

Problem-Based Learning Assisted by Articulate Storyline 3 and Students' Mathematical Problem-Solving Ability: A Quasi-Experimental Study

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ABSTRACT

Mathematical problem-solving is a central competency in mathematics learning, yet Indonesian students continue to experience difficulty, particularly when translating contextual situations into mathematical representations. This study examined differences in mathematical problem-solving performance between Grade X students who received Problem-Based Learning (PBL) assisted by Articulate Storyline 3 and students who received conventional instruction. A quantitative quasi-experimental nonequivalent control-group design involved 78 students at SMAN 14 Pekanbaru, with 39 students in each class selected through purposive sampling. Data were collected using six constructed-response items representing four problem-solving indicators. The reported instrument evidence included item correlations and internal consistency (Cronbach's alpha = 0.673 for the pretest and 0.751 for the posttest). Descriptive statistics, Shapiro-Wilk tests, Levene's tests, independent-samples t-tests, and Cohen's d were computed in IBM SPSS Statistics 23. The classes did not show sufficient evidence of a pretest mean difference, $t(76) = -1.40$, $p = 0.166$. At posttest, the experimental class obtained a higher mean score ($M = 65.48$) than the control class ($M = 46.36$), $t(76) = 8.95$, $p < 0.001$, mean difference = 19.12, 95% CI [14.86, 23.37], $d = 2.03$, 95% CI [1.47, 2.57]. However, the control-class mean declined from 60.09 at pretest to 46.36 at posttest, so the very large between-group difference should be interpreted cautiously. Overall, the combined PBL and Articulate Storyline 3 intervention was associated with substantially higher posttest problem-solving scores than the comparison condition in this sample.

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INTRODUCTION

Mathematical problem-solving is a fundamental objective of school mathematics education because students are expected not only to perform procedures but also to interpret situations, formulate mathematical representations, select strategies, execute solutions, and evaluate results (Afsari et al., 2021; Badan Standar, Kurikulum, dan Asesmen Pendidikan, 2025; Putri et al., 2021; Yapatang & Polyiem, 2022). In the Indonesian curriculum, these competencies are reflected in learning outcomes that emphasize understanding problems, constructing mathematical models, solving them, and interpreting the obtained solutions (Badan Standar, Kurikulum, dan Asesmen Pendidikan, 2025). These stages also correspond closely to the problem-solving processes commonly used in mathematics education: understanding the problem, planning a solution, implementing the plan, and reviewing the result (Yapatang & Polyiem, 2022). Consequently, difficulties in any of these stages can limit students' ability to use mathematics meaningfully in contextual situations (Putri et al., 2021).

Within this framework, mathematical problem-solving ability (KPM) is operationalized in this study through four processes: identifying relevant information, planning a solution, implementing the strategy, and evaluating the result. This operationalization provides a direct link between curriculum expectations and the outcome measured in the study (Badan Standar, Kurikulum, dan Asesmen Pendidikan, 2025; Dorimana et al., 2022; Yapatang & Polyiem, 2022).

National and international assessment evidence provides broader context for the need to strengthen these abilities, although it does not directly describe the present sample. PISA 2025 defines mathematical proficiency as the capacity to reason mathematically and to formulate, employ, and interpret mathematics in real-world contexts (OECD, 2026). Indonesia's mean mathematics score was 364 compared with the OECD average of 463, and a large proportion of Indonesian students remained below the basic proficiency level (OECD, 2026). These national data are therefore treated as contextual evidence supporting the importance of problem formulation and interpretation, rather than as a direct measure of the Grade X students participating in this study.

School-level studies report a recurring pattern of difficulty across problem-solving stages. Students may be able to identify known information but still struggle to translate contextual information into mathematical models, execute procedures accurately, or verify their final answers (Hafizah et al., 2025; Prameswari & Abadi, 2025; Sagala et al., 2024). At the upper-secondary level, even students with relatively high ability have been reported to omit or inadequately perform the checking stage, while lower-performing students often have difficulty completing the planned strategy (Prameswari & Abadi, 2025). Taken together, these findings suggest that the problem is not limited to calculation; it also concerns problem representation, strategy execution, and evaluation. What remains important is to identify instructional arrangements that repeatedly engage students in these stages within contextual tasks.

Interest in strengthening mathematical problem solving has increased internationally. Bibliometric evidence shows sustained growth in research on mathematical problem solving in mathematics education (Wahyuni et al., 2024), while recent meta-analytic work indicates that PBL-based approaches can produce meaningful improvements in problem-solving outcomes across settings (Yuhana & Fajari, 2025). However, heterogeneity across populations, instructional designs, and measurement approaches means that the effectiveness of a particular PBL implementation should be evaluated within its specific context rather than assumed from prior studies. This consideration is especially relevant when PBL is combined with interactive digital media.

One instructional factor that may constrain the development of problem-solving ability is a learning environment in which students have limited opportunities to explore, explain, test, and revise solution strategies (Taufiqurrahman & Hidayat, 2022; Zetriuslita et al., 2025). This should not be treated as a single causal explanation, because students' conceptual understanding, developmental characteristics, reading of contextual information, and the broader learning process can also contribute to difficulty (Wahyuni et al., 2025). PISA 2025 similarly emphasizes cognitive activation—teaching practices that require students to reason, explain ideas, connect concepts, solve nonroutine problems, and reflect on evidence (OECD, 2026). In this view, instruction that actively engages students with meaningful problems is theoretically relevant to the stages measured in this study.

Problem-Based Learning (PBL) is relevant to these needs because learning begins with contextual problems that students must interpret and investigate rather than with teacher exposition alone (Ardianti et al., 2021; Marchy et al., 2022). In the orientation stage, students identify known and unknown information; during organization and investigation, they formulate mathematical models, select strategies, and carry out procedures; and during presentation and evaluation, they justify and re-examine their solutions (Ardianti et al., 2021; Azizah et al., 2023). These phases correspond closely to the four problem-solving indicators used in this study: identifying the problem, planning the solution, executing the plan, and evaluating the result (Dorimana et al., 2022). Experimental and development studies also indicate that PBL can support

problem solving, higher-order thinking, and the development of learning materials (Ariawan & Zetriuslita, 2023; Sari et al., 2021; Seibert, 2021). This conceptual alignment provides the main rationale for expecting PBL to support the measured outcome.

The potential contribution of Articulate Storyline 3 lies not simply in presenting digital content but in how the media can structure students' engagement with a problem. The platform can integrate text, images, animation, audio, video, simulations, and quizzes in a single interactive environment (Agustina et al., 2022; Hidayah et al., 2023). In the present intervention, contextual problems, supporting information, simulations, and quizzes with automatic feedback were incorporated into PBL activities. Such features can make problem information more explicit, allow students to revisit representations, and provide immediate feedback while they develop and check solution strategies (Agustina et al., 2022; Hidayah et al., 2023; Sari & Hanif, 2023). This role is theoretically consistent with the need to support students at the problem-representation and evaluation stages. Nevertheless, digital media should support rather than replace students' cognitive effort; PISA 2025 similarly cautions that technology is most useful when it strengthens active engagement with learning tasks (OECD, 2026).

Previous studies have provided promising yet fragmented evidence regarding these instructional approaches. Articulate Storyline has been associated with improved mathematical problem solving in probability learning (Habuke et al., 2022), while PBL assisted by Articulate Storyline 3 has been examined mainly with elementary-school students (Nurdiansah et al., 2025; Rahayu & Wiarsih, 2025). Other studies have investigated PBL with visual or mathematical software (Novella et al., 2024; Yulianti & Zetriuslita, 2024; Zetriuslita et al., 2025), but these differ in population, digital tool, or outcome. Consequently, the unresolved issue is not whether PBL or interactive media can be useful in general, but whether the combined PBL + Articulate Storyline 3 intervention is associated with higher mathematical problem-solving performance among upper-secondary students under a nonequivalent-group design. The present study addresses this gap by examining the combined intervention among upper-secondary students. Because both PBL and Articulate Storyline 3 were delivered together, the design evaluates the combined intervention rather than the unique effect of either component.

This study therefore addressed the following research question: Do Grade X students who receive PBL assisted by Articulate Storyline 3 demonstrate different posttest mathematical problem-solving scores from students receiving conventional instruction? The null hypothesis specified no posttest mean difference between the two classes, whereas the alternative hypothesis specified a difference. The study contributes evidence from an upper-secondary context while interpreting the results within the limitations of a nonrandomized nonequivalent control-group design.

METHOD

Research Design and Participants

This study employed a quantitative quasi-experimental approach with a nonequivalent control-group design (Macapayad, 2025). Two intact Grade X classes were included without individual random assignment. Both classes completed a pretest and posttest. The experimental class received PBL assisted by Articulate Storyline 3, whereas the control class received the conventional instructional approach used by the teacher. Because treatment assignment was not randomized, baseline pretest scores were examined to characterize initial mean differences, but a non-significant pretest result was not interpreted as proof that the groups were fully equivalent. The design therefore supports cautious comparison of outcomes between the two instructional conditions rather than unrestricted causal inference.

Research was conducted at SMAN 14 Pekanbaru during the odd semester of the 2026/2027 academic year. The target population comprised Grade X students at the school. Two classes were selected purposively based on class availability and compatibility with the learning schedule,

resulting in 39 students in the experimental class and 39 in the control class ($N = 78$). The independent instructional condition was PBL assisted by Articulate Storyline 3, and the dependent variable was mathematical problem-solving ability. The use of purposive selection and intact classes may introduce selection-related differences that cannot be eliminated by the design; this issue is considered when interpreting the findings.

Intervention and Data Collection

In the experimental class, learning followed five PBL stages: orienting students to the problem, organizing students for learning, guiding individual and group investigation, developing and presenting work, and analyzing and evaluating the problem-solving process (Azizah et al., 2023). Articulate Storyline 3 was integrated by presenting contextual problems, supporting information, simulations, and quizzes with automatic feedback. These features were used to support problem understanding, strategy development, and checking of responses throughout the PBL sequence. The control class received conventional learning consisting of lectures, question-and-answer activities, and practice questions. Both classes studied the same material with the same allocation of instructional time and the same number of meetings.

Research Instrument

The data-collection instrument was a six-item constructed-response test administered as a pretest and posttest. Items were organized around four indicators of mathematical problem solving—identifying the problem, planning the solution, executing the plan, and evaluating the result—following Dorimana et al. (2022) (Table 1). These indicators provided the conceptual basis for evaluating students' written responses.

Table 1. Indicators of Mathematical Problem-Solving Ability

No	Indicator	Description of Student Performance
1	Identify the problem	Identify and state the known and required information correctly
2	Plan the solution	State an appropriate model, formula, or solution strategy
3	Execute the solution	Implement the plan and perform calculations correctly
4	Evaluate the result	Draw a conclusion and re-check the correctness of the answer

Before the main study, the pretest and posttest instruments were pilot-tested with 37 and 33 students, respectively, outside the study sample. Item-total relationships were examined using Pearson product-moment correlations, and internal consistency was examined using Cronbach's alpha. Items were retained when the calculated item-total correlation exceeded the corresponding critical correlation value at the 5% level (0.325 for $n = 37$ and 0.344 for $n = 33$), while alpha values of at least 0.60 were treated as adequate within the study's original criterion. Table 2 summarizes these results. Because this evidence is limited to item correlations and internal consistency, it is interpreted as preliminary measurement evidence rather than as comprehensive validation of the instrument.

Table 2. Item Validity and Internal Consistency Results

Item	Pretest item-total r	Sig.	Decision	Posttest item-total r	Sig.	Decision
1	0.566	< 0.001	Valid	0.458	0.007	Valid
2	0.536	0.001	Valid	0.662	< 0.001	Valid
3	0.501	0.002	Valid	0.729	< 0.001	Valid
4	0.788	< 0.001	Valid	0.829	< 0.001	Valid
5	0.566	< 0.001	Valid	0.772	< 0.001	Valid
6	0.730	< 0.001	Valid	0.677	< 0.001	Valid
Alpha	0.673		Reliable	0.751		Reliable

All six items in each form met the study's item-correlation criterion. The reported alpha coefficients were 0.673 for the pretest and 0.751 for the posttest. These coefficients indicate the observed internal consistency of the respective six-item test forms, but they do not by themselves establish content validity or scoring reliability. Therefore, the available instrument evidence is reported cautiously.

Data Analysis

Data were analyzed using IBM SPSS Statistics 23. Descriptive statistics summarized minimum, maximum, mean, and standard deviation values (Subhaktiyasa et al., 2025). Shapiro-Wilk tests were used to assess normality because each class contained fewer than 50 students (Sianturi, 2025), and Levene's tests were used to examine homogeneity of variance (Nurhaswinda et al., 2025). A significance level of 0.05 was adopted. Because the design used intact, nonrandomized groups, the main inferential results are interpreted as between-group mean differences. The analysis did not statistically adjust the posttest outcome for pretest scores; this limitation is acknowledged when interpreting the findings.

The primary inferential comparison was the posttest score between the experimental and control classes using an independent-samples t-test (Syafriani et al., 2023). A separate pretest t-test was used only to describe the evidence concerning baseline mean differences. H0 for the posttest stated that the two classes had no statistically significant mean difference, while H1 stated that a significant mean difference existed. H0 was rejected when $p < 0.05$; otherwise, the analysis failed to reject H0. Because the posttest t-test does not adjust for baseline variability, its result is interpreted cautiously as an unadjusted group comparison.

$$d = (M_1 - M_2) / s_{pooled} \quad (1)$$

Cohen's d was calculated for the posttest comparison as the difference between the experimental and control posttest means divided by the pooled posttest standard deviation (Cohen, 1988). M_1 and M_2 represent the two group means and s_{pooled} the pooled standard deviation. Following Cohen (1988), values around 0.20, 0.50, and 0.80 are commonly described as small, medium, and large; Sawilowsky (2009) proposed additional labels for larger values. Because the observed effect was unusually large, the magnitude is reported together with a 95% confidence interval and interpreted in the context of the nonrandomized design and the observed decline in the control-group mean.

RESULTS AND DISCUSSION

Descriptive Statistics of Mathematical Problem-Solving Scores

Table 3 summarizes the descriptive scores. At pretest, the control class had a slightly higher mean ($M = 60.09$, $SD = 10.58$) than the experimental class ($M = 57.16$, $SD = 7.73$). At posttest, the experimental-class mean increased to 65.48 ($SD = 10.45$), whereas the control-class mean decreased to 46.36 ($SD = 8.29$). The 13.73-point decline in the control-class mean is an important feature of the observed data and contributes to the large posttest difference. Because the available data do not identify the cause of this decline, it should not be attributed to the intervention. Possible explanations such as differences between test forms, instructional conditions, scoring, or other contextual factors cannot be evaluated from the available study information.

Table 3. Descriptive Statistics of Mathematical Problem-Solving Scores

Class	Test	N	Minimum	Maximum	Mean	Std. Deviation
Control	Pretest	39	37.6	85.6	60.092	10.5822
Control	Posttest	39	31.2	64.6	46.364	8.2884
Experimental	Pretest	39	41.7	78.1	57.156	7.7317
Experimental	Posttest	39	44.8	84.4	65.479	10.4485

Descriptively, the experimental class increased by 8.32 points from pretest to posttest, whereas the control class decreased by 13.73 points. These changes provide context for the posttest comparison but do not constitute a causal estimate because individual change scores and baseline-adjusted analyses were not used as the primary inferential model. Previous studies indicate that structured problem-solving activity and contextual representation can support nonroutine problem solving (Dinglasan et al., 2023; Sari & Hanif, 2023; Seibert, 2021), but the present pattern must be interpreted with the unexplained control-group decline in mind.

Assumption Testing

Before hypothesis testing, Shapiro–Wilk normality tests and Levene’s homogeneity tests were examined as prerequisites for the independent-samples t-tests (Nurhaswinda et al., 2025; Sianturi, 2025). The Shapiro–Wilk tests yielded p-values greater than 0.05 for all four score distributions (pretest control $p = 0.128$; pretest experimental $p = 0.258$; posttest control $p = 0.353$; posttest experimental $p = 0.204$), providing no evidence of substantial departures from normality under the adopted criterion.

Table 4. Shapiro–Wilk Normality Test Results

Data	Statistic	df	Sig.	Decision
Pretest control	0.956	39	0.128	Normal
Pretest experiment	0.965	39	0.258	Normal
Posttest control	0.969	39	0.353	Normal
Posttest experiment	0.962	39	0.204	Normal

Levene's tests also produced p-values greater than 0.05 for the pretest ($F = 1.672$, $p = 0.200$) and posttest ($F = 2.351$, $p = 0.129$), so equal variances were assumed for the reported t-tests (Nurhaswinda et al., 2025; Syafriani et al., 2023). These checks support the use of the planned parametric comparisons, while they do not address selection bias arising from the nonequivalent-group design.

Table 5. Levene’s Test for Homogeneity of Variances

Data	Levene Statistic	df1	df2	Sig.	Decision
Pretest	1.672	1	76	0.200	Homogeneous
Posttest	2.351	1	76	0.129	Homogeneous

Hypothesis Testing

Table 6 presents the independent-samples t-tests. At pretest, the mean difference was -2.94 points (experimental minus control), $t(76) = -1.40$, $p = 0.166$, 95% CI [-7.12, 1.24], $d = -0.32$. Thus, the analysis failed to reject H_0 for the pretest mean comparison. This result indicates insufficient evidence of a baseline mean difference under the selected test; it does not demonstrate that the two intact classes were equivalent on all relevant characteristics.

Table 6. Independent-Samples t-Test Results

Data	t	df	Sig. (2-tailed)	Mean Difference	95% CI	Decision
Pretest	-1.40	76	0.166	-2.94	[-7.12, 1.24]	Failed to reject H_0
Posttest	8.95	76	< 0.001	19.12	[14.86, 23.37]	Reject H_0

At posttest, the experimental class scored 19.12 points higher on average than the control class, $t(76) = 8.95$, $p < 0.001$, 95% CI [14.86, 23.37]. The corresponding Cohen's d was 2.03, 95% CI [1.47, 2.57], indicating a very large standardized difference under the classifications of Cohen (1988) and

Sawilowsky (2009). This magnitude should nevertheless be interpreted cautiously because the study used intact nonrandomized classes and the control-group mean declined substantially from pretest to posttest. The result therefore supports a substantial unadjusted posttest difference associated with the combined PBL + Articulate Storyline 3 condition in this sample, rather than an unrestricted causal claim.

Discussion

The observed pattern can be interpreted through the conceptual alignment between PBL phases and the four measured problem-solving indicators, although the study did not directly measure students' cognitive processes during each phase. In theory, problem orientation can support identification of known and unknown information; organization and investigation can create opportunities to formulate models and implement strategies; and presentation and evaluation can encourage students to re-examine the correctness of their solutions (Ardianti et al., 2021; Yapatang & Polyiem, 2022). Because these processes were embedded repeatedly in the experimental learning sequence, they offer a plausible explanation for the higher posttest performance. This explanation remains theoretical rather than direct evidence of the mechanism.

Articulate Storyline 3 may also have supported the combined intervention by presenting contextual information through multiple representations and by providing quizzes with automatic feedback (Agustina et al., 2022; Hidayah et al., 2023; Sari & Hanif, 2023). Such features are relevant to previously reported difficulties in translating everyday situations into mathematical models (Darmawan et al., 2023; Prameswari & Abadi, 2025; Sagala et al., 2024). However, the present design did not include a PBL-only group or a media-only group. Therefore, the study cannot determine how much of the observed difference is attributable specifically to Articulate Storyline 3, to PBL, or to their interaction. The findings provide evidence of higher posttest performance associated with the combined PBL and Articulate Storyline 3 intervention as implemented in this study.

The findings are consistent with earlier studies reporting favorable problem-solving outcomes from Articulate Storyline or PBL-assisted digital learning, but the contexts are not identical. Habuke et al. (2022) examined Articulate Storyline in probability learning, while Rahayu and Wiarsih (2025) and Nurdiansah et al. (2025) focused on elementary-school students. Novella et al. (2024) used other visual media, and Yulianti and Zetriuslita (2024) examined PBL in a different student population. The present study therefore extends the evidence to Grade X students in an upper-secondary setting. At the same time, its posttest standardized difference ($d = 2.03$) is larger than would typically be interpreted as a conventional large effect. Part of this magnitude may reflect the simultaneous increase in the experimental mean and substantial decline in the control mean, so direct comparisons of effect magnitude with prior studies should be made cautiously.

More broadly, prior research and meta-analytic evidence indicate that PBL can support problem solving by requiring students to engage actively with complex tasks, justify strategies, and persist through solution processes (Sari et al., 2021; Seibert, 2021; Yuhana & Fajari, 2025). Dorimana et al. (2022) likewise reported improvement in upper-secondary learners' problem-solving ability under PBL. Studies of PBL in other student populations have also examined mathematical problem-solving outcomes (Setyaningsih & Rahman, 2022) and PBL supported by interactive multimedia (Suleman et al., 2023); these designs differ from the present comparison and do not isolate the contribution of Articulate Storyline 3. The present findings are compatible with this literature, but they add evidence only for the specific combined intervention and sample studied here. Alternative explanations related to nonrandom class selection, measurement characteristics, or differences not captured by the pretest remain possible.

Practical Implications

For classroom practice, the results suggest that a carefully structured combination of PBL and interactive media may be a promising option for supporting mathematical problem solving in similar upper-secondary contexts. The implication is not that the intervention should be adopted

universally, but that teachers may consider using contextual problems, multiple representations, and timely feedback while maintaining students' active responsibility for reasoning. Successful implementation would also depend on adequate teacher preparation, access to the required digital resources, sufficient instructional time, and consistent implementation of the PBL sequence (Sari & Hanif, 2023; Setiawati & Agoestanto, 2023). These conditions should be considered before transferring the approach to other schools or topics.

Limitations and Future Research

Several limitations should be considered. First, students were drawn from two intact classes in one school and were selected purposively rather than randomly assigned, which restricts causal inference and generalizability. Second, the experimental condition combined PBL and Articulate Storyline 3, so the unique contribution of either component cannot be separated. Third, the marked decline in the control-group mean between pretest and posttest remains unexplained by the available data and may have contributed to the very large posttest difference. Fourth, the reported instrument evidence is limited to item correlations and internal consistency; the available report does not provide information on scoring rubrics, inter-rater agreement, or the comparability of the pretest and posttest forms. Finally, the analysis relied on unadjusted independent-samples t-tests rather than a baseline-adjusted model.

Future studies should use larger multi-school samples, random assignment where feasible, or stronger quasi-experimental controls such as matching and baseline-adjusted analysis. A three-group design comparing conventional instruction, PBL without Articulate Storyline 3, and PBL with Articulate Storyline 3 would help isolate the added value of the digital media. Researchers should also document implementation fidelity, establish scoring consistency for constructed responses, examine the comparability of test forms, and include delayed assessments to determine whether gains are retained and transferred to new problem contexts.

CONCLUSIONS

In this sample of Grade X students at SMAN 14 Pekanbaru, the class receiving PBL assisted by Articulate Storyline 3 obtained a substantially higher posttest mathematical problem-solving mean than the class receiving conventional instruction, $t(76) = 8.95$, $p < 0.001$, mean difference = 19.12, 95% CI [14.86, 23.37], $d = 2.03$. The pretest comparison did not provide sufficient evidence of a mean difference between the two classes, but this finding should not be interpreted as proof of baseline equivalence. Given the nonequivalent-group design and the marked decline in the control-group mean, the results are best interpreted as evidence of a strong association between the combined intervention and higher posttest performance in this particular sample rather than as an unrestricted causal effect.

The findings indicate that integrating contextual PBL activities with interactive representations and feedback may be promising for supporting mathematical problem solving in comparable upper-secondary settings. Implementation should be tailored to the instructional context and supported by appropriate teacher preparation, access to digital resources, and monitoring of implementation fidelity. Further research with stronger baseline control, broader samples, separate comparison conditions, and delayed outcome measurement is needed before the findings can be generalized more widely.

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