



Effects of project-based learning supported by Articulate Storyline on students' higher-order thinking skills in junior high school social studies

Rahma Mauliah *, Sumarno , Gusnardi

Universitas Riau, Indonesia.

* Corresponding Author. E-mail: rahmamauliah11@gmail.com

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ABSTRACT

This study examined the effectiveness of Project-Based Learning (PjBL) supported by Articulate Storyline in improving junior high school students' higher-order thinking skills (HOTS) in social studies and explored differences in HOTS according to students' achievement motivation. A quantitative pre-experimental approach with a one-group pretest–posttest design was employed. The participants were 30 eighth-grade students at SMP Negeri 47 Pekanbaru, selected through purposive sampling. Data were collected using a HOTS test and an achievement motivation questionnaire and analyzed using descriptive statistics, paired- and independent-samples t-tests, and N-gain analysis. The results showed a substantial increase in students' HOTS, with the mean score rising from 30.13 on the pretest to 83.77 on the posttest ($t = 36.42$, $p < .001$, Cohen's $d = 6.65$). The mean N-gain of 0.764 further indicated improvement following the intervention. Students with high achievement motivation also achieved significantly higher posttest HOTS scores than those with low achievement motivation ($t = 2.24$, $p = .033$, Cohen's $d = 0.83$). These findings suggest that PjBL supported by Articulate Storyline has potential to promote higher-order thinking in junior high school social studies. However, given the one-group design and limited sample, the findings should be interpreted within the context of this study.

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INTRODUCTION

Higher-order thinking skills (HOTS) are increasingly important for students as they encounter complex problems in academic and everyday contexts. Rather than relying primarily on the recall of information, HOTS involves more complex cognitive processes, including analysis, synthesis, and evaluation, through which students develop meaningful understanding (Wardani & Ibrahim, 2020). Developing these skills has therefore become an important educational goal, particularly as students are expected to interpret information, evaluate alternatives, and respond thoughtfully to problems encountered in contemporary society.

Despite their importance, developing HOTS remains challenging in many educational settings, including social studies. Learning environments that provide limited opportunities for students to explore ideas, analyze information, and solve problems may restrict the development of higher-level cognitive processes (Fadillah & Takiddin, 2022). This concern extends beyond the Indonesian context. Suseelan et al. (2023), for example, found that low-achieving students from different types of schools in Malaysia experienced difficulties in solving problems requiring higher-order thinking, particularly in comprehension, transformation, process skills, and encoding. Such findings highlight the need for instructional approaches that move beyond the transmission of information and provide students with meaningful opportunities to engage in complex thinking.

HOTS-oriented instruction requires active student involvement in inquiry, analysis, and problem solving. This orientation is consistent with the Indonesian Independent Curriculum, which emphasizes competencies such as critical reasoning and creative thinking (Tasrif, 2022). In practice, however, the development of these competencies remains challenging. Limited literacy, low motivation, and insufficient opportunities to analyze and solve problems have been identified as barriers to students' critical thinking development (Nadhiroh & Anshori, 2023). Teachers may also experience difficulties in designing HOTS-oriented instruction, problem-solving activities, and appropriate assessments (Marlina & Erita, 2023). As a result, classroom learning may remain concentrated on lower-order cognitive processes rather than providing sustained opportunities for students to analyze, evaluate, and create.

Similar concerns were identified in the context of SMP Negeri 47 Pekanbaru. Preliminary classroom observations indicated that social studies instruction remained largely theoretical and teacher-centered, while the teaching materials provided limited opportunities for active student involvement. Students tended to be passive when analyzing information, developing solutions, and addressing contextual problems. Their higher-order thinking skills had also not been systematically mapped. These conditions suggested a need for an instructional approach that could provide students with more opportunities to investigate problems, make decisions, and construct their understanding through active learning.

Project-Based Learning (PjBL) offers one possible response to this need. Grounded in constructivist principles, PjBL engages students in projects centered on meaningful problems and provides opportunities to develop analytical, creative, and problem-solving skills (Luchang & Nasri, 2023). Previous research has associated PjBL with improvements in students' HOTS (Hikmawati et al., 2022; Zhang & Ma, 2023), while other studies have highlighted its contribution to reasoning and problem solving through authentic and contextual learning experiences (Chiang & Lee, 2016; Sidiq et al., 2021). The potential of PjBL to support higher-order thinking is closely related to the cognitive demands of project activities, which require students to analyze information, evaluate possible solutions, make decisions, and create products or responses to meaningful problems (Kokotsaki et al., 2016). These characteristics can promote deeper cognitive engagement when students work with contextual and authentic learning tasks (Guo et al., 2020).

The benefits of PjBL, however, may not be experienced equally by all students. Achievement motivation can influence the extent to which students engage cognitively and persist when working on challenging learning tasks (Fitri et al., 2018; Hidayatullah et al., 2023). Students with stronger achievement motivation may be more willing to explore information, sustain effort, and engage in the complex thinking required during project work. Previous research has reported an association between motivation and HOTS (Mahendika et al., 2023), while Alatawi et al. (2024) identified a positive relationship between achievement motivation and higher-order thinking. At the same time, achievement motivation varies among students. Dianto (2019) reported relatively low achievement motivation among some junior high school students, and Wijnia et al. (2024) showed that motivation does not necessarily increase uniformly across PjBL conditions. These findings suggest that motivational differences are relevant when examining students' responses to project-based instruction.

Digital media may provide additional support for project-based learning by presenting information in more interactive and accessible ways. Articulate Storyline, in particular, enables the integration of visual, audio, interactive, and nonlinear elements within a structured learning environment. Previous studies have associated the use of Articulate Storyline with students' interest, motivation, and higher-order thinking (Agustin & Kurniawan, 2021). More broadly, interactive multimedia can support cognitive engagement by combining multiple forms of representation with activities that encourage analysis and evaluation (Lu et al., 2021). Setyaningsih et al. (2020) similarly reported that interactive learning media can contribute to students' learning motivation. When incorporated into PjBL, Articulate Storyline may therefore help organize learning activities, provide interactive access to information, and sustain students' engagement as they investigate and respond to project-based problems.

The combination of PjBL and interactive digital media is particularly relevant because successful project work requires both sustained cognitive engagement and motivation. PjBL

encourages students to investigate problems and construct knowledge through experience, exploration, and reflection, while interactive media can provide additional support for navigating the learning process. Research on project-based learning has shown that students' engagement with complex problem-solving activities can contribute to higher-order thinking (Zhang & Ma, 2023), and motivation has also been associated with students' HOTS (Mahendika et al., 2023). Students with stronger achievement motivation may engage more actively in information seeking, problem solving, and reflection during project activities (Guo et al., 2020). At the same time, interactive elements may stimulate interest among students whose initial motivation is lower, potentially encouraging greater participation in project activities (Azkiya, 2023; Shin, 2018).

From a theoretical perspective, this relationship can be understood through the integration of constructivist learning principles and achievement motivation. PjBL provides opportunities for students to construct knowledge through engagement with authentic problems, while Articulate Storyline supports this process through an interactive digital learning environment. These activities are consistent with the higher cognitive processes represented in the revised Bloom's taxonomy, particularly analysis, evaluation, and creation (Listiani & Rachmawati, 2022). PjBL has consequently been identified as a relevant instructional model for developing HOTS in contemporary learning environments (Susanto et al., 2025). Interactive multimedia can further support these learning experiences by providing responsive and engaging learning resources that allow students to interact with content more independently (Atmaja et al., 2024). The conceptual relationship among the instructional intervention, students' higher-order thinking skills, and achievement motivation is illustrated in Figure 1.

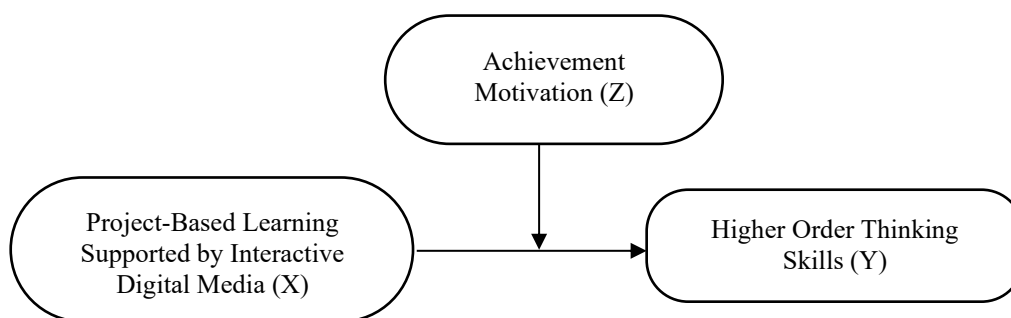


Figure 1. Conceptual Framework of the Study

Although previous studies have provided evidence concerning PjBL, HOTS, achievement motivation, and interactive learning media, these elements have often been examined separately. Evidence remains limited regarding the use of PjBL supported specifically by Articulate Storyline in junior high school social studies and whether students with different levels of achievement motivation demonstrate different HOTS outcomes following this form of instruction. This issue is particularly relevant in social studies, where students are expected to analyze contextual problems, consider different perspectives, and make reasoned judgments rather than simply recall factual information. Examining these elements together may therefore provide a more contextualized understanding of how project-based and digitally supported instruction relates to students' higher-order thinking.

Accordingly, this study examined the use of Project-Based Learning supported by Articulate Storyline in developing the higher-order thinking skills of eighth-grade students in social studies at SMP Negeri 47 Pekanbaru. It also examined whether post-intervention HOTS differed between students with high and low achievement motivation. In this study, PjBL supported by Articulate Storyline represents the instructional intervention, HOTS represents the primary learning outcome, and achievement motivation is used to distinguish students according to their motivational level. The study therefore seeks to provide empirical evidence on the use of digitally supported project-based learning in junior high school social studies while considering differences in students' achievement motivation.

METHOD

This study employed a quantitative pre-experimental approach using a one-group pretest–posttest design (Sugiyono, 2022). The design was selected because the study was conducted under field conditions that did not allow the inclusion of a control group or random assignment of participants. One group of students completed a pretest to assess their initial HOTS, participated in social studies instruction using PjBL supported by Articulate Storyline, and subsequently completed a posttest. The pretest and posttest scores were compared to examine changes in students' HOTS following the intervention. Given the absence of a control group and random assignment, the design is potentially susceptible to threats to internal validity, including selection, maturation, and testing effects. The findings were therefore interpreted as changes observed following the intervention rather than as definitive evidence that the intervention alone caused those changes.

The population comprised all eighth-grade students at SMP Negeri 47 Pekanbaru. Participants were selected through purposive sampling based on the suitability of the class characteristics and its readiness to participate in the intervention. One eighth-grade class (Class VIII A), consisting of 30 students, was included in the study. This sample size was considered appropriate for the small-scale educational study and the statistical analyses employed, with reference to the sample-size considerations described by Sugiyono (2022). The intervention was implemented over six instructional meetings using PjBL supported by Articulate Storyline. The implementation followed six phases of PjBL: starting with an essential question, designing a project plan, creating a schedule, monitoring students and project progress, assessing the outcomes, and evaluating the learning experience (Fahlevi, 2022). A social studies teacher observed the implementation of the learning activities using an observation sheet.

Data were collected using a HOTS test, an achievement motivation questionnaire, and the learning implementation observation sheet. The HOTS test consisted of open-ended questions designed to assess analyzing, evaluating, and creating skills based on the indicators adopted from Mbayowo and Pasaribu (2022). Achievement motivation was measured using a five-point Likert-scale questionnaire based on McClelland's theoretical framework as presented by Sardiman (2014). The questionnaire covered success orientation, future orientation and appreciation of time, responsibility for tasks, attention to feedback, preference for challenging tasks, and persistence in completing work. Before data collection, the instruments underwent validity and reliability testing. Content validity was assessed by experts, including university lecturers and social studies teachers, while item validity for the HOTS test and achievement motivation questionnaire was examined using data from 30 students who were not included in the study sample. All HOTS test items were reported as valid, with r values ranging from .873 to .973, and the test demonstrated high internal consistency (Cronbach's $\alpha = .925$). The items also showed satisfactory discrimination and varying levels of difficulty. Of the initial 24 achievement motivation items, two were excluded because they did not meet the validity criterion, leaving 22 items in the final questionnaire. The retained items had r values ranging from .457 to .805, and the questionnaire demonstrated high internal consistency (Cronbach's $\alpha = .915$).

Data were analyzed using descriptive and inferential statistics. Descriptive statistics were used to summarize students' HOTS and achievement motivation scores. Achievement motivation scores were divided into high- and low-motivation groups using a median split: students with scores equal to or above the median were classified into the high-motivation group, whereas those scoring below the median were classified into the low-motivation group (Azwar, 2022). A paired-samples t -test was used to examine differences between students' pretest and posttest HOTS scores, while an independent-samples t -test was used to compare posttest HOTS scores between the high- and low-achievement-motivation groups. The normality assumption was examined using the Kolmogorov–Smirnov test before inferential analyses were conducted. N-gain scores were also calculated to describe the magnitude of improvement in HOTS following the intervention. All statistical analyses were performed using SPSS version 25 at a significance level of .05.

RESULTS AND DISCUSSION

Results

Students' Higher-Order Thinking Skills Before and After the Intervention

Students' HOTS were assessed before and after the implementation of PjBL supported by Articulate Storyline. **Table 1** presents the pretest results across the three HOTS indicators: analyzing, evaluating, and creating.

Table 1. Descriptive Statistics of Students' Pretest HOTS Scores

Indicator	Mean	Category
Analysing	59.83	Currently
Evaluating	29.42	Low
Creating	18.57	Very Low
Overall Mean	30.13	Low

The overall pretest mean was 30.13, which was classified in the low category. Among the three indicators, analyzing had the highest mean score (59.83), followed by evaluating (29.42) and creating (18.57). Creating therefore had the lowest initial score. Following six instructional meetings using PjBL supported by Articulate Storyline, students completed the posttest. As shown in **Table 2**, higher scores were observed across all three HOTS indicators.

Table 2. Descriptive Statistics of Students' Posttest HOTS Scores

Indicator	Mean	Category
Analysing	98.00	Very High
Evaluating	88.75	Very High
Creating	74.58	High
Overall Mean	83.77	Very High

The overall posttest mean was 83.77, compared with 30.13 at pretest. Analyzing recorded the highest posttest mean (98.00), followed by evaluating (88.75) and creating (74.58). Although creating remained the lowest of the three indicators, its mean increased from 18.57 at pretest to 74.58 at posttest.

Pretest–Posttest Differences in HOTS

Before the pretest and posttest scores were compared, their distributions were examined using the Kolmogorov–Smirnov test. The results are presented in **Table 3**.

Table 3. Normality Test for Pretest and Posttest HOTS Scores

Variable	D	p
Pretest	0.106	0.200
Posttest	0.106	0.200

Both pretest and posttest scores met the normality assumption ($p > .05$). A paired-samples t-test was subsequently conducted to examine the difference between students' HOTS scores before and after the intervention.

Table 4. Paired-Samples t-Test for Pretest and Posttest HOTS Scores

Measure	Mean	Mean Difference	t	p	Cohen's d
Pretest	30.1333				
Posttest	83.7667	-53.633	-36.418	0.000	6.65

The paired-samples t-test showed a statistically significant difference between pretest and posttest HOTS scores, $t = -36.42$, $p < .001$. The mean score increased from 30.13 at pretest to 83.77 at posttest, corresponding to an absolute mean difference of 53.63 points. The reported effect size was Cohen's $d = 6.65$.

Improvement in HOTS Based on N-Gain

N-gain scores were calculated to provide additional information on the magnitude of students' improvement following the intervention. Table 5 presents the distribution of students according to the N-gain classifications used in the study.

Table 5. Distribution of Students by N-Gain Classification

N-Gain Interval	Category	Frequency	Percentage
< 0.56	Less Effective / Ineffective	0	0%
0.56 - 0.75	Moderately Effective	12	40%
> 0.75	Effective	18	60%
Mean N-Gain		0,764	Effective

The mean N-gain was .764. Eighteen students (60%) were classified in the effective category, while 12 students (40%) were classified in the moderately effective category. No students were classified in the less effective/ineffective category.

Differences in HOTS by Achievement Motivation

An independent-samples t-test was conducted to compare posttest HOTS scores between students classified as having high and low achievement motivation. The results are presented in Table 6.

Table 6. Comparison of Posttest HOTS Scores by Achievement Motivation

Motivation Level	N	Mean	Mean Difference	t	p	Cohen's d
High	17	85.9412	5.0181	2.237	0.033	0.83
Low	13	80.9231				

Students in the high-achievement-motivation group ($n = 17$) obtained a higher mean posttest HOTS score (85.94) than those in the low-achievement-motivation group ($n = 13$; $M = 80.92$). The mean difference between the groups was 5.02 points. The independent-samples t-test indicated that this difference was statistically significant, $t = 2.24$, $p = .033$, with a reported Cohen's d of .83.

Discussion

The findings show a substantial improvement in students' HOTS following the implementation of PjBL supported by Articulate Storyline. The overall mean increased from 30.13 at pretest to 83.77 at posttest, with improvements observed across analyzing, evaluating, and creating. The particularly marked increases in evaluating and creating are noteworthy because these processes require students to move beyond recalling information toward judging alternatives, integrating ideas, and developing solutions. The N-gain results provide a similar pattern, with a mean of .764 and 60% of students classified in the effective category. Taken together, these findings indicate that students demonstrated considerably stronger HOTS performance after participating in the digitally supported project-based learning activities. Given the one-group design, however, this improvement should be interpreted as a change observed following the intervention rather than as evidence that PjBL supported by Articulate Storyline was solely responsible for the change.

One possible explanation for this improvement lies in the cognitive demands of project-based learning. PjBL engages students with authentic and relatively open-ended problems that require them to analyze information, evaluate alternatives, make decisions, and create meaningful products. These activities correspond closely to the higher cognitive processes emphasized in the revised Bloom's taxonomy (Ali et al., 2025). The taxonomy provides a useful framework for organizing learning objectives and assessment around increasingly complex cognitive processes, particularly analysis, evaluation, and creation (Listiani & Rachmawati, 2022). From this perspective, the observed improvement in HOTS is consistent with the nature of the learning activities undertaken during the intervention: students were not simply expected to acquire information but to use it in completing project-based tasks.

Articulate Storyline may have provided additional cognitive support within this process. Well-designed multimedia environments can help learners select, organize, and integrate information by presenting content through coordinated visual and verbal representations (Mayer, 2024). In the present study, Articulate Storyline was incorporated into the project-based learning environment to structure learning content and support students' interaction with the material. This interpretation is consistent with Cognitive Load Theory, which suggests that appropriately organized visual information and navigation can reduce unnecessary processing demands and allow learners to devote more cognitive resources to task-relevant activities (Gkintoni et al., 2025). Rather than treating digital media as the source of improvement itself, the findings therefore suggest that its value may lie in how it supports the cognitively demanding activities required during project work.

A related explanation concerns students' metacognitive engagement. Project work involves planning, monitoring progress, evaluating possible solutions, and reflecting on outcomes, all of which require students to regulate aspects of their own thinking. Digital tools can support such processes when they provide learners with clear structures for organizing, monitoring, and revisiting their learning activities (Gkintoni et al., 2025). Interactive learning environments may also contribute to engagement when students perceive activities as meaningful and manageable (Wong & Hughes, 2023). In this sense, the combination of PjBL and interactive digital media may be particularly relevant to HOTS because it brings together cognitively demanding project activities with a learning environment that can help students navigate those demands.

The pattern observed in this study is broadly consistent with previous research on PjBL and higher-order thinking. Chatila and Malaeb (2025) reported that project-based learning can support the development of HOTS, while Fitri et al. (2018), Fadillah and Takiddin (2022), and Hikmawati et al. (2022) similarly reported positive outcomes associated with PjBL. A broader synthesis by Luchang and Nasri (2023) also identified positive effects of PjBL on higher-order thinking across learning contexts. Evidence from related forms of technology-supported and interdisciplinary project learning points in a similar direction. STEM-based PjBL has been associated with opportunities for students to engage in higher-order thinking through meaningful and contextual projects (Setiawan et al., 2026), while digitally supported argumentation can provide structured opportunities to construct and evaluate arguments (Lukitasari et al., 2025). Electronic forms of PjBL have likewise been associated with HOTS and related competencies (Rati et al., 2023), and structured project-based environments have been linked to the development of critical and creative thinking (Loyens et al., 2023).

The present study extends this body of work to the use of Articulate Storyline within junior high school social studies. Although previous research has examined PjBL in combination with STEM, online learning, digital argumentation, and other technology-supported environments, the use of Articulate Storyline as digital support for project-based social studies learning has received comparatively less attention. The present findings therefore provide context-specific evidence that students can demonstrate substantial HOTS gains when project-based social studies activities are accompanied by structured interactive digital content. This contribution should nevertheless be understood as preliminary because the present design does not allow the relative contribution of PjBL and Articulate Storyline to be separated.

Achievement motivation provides another important perspective on the findings. Students classified as having high achievement motivation obtained a higher mean posttest HOTS score (85.94) than those in the low-motivation group (80.92), with a statistically significant difference and a reported Cohen's *d* of .83. This pattern suggests that achievement motivation was associated with differences in HOTS performance following the intervention. Students with stronger achievement motivation may be more likely to persist with demanding tasks, explore alternative solutions, and remain engaged during project activities. This interpretation is consistent with the role of achievement motivation in encouraging persistence and responsibility in learning Uno (2021) and in directing students' learning behavior (Sardiman, 2014).

At the same time, students in the low-achievement-motivation group still obtained a relatively high mean posttest score. This finding is important because it suggests that lower initial achievement motivation did not necessarily prevent students from performing well on the posttest. It would be premature, however, to conclude that Articulate Storyline compensated for low motivation

because the study did not directly test such a mechanism. Self-Determination Theory provides a useful perspective for interpreting this pattern: students' engagement is shaped not only by individual motivation but also by features of the learning environment that support meaningful participation (Ryan & Deci, 2020). Previous studies have similarly shown that the effects of digital tools depend on the contexts in which they are used (Stalmach et al., 2025), while digital learning environments can influence both learning outcomes and motivation (Wang et al., 2023). Technology-supported environments may also facilitate self-regulated and metacognitive learning processes (Azevedo et al., 2022). Interactive media can attract students' attention and interest (Dimiyati & Mudjiono, 2013), while structured PjBL environments may help sustain engagement among students with different motivational profiles (Wijnia et al., 2024). These perspectives offer plausible explanations for the observed pattern, although the mechanisms themselves require direct investigation in future research.

The findings have implications for both theory and practice. Theoretically, they reinforce the view that the relationship between project-based learning and higher-order thinking is likely to depend not only on the presence of a project but also on how learning activities and cognitive supports are designed. From the perspective of Cognitive Load Theory, interactive digital media may serve as a form of cognitive support when information, navigation, and learning tasks are organized in ways that allow students to concentrate on relevant problem-solving processes. From the perspective of Self-Determination Theory, the findings also draw attention to the importance of considering students' motivational differences when designing demanding learning activities. The present results do not establish these mechanisms directly, but they suggest that cognitive support, project design, and learner motivation are useful dimensions for understanding digitally supported PjBL.

Practically, the findings suggest that social studies teachers may benefit from designing PjBL activities in which digital media serves a clear pedagogical purpose rather than functioning merely as a presentation tool. Articulate Storyline can be used to organize problem contexts, project instructions, learning resources, and opportunities for reflection in a coherent digital environment. Such integration may be particularly useful in social studies, where students are expected to examine contextual problems, evaluate information and perspectives, and develop reasoned responses. The findings also highlight the importance of designing learning activities that remain accessible to students with different levels of achievement motivation. For schools and curriculum developers, this points to the value of strengthening teachers' capacity to design HOTS-oriented project learning in which technology supports, rather than replaces, meaningful cognitive activity.

Several limitations should be considered when interpreting these findings. First, the study employed a one-group pretest–posttest design without a control group or random assignment. Consequently, alternative explanations for the observed improvement—including testing, maturation, and other contextual influences—cannot be ruled out. Second, the study involved only 30 students from a single school, which limits the generalizability of the findings to other schools, student populations, and social studies contexts. Third, the comparison between high- and low-achievement-motivation groups was based on a median split. Although this approach facilitated group comparison, converting a continuous motivation score into two categories may reduce information about individual differences. In addition, the study compared posttest HOTS scores between motivation groups rather than statistically testing achievement motivation as a moderator of the relationship between the intervention and HOTS. The findings should therefore not be interpreted as evidence of a moderation effect.

Future research could address these limitations by using controlled experimental or stronger quasi-experimental designs with larger samples drawn from multiple schools. Including a comparison group would make it possible to distinguish intervention-related change more clearly from changes attributable to other factors. Future studies could also retain achievement motivation as a continuous variable and examine its relationship with HOTS through regression or an appropriate interaction model rather than relying solely on high–low group comparisons. Designs that compare PjBL with and without Articulate Storyline would be particularly useful for identifying the added contribution of interactive digital media. Finally, longitudinal research could examine whether improvements in HOTS persist beyond the immediate posttest and whether changes in

motivation, metacognition, and cognitive engagement help explain how digitally supported PjBL influences students' learning over time.

CONCLUSION

This study found a substantial improvement in students' HOTS following the implementation of PjBL supported by Articulate Storyline in junior high school social studies. Improvements were observed across all three HOTS indicators—analyzing, evaluating, and creating—with the overall mean increasing from 30.13 at pretest to 83.77 at posttest and a mean N-gain of .764. Students with high achievement motivation also achieved significantly higher posttest HOTS scores than those with low achievement motivation, although both groups demonstrated relatively high posttest performance. These findings contribute to the growing evidence on digitally supported project-based learning by showing how PjBL and interactive digital media can be integrated to support cognitively demanding learning activities in social studies. In practice, the findings highlight the value of designing project-based instruction in which digital media serves a clear pedagogical purpose by structuring learning activities, supporting students' engagement with complex tasks, and providing opportunities to analyze, evaluate, and create.

These findings should be interpreted in light of several limitations. The study employed a one-group pretest–posttest design without a control group or random assignment, involved only 30 students from a single school, and therefore cannot rule out alternative explanations such as testing or maturation effects or support broad generalization beyond the study context. In addition, achievement motivation was categorized into high and low groups rather than examined as a continuous variable, so the findings should not be interpreted as evidence of a moderation effect. Future research should employ stronger quasi-experimental or randomized controlled designs with larger and more diverse samples across schools, educational levels, and subject areas. Studies comparing PjBL with and without Articulate Storyline would also help clarify the added contribution of interactive digital media, while longitudinal and multivariate research could examine whether HOTS gains are sustained over time and how achievement motivation, learning interest, and other psychological factors relate to students' responses to digitally supported PjBL.

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