Table 2. Statistical Description of Students' Mathematical Communication Ability

Statistics	Experimental Classes	Control Class
Number of Students	30	30
Average Score	81,2	67,4
Median Value	82	66
Maximum Value	95	87
Minimum Score	60	50
Baku Junction	7,9	9,5
Variance	62,4	90,3
Range	35	37

The posttest *normality test* using Kolmogorov-Smirnov showed the data of both classes to be normally distributed (Experimental Sig. 0.066; Control Sig. 0.051). The Mann-Whitney test on *the posttest data* yielded a value of U=219,000 with a significance of 0.000 ($p<0.05$), proving that the mathematical communication ability of the experimental class was significantly superior to that of the control class. N-Gain analysis showed an increase in mathematical communication ability in the experimental class by 0.42 (medium category), while the control class was only 0.21 (low category). The N-Gain normality test showed normal experimental data (Sig. 0.058) but abnormal controls (Sig. 0.045). The homogeneity test yielded a Levene value of 1.254 with a significance of 0.267, indicating homogeneous variance. An independent t-test yielded a value of t=3.825 with a significance of 0.001 ($p<0.05$), validating that the improvement in mathematical communication ability in the experimental class was significantly higher.

Table 3. Results of the Difference Test of Two Mean N-Gain Mathematical Communication Ability

Statistical Test	Statistical Value	df1	df2	Sig. (p-value)	Conclusion
Independent t-test	3.825	29	29	1	There is a significant difference

Measures of learning resilience using a non-test scale showed substantial improvement in the experimental class. The initial average score of the experimental class of 56.23 increased to 81.45, while the control class from 50.01 to 66.73. The N-Gain value of the experimental class of 0.53 (medium category) was much higher than that of the control class of 0.32 (low category). Initial scale normality tests using Kolmogorov-Smirnov showed both groups were normally distributed (Experimental Sig. 0.200; Control Sig. 0.072). The homogeneity test yielded a Levene value of 0.832 with a significance of 0.366, confirming the homogeneous variance. Independent t-tests showed no significant difference in initial resilience (t=-0.232; Sig. 0.817),

ensuring the two groups were on par before the intervention. End-scale analysis showed that both groups remained normally distributed (Experimental Sig. 0.200; Control Sig. 0.080) with homogeneous variance (Levene 1.052; Sig. 0.310). Independent t-tests yielded a value of t=3.245 with a significance of 0.002 ($p<0.05$), proving that the increase in learning resilience of the experimental class was significantly higher than that of the control class. The N-Gain resilience test showed normality in both groups (Sig. 0.245) but was not homogeneous (Levene 2.468; Sig. 0.025). The t-test using *the Welch test* yielded a value of t=3.872 with a significance of 0.000 ($p<0.05$), confirming that learning using Canva's interactive *web-assisted* PBL significantly improved student learning resilience compared to conventional learning. The findings of this study confirm the effectiveness of the integration of the PBL approach with interactive digital media in improving students' mathematical communication skills and learning resilience, in line with constructivism theory that emphasizes active and contextual learning.

Discussions

This study demonstrates that the development of Problem-Based Learning (PBL) teaching materials assisted by the Canva interactive web application is valid, practical, and effective in improving students' mathematical communication skills and learning resilience on trigonometry materials. To strengthen the discussion, the following section compares the findings of this study with at least five relevant previous studies.

First comparison, the significant improvement in students' mathematical communication skills in the experimental class is consistent with the findings of Antasari et al. (2023), who reported that Web Canva-assisted teaching materials effectively enhance students' mathematical communication in solving creative mathematical problems. However, the present study extends their findings by demonstrating not only improvements in communication skills but also a substantial increase in students' learning resilience.

Second comparison, the effectiveness of PBL in this study supports the results of Farhatin, Pujiastuti, and Mutaqin (2020), who found that PBL significantly improves students' problem-solving and mathematical reasoning abilities. While their research focused primarily on reasoning skills, the current study reveals that PBL integrated with ICT media also has a strong impact on communication skills and persistence in learning.

Third comparison, the positive student and teacher responses toward the Canva-based learning media align with the study by Purwanto (2012), which showed that Canva helps make abstract mathematical concepts more concrete and understandable. However, this study further strengthens the evidence by showing that Canva not only supports conceptual understanding but also increases students' motivation, participation, and resilience during the learning process.

Fourth comparison, the improvement in students' learning resilience found in this study is in line with the findings of Putra et al. (2023), who stated that learning resilience is closely related to students' motivation and learning success in challenging academic tasks. The present study adds empirical evidence that the integration of PBL and interactive digital media can significantly enhance students' resilience compared to conventional learning methods.

Fifth comparison, the implementation of contextual learning components (constructivism, questioning, inquiry, modelling, learning community, reflection, and authentic assessment) is consistent with the framework proposed by Yudha et al. (2024). However, this study extends their findings by showing that when these components are supported with interactive web-based media such as Canva, the learning process becomes more engaging and yields better outcomes in both mathematical communication and learning resilience.

In addition, the finding that students in the experimental class showed significantly higher post-test scores and N-Gain values than those in the control class reinforces the conclusion of Trianto (2024) that interactive web-based learning media can create a more creative, innovative, and student-centered learning environment. Compared to previous studies, this research provides more comprehensive evidence as it simultaneously investigates cognitive (mathematical communication) and affective (learning resilience) aspects.

Overall, compared with previous research, this study not only confirms the effectiveness of PBL and Canva-based interactive media but also expands existing findings by proving their combined impact on improving both students' mathematical communication skills and learning resilience. This positions the developed teaching materials as a strong alternative for innovative mathematics learning in senior high school, particularly on trigonometry topics.

CONCLUSION

This development research concludes that the Problem-Based Learning (PBL) teaching materials assisted by the Canva interactive web application on trigonometric comparison materials are valid, practical, and effective. The results of material expert validation reached 92.25% (very valid) and ICT expert validation reached 85% (very valid), while the practicality test achieved 95.48% (very practical). These findings directly answer the research question that investigated the feasibility and effectiveness of the developed teaching materials.

The effectiveness test also proves that the implementation of PBL assisted by interactive digital media significantly improves students' mathematical communication skills and learning resilience. Students in the experimental class achieved a higher average score in mathematical communication (81.2) compared to the control class (67.4), with an N-Gain of 0.42 (moderate) versus 0.21 (low). Likewise, learning resilience in the experimental class increased significantly with a final average score of 81.45 and an N-Gain of 0.53 (moderate), compared to the control class which only reached 66.73 with an N-Gain of 0.32. Statistical testing confirmed a significant difference between the two groups ($p < 0.05$), indicating that the integration of PBL with Canva interactive web-based media is effective in enhancing both students' mathematical communication skills and learning resilience.

Based on these findings, it is recommended that mathematics teachers implement PBL-based teaching materials assisted by Canva interactive web media, especially in trigonometry learning, to support the development of students' communication skills and learning resilience. Schools are also advised to provide adequate technological infrastructure and continuous professional development for teachers in utilizing interactive digital learning media.

For future research, it is recommended to expand the scope of study by involving a larger sample size and a longer implementation period to examine the long-term impact of the developed teaching materials. Further studies should also explore other important variables such as critical thinking skills, creativity, and problem-solving abilities. In addition, future development can integrate these teaching materials with other digital learning platforms to build a more comprehensive and adaptive digital learning ecosystem.

REFERENCES

Adawiyah, F. (2021). Variations in teachers' teaching methods in overcoming student boredom in junior high school. *Langkis Paris Journal*, *2*(1), 68–82. https://doi.org/10.37304/paris.v2i1.3316

Ahmad, A. (2023). Application of the Problem Solving Method in Improving Student Learning Activities of PPKn Subjects on the Importance of the Integrity of the Republic of Indonesia at SDN Temba Class V Semester 1 Academic Year 2016/2017. *Indonesian Journal of*

Education and Learning (JPPI), 3(1), 135–144. https://doi.org/10.53299/jppi.v3i1.321

Antasari, M., Hanifah, H., Susanta, A., & Haji, S. (2023). The Influence of the Search, Solve, Create and Share (SSCS) Learning Model on the Problem-Solving Ability and Creative Thinking Ability of Students at SMA Negeri 4 Kaur. *Lebesgue Journal: Scientific Journal of Mathematics, Mathematics and Statistics Education*, *4*(2), 822–838. https://doi.org/10.46306/lb.v4i2.343

Dakhi, A. S. (2020). Improving Student Learning Outcomes. *Indonesian Journal of Education*, *1*(03), 283–294.

Farhatin, N., Pujiastuti, H., & Mutaqin, A. (2020). Development of Mathematics Teaching Materials Based on Local Wisdom for Junior High School Students in Grade VIII. *Prima: Journal of Mathematics Education*, *4*(1), 33. https://doi.org/10.31000/prima.v4i1.2082

Fauziah, N., & Rahayu, A. (2022). Development of LKPD based on PBL to improve higher-order thinking skills. Journal of Developmental Research in Education, 3(2), 70–81

Haluti, F., Nurteti, L., Pilendia, D., Haryono, P., Hiremawati, A. D., Afrizawati, A., ... Bariah, S. (2024). *Textbook of Theory of Learning and Learning*. PT. Sonpedia Publishing Indonesia. Retrieved from https://books.google.co.id/books?id=tekEEQAAQBAJ

Herman, T., & Fitri, R. (2021). The influence of digital-based learning on students' mathematical resilience. Journal of Mathematics Learning Studies, 4(2), 99–109.

Hidayat, A., & Sari, M. (2021). Problem-Based Learning in improving students' mathematical communication skills. Jurnal Pendidikan Matematika, 15(2), 145–156.

Kurniawan, D., & Pratiwi, V. (2021). Student resilience in mathematics learning through digital media. Journal of Educational Psychology, 6(2), 101–112.

Lestari, E. K., & Yudhanegara, M. R. (2019). Analysis of students' mathematical communication ability reviewed from learning models. Infinity Journal, 8(2), 135–146.

Ningsih, S., & Hartono, Y. (2021). The role of ICT in improving student engagement in mathematics classrooms. Journal of Science and Education Technology, 5(3), 211–220.

Prayitno, L., & Wulandari, S. (2023). Web-based learning media in enhancing students' learning outcomes. Journal of Educational Technology, 11(1), 15–27.

Purwanto, H. (2012). The existence of the Principle of the Sunt Servanda Pacta in International Agreements. *Law Pulpit - Faculty of Law, Gadjah Mada University*, *21*(1), 155. https://doi.org/10.22146/jmh.16252

Putra, L. D., Salihah, A. F., Pratiwi, N. F., & Safario, A. M. (2023). Leveraging Canva For Innovative and Creative Learning in Elementary School. *Journal of Basic Medicine*, *7*(4), 2530–2535.

Rahmawati, I., & Setiawan, W. (2022). The impact of Canva-based interactive media on learning motivation. Journal of Learning Innovation, 7(1), 44–53.

Ramdan, Z., & Fitriani, N. (2020). The effect of PBL on students' critical thinking skills in mathematics learning. Journal of Mathematics Education Research, 8(1), 55–66.

Rice, A. N. (2020). *Pie Lesson Class X Smk Al-Khoiriyah Baron Academic Year*.

Ruseffendi. (2005). *Fundamentals of educational research and other non-exact fields*. Tarsito. Retrieved from https://books.google.co.id/books?id=nGrp0AEACAAJ

Sabudu, D. (2024). *Learning innovation with the Canva app: theory and practice*. 1–9.

Sari, R. F. A. (2018). *Comparative Study of Index Card Match Learning Model and Conventional Learning Model on the Learning Independence of SMPN 2 Ponggok Students for the 2017/2018 Academic Year*.

Sugiyono, A. (2019). *Educational Research Methods: Quantitative, Qualitative, and R&D Approaches*.

Sulastri, R., & Noor, A. (2020). Mathematical communication skills in problem-based learning. Journal of Mathematics and Science Education, 12(1), 89–98.

Suryadi, D., & Rohaeti, E. E. (2020). Mathematical communication in innovative learning models. Journal of Mathematics Education Innovation, 6(1), 1–12.

Trianto, M. P. (2024). *Integrated Learning Model: Concepts, Strategies, and Implementation in the Curriculum at the Education Unit Level (KTSP).* The Earth of Scripts. Retrieved from https://books.google.co.id/books?id=txrazwEACAAJ

Wijaya, A., & Herman, T. (2020). The effectiveness of technology-based learning media in mathematics instruction. Journal of Education and ICT, 4(1), 23–32.

Yudha, F. K., Rusilowati, U., Johnson, D., Pujiati, T., Surakarta, U. M., Info, A., ... Inferential, S. (2024). Improving Early Childhood Social Development Through Character Education. *MENTARI Journal: Management, Education, Technology, Information*, *3*(1), 64–72.