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Project-based learning with canva advances students' critical thinking in digestive physiology

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ABSTRACT

Biology learning becomes meaningful when students can explain how organs, enzymes, and nutrients interact as an integrated physiological system. Yet digestive physiology is often reduced to memorized labels, leaving a representational gap in how learners reason about invisible biochemical processes. Addressing this gap, this study examined the uniqueness of Canva-supported Project-Based Learning (PjBL) as a student-generated visual representation strategy for strengthening critical thinking and cognitive learning outcomes in the human digestive system. A quasi-experimental pretest-posttest control group design was implemented with 66 Grade XI students selected through purposive sampling at a public senior high school in Riau Province, Indonesia. Students were assigned to an experimental class taught through Canva-integrated PjBL and a control class taught through conventional instruction. Data were collected using critical thinking essays, cognitive tests, observation sheets, and student response questionnaires, then analyzed through baseline comparison, independent-samples testing, and normalized gain. Initial ability was comparable between groups ($p = 0.385$), but the experimental class achieved significantly higher posttest scores in cognitive learning outcomes (82.62 vs. 73.13) and critical thinking (82.52 vs. 73.08), with $p < 0.001$. N-gain results also favored the PjBL class for cognitive achievement (0.65 vs. 0.47) and critical thinking (0.61 vs. 0.41). High implementation fidelity (95.24%) and positive engagement supported these gains, although scheduling remained a self-regulation challenge (76.14%). The study contributes evidence that digital artifact-based PjBL can move biology instruction beyond recall toward mechanistic reasoning, with broader implications for designing student-centered, representation-rich biology education in complex physiology topics.

INTRODUCTION

Human digestive physiology requires students to coordinate structures, processes, and functions across organ, cellular, and molecular levels. Yet many learners treat the digestive system as a list of organs and enzymes rather than a set of interacting mechanisms, while classroom activities may still emphasize memorization over analytical reasoning and scientific argumentation (Sembiring et al., 2026). Research on systems thinking in biology shows that students often attend to isolated components and have difficulty connecting structures, behaviors, and functions across levels of organization (Hmelo-Silver & Pfeffer, 2004; Boersma et al., 2011; Verhoeff et al., 2008; Gilissen et al., 2020). Mechanistic reasoning is essential for explaining causal relationships in scientific inquiry (Russ et al., 2008), and learner-generated representations can make otherwise invisible processes available for explanation and revision (Quillin & Thomas, 2015; Van Meter & Garner, 2005). Consequently, when instruction does not require students to coordinate these relationships, their knowledge may remain fragmented and difficult to apply to enzyme action, nutrient absorption, and digestive disorders.

Biology education should develop critical thinking, scientific reasoning, collaboration, communication, creativity, and digital literacy alongside factual knowledge. Project-based Learning (PjBL) is relevant because it positions students to investigate authentic problems, organize evidence, develop products, and communicate findings. Core PjBL features include sustained inquiry, student agency, collaboration, iterative product development, reflection, and opportunities for innovative thinking (Blumenfeld et al., 1991; Barron et al., 1998; Bell, 2010; Kokotsaki et al., 2016; Barak & Yuan, 2021; Markula & Aksela, 2022). Meta-analytic evidence also indicates that PjBL can improve academic achievement when implementation includes meaningful tasks and structured support (Chen & Yang, 2019; Guo et al., 2020).

Although PjBL has been used to improve engagement and achievement, the mechanism through which project work supports biological reasoning remains less explicit in many general implementations (Guo et al., 2020; Heo et al., 2010). Digital tools are also often used mainly as presentation media rather than as cognitive tools that enable students to externalize, revise, and defend biological explanations. This distinction matters in digestive physiology because students must integrate anatomical structures, enzymatic processes, nutrient absorption, and physiological consequences into coherent accounts rather than isolated facts.

The representational gap is central to this study because many biological processes occur at microscopic, molecular, or systemic levels that students cannot observe directly. Research on multimedia and multiple representations indicates that visual representations support understanding when students compare, coordinate, and explain the information they contain, provided that the visual format fits the conceptual process being represented (Ainsworth, 2006; Tversky et al., 2002; Höffler & Leutner, 2007; Rau, 2017). Learner-generated drawings and visual explanations are particularly valuable when students select and organize information rather than simply view ready-made graphics (Van Meter, 2001; Van Meter & Garner, 2005; Bobek & Tversky, 2016). Based on these perspectives, Canva-supported PjBL enables students to transform abstract digestive concepts into digital posters and instructional videos while organizing, visualizing, and communicating biological explanations.

This activity reflects generative learning because students select, organize, and integrate biological information into meaningful visual and verbal representations (Fiorella & Mayer, 2016). For student-produced instructional videos, design quality also depends on the alignment of visual and verbal information and on manageable segment length (Brame, 2016). In this study, Canva is therefore treated not merely as a design application but as a representation medium for visualizing invisible biochemical interactions, negotiating scientific meaning, and justifying interpretations through peer discussion.

The novelty of this study lies in its integration of Canva-supported PjBL with explicit critical-thinking indicators in human digestive physiology. The theoretical framework assumes that PjBL provides repeated inquiry, collaboration, and reflection; Canva provides a shared medium for constructing and revising visual explanations; and Ennis' indicators provide the reasoning outcomes to be assessed. As students select evidence, decide how to represent causal relationships, explain design choices, and defend claims in peer discussion, they practice clarification, evidence evaluation, inference, and strategy selection (Chi & Wylie, 2014; Russ et al., 2008; Abrami et al., 2015).

The urgency of this study is grounded in the classroom context of a public senior high school in Riau Province, Indonesia. Preliminary observations indicated that biology instruction was predominantly teacher-centered, and 65% of students did not meet the minimum mastery criterion for the human digestive system topic. To protect institutional confidentiality, the school name and class labels are withheld. This observation suggests that students may need learning activities that support active engagement and the integration of structure, process, and function (Tanner, 2013; Minner et al., 2010; Furtak et al., 2012). Digital artifacts can help students move from passive reception to active construction of meaning when they are paired with guided inquiry and feedback (Lazonder & Harmsen, 2016; Brame, 2016).

Based on the identified gaps, novelty, and urgency, this study formulates the following research problems: (1) To what extent does Canva-supported project-based learning improve students' critical thinking skills in human digestive physiology? (2) To what extent does Canva-supported project-based learning improve students' cognitive learning outcomes compared with conventional instruction? (3) How do student engagement, implementation fidelity, and project management challenges influence the feasibility of Canva-supported PjBL in biology learning? By answering these questions, this study contributes to the development of student-centered and representation-rich biology instruction. More broadly, it provides empirical and practical insight into how digital project-based learning can support mechanistic reasoning, critical thinking, and conceptual understanding in complex physiological topics.

METHODS

Research Design

This study used a quantitative quasi-experimental approach in an authentic classroom setting, where individual random assignment was not feasible. A quasi-experimental design is appropriate when existing classroom groups are compared while maintaining treatment and control conditions (Campbell & Stanley, 1963; Shadish et al., 2002). The study used a pretest-posttest control-group design to compare learning gains between an experimental class that received Canva-supported Project-Based Learning (PjBL) and a control class that received conventional instruction.

Both groups completed equivalent pretests before instruction and equivalent posttests after instruction. The pretest was used to establish baseline comparability, while the posttest was used to estimate the effect of treatment on students' critical thinking skills and cognitive learning outcomes. This design also allowed the researcher to analyze learning improvement through normalized gain and to compare group differences statistically.

The study used a pretest-posttest control-group design. After participant selection, both groups completed the pretest. The experimental group received Canva-supported PjBL, whereas the control group received conventional instruction. Teacher and student activities were observed during implementation. Both groups then completed the posttest, the experimental group completed the response questionnaire, and the data were analyzed statistically. Both groups followed the same assessment sequence but received different instructional treatments. The experimental group completed Canva-supported PjBL across three meetings, whereas the control group received lecture and question-and-answer activities. This procedure supports comparison of baseline and final achievement while documenting the implementation process.

Population and Samples

The research was conducted at a public senior high school in Riau Province, Indonesia, in November 2025 during the odd semester of the 2025/2026 academic year. The population comprised Grade XI students at the participating school. The sample consisted of 66 students drawn from two intact classes. One class of 33 students served as the experimental group and one class of 33 students served as the control group. The two classes were selected purposively because the biology teacher considered their prior academic achievement broadly comparable. To protect institutional confidentiality, the school name and class labels are not reported.

Table 1
Demographic Profile of Population and Sample Distribution

Aspect	Experimental Group	Control Group
School	Public senior high school in Riau Province, Indonesia	Public senior high school in Riau Province, Indonesia
Academic year	2025/2026	2025/2026
Semester	Odd semester	Odd semester
Grade level	XI	XI

Aspect	Experimental Group	Control Group
Class	Experimental class	Control class
Number of students	33	33
Percentage of total sample	50%	50%

As shown in Table 1, both groups had the same number of students, with each class contributing 50% of the total sample. Both groups came from the same school, grade level, academic year, and semester, which helped maintain contextual equivalence between the experimental and control groups. The selection of the two classes based on the biology teacher's recommendation further supported their comparability before the intervention. Therefore, the sample distribution was appropriate for a quasi-experimental design using intact classroom groups.

Intervention: Canva-Supported Project-Based Learning

The experimental class was taught using Canva-supported project-based learning. The intervention was implemented through six main stages: defining the essential question, designing the project plan, developing a work timeline, monitoring progress, assessing the outcome, and evaluating the learning experience. These stages were designed to help students transform abstract concepts of the human digestive system into visible, communicable digital artifacts.

The control class was taught using conventional instruction, primarily through lectures and question-and-answer activities. Both groups studied the same topic, namely the human digestive system, but the experimental group was required to develop Canva-based learning products, including digital posters and instructional videos. The instructional syntax of Canva-supported PjBL is shown in Table 2. This table is included to clarify the teacher's and students' activities at each stage of the intervention.

Table 2
PjBL Instructional Syntax

PjBL Stage	Teacher's Activities	Students' Activities
Defining an Essential Question	Presents the essential question regarding human digestive health.	Engage in group brainstorming to identify the main problem.
Designing the Project Plan	Divides students into groups, explains the project rules, and provides a 15-minute technical orientation on Canva and collaborative links.	Assign group roles such as Lead Researcher, Canva Designer, and Scriptwriter.
Developing a Work Timeline	Facilitates the arrangement of a work schedule to ensure project completion within the designated meetings.	Coordinate synchronous and asynchronous work, including research, drafting, designing, narration, and editing.
Monitoring Progress	Circulates as a facilitator, monitors group progress, and provides scaffolding for conceptually dense topics such as enzymatic reactions and nutrient absorption.	Synthesize information from the module into digital posters and instructional videos using Canva.
Assessing the Outcome	Assesses the Canva artifacts and students' evidence of learning.	Present finalized digital artifacts and participate in peer-defense sessions to justify their design and scientific explanations.
Evaluating the Experience	Facilitates collective reflection and administers the posttest.	Reflect on the learning process, evaluate group collaboration, and complete the final assessment.

As shown in Table 2, the intervention did not limit itself to product creation. Each stage required students to engage in inquiry, planning, collaboration, scientific explanation, and reflection. This structure was important because the intervention's main purpose was not only to produce Canva artifacts but also to develop students' critical thinking and biological reasoning about digestive physiology.

Implementation Schedule

The Canva-supported PjBL intervention was implemented across three intensive meetings. Meeting 1 focused on orientation, group formation, and project planning. Meeting 2 focused on inquiry, digital product development, and teacher monitoring. Meeting 3 focused on product finalization, peer-defense presentation, reflection, and posttest administration. The detailed time allocation and instructional flow are presented in Table 3.

Table 3

Detailed Time Distribution and Lesson Plan for PjBL Intervention

Meeting, Duration	Phase	Duration (minutes)	Activities and Instructional
Meeting 1, 90 minutes	Introduction	15	The teacher presents the essential question regarding digestive health.
Meeting 1, 90 minutes	Planning	30	Students are divided into heterogeneous groups and receive technical orientation on Canva collaborative tools.
Meeting 1, 90 minutes	Brainstorming	45	Students define the project scope and assign roles such as Lead Researcher, Canva Designer, and Scriptwriter.
Meeting 2, 135 minutes	Inquiry	30	Students synthesize module information into scripts and visual outlines.
Meeting 2, 135 minutes	Development	75	Students design digital posters and instructional videos using Canva.
Meeting 2, 135 minutes	Monitoring	30	The teacher provides scaffolding on difficult biological concepts, especially enzymatic reactions and nutrient absorption.
Meeting 3, 135 minutes	Finalization	30	Groups revise and finalize Canva artifacts before presentation.
Meeting 3, 135 minutes	Publication	60	Groups present digital artifacts and participate in peer-defense sessions.
Meeting 3, 135 minutes	Evaluation	45	The teacher facilitates reflection and administers the posttest.

As presented in Table 3, each meeting had a specific instructional focus. The time distribution gave students sufficient opportunity to investigate biological content, construct digital representations, receive feedback, and communicate their understanding. This structured sequence reflects the principle of instructional alignment: learning objectives, materials, activities, and assessments should be coordinated to support effective implementation (Branch, 2009). The schedule also makes the intervention replicable in future classroom settings.

Instrument

Data were collected using a critical thinking essay test, a cognitive learning outcome test, observation sheets, and a student response questionnaire. The critical thinking essay test was administered as both a pretest and a post-test and was developed based on five indicators proposed by Ennis (2011): elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. The essay items were supported by a test blueprint and an analytic scoring rubric with score levels from 1 to 4 (Table 4).

Cognitive learning outcomes were assessed using a multiple-choice test covering digestive organs, enzymatic processes, nutrient absorption, and digestive disorders. Observation sheets documented teacher and student activities during the learning process, while the student response questionnaire was administered to the experimental group to assess students' perceptions of instructional clarity, project engagement, collaboration, time management, and perceived learning benefits. The study also used a PjBL-based module and project worksheets aligned with Phase F learning outcomes in *Kurikulum Merdeka*. The project products consisted of Canva-based digital learning artifacts, namely posters and instructional videos lasting approximately 3 to 5 minutes. The relationship between critical thinking indicators and PjBL activities is presented in Table 4.

Table 4

Operationalization of Critical Thinking Indicators in PjBL Activities

Indicator	Operational Definition	Representative Project-Based Activity
Elementary Clarification	Identifying the core problem and asking clarifying questions.	Stage 1: Engaging in group brainstorming to define the scope of the essential question regarding digestive health.
Basic Support	Evaluating the credibility of sources and gathering relevant evidence.	Stage 2 and Stage 4: Researching and selecting scientific information from the PjBL module to be included in Canva artifacts.

Indicator	Operational Definition	Representative Project-Based Activity
Inference	Drawing logical conclusions and identifying relationships between concepts.	Stage 4: Synthesizing anatomical structures with biochemical processes, such as enzymatic reactions, in instructional videos.
Advanced Clarification	Defining terms and eliminating irrelevant information to maintain conceptual focus.	Stage 5: Participating in peer-defense sessions to justify design decisions and technical explanations.
Strategy and Tactics	Deciding on an action plan and collaborating to achieve project goals.	Stage 3: Developing a work timeline, assigning roles, and managing Canva collaboration.

As shown in Table 4, each critical thinking indicator was connected to a specific project activity. This alignment ensured that the essay test measured reasoning processes relevant to the Canva supported PjBL intervention. For example, the inference indicator assessed students' ability to explain relationships among anatomical structures, enzymatic processes, and nutrient absorption in the human digestive system.

Validity and Reliability of Instruments

Before the main study, the instruments were pilot-tested and refined through item analysis using Anates V4. The analysis included item validity, reliability, difficulty level, and discrimination index. The essay test was aligned with Ennis' critical-thinking indicators, whereas the multiple-choice test was developed from the learning objectives for the human digestive system. The essay rubric supported scoring consistency, and the multiple-choice items were examined for quality. The discrimination index was interpreted according to Arikunto's classification (2011), and reliability was estimated using KR-21. The reported r11 coefficients indicated strong reliability for both instruments. Table 5 summarizes the instrument-quality testing.

Table 5
Validity and Reliability Testing of Research Instruments

Instrument	Construct Measured	Validation Procedure	Reliability and Quality Evidence
Essay test	Critical thinking skills	Blueprint alignment with Ennis' indicators and item analysis using Anates V4.	Analytic rubric with score levels 1-4; reliability estimated using KR-21; r11 coefficient indicated strong reliability.
Multiple-choice test	Cognitive learning outcomes	Item validity, difficulty level, and discrimination analysis using Anates V4.	Reliability estimated using KR-21; item discrimination interpreted using Arikunto (2011).
Observation sheet	Teacher and student activities	Alignment with instructional stages of PjBL and conventional learning.	Descriptive percentage interpretation of implementation and activity.
Student response questionnaire	Student perception of Canva-supported PjBL	Alignment with indicators of instructional clarity, engagement, collaboration, time management, and perceived benefits.	Percentage-based interpretation using predetermined criteria.

As presented in Table 5, the test instruments were evaluated through item analysis and reliability estimation, while the observation sheet and questionnaire were checked based on their alignment with instructional indicators. This procedure ensured that each instrument had a clear validation basis according to its function in the study.

Procedure

The data collection procedure consisted of three phases: preparation, implementation, and finalization. In the preparation phase, the researcher coordinated with the biology teacher, conducted preliminary observation, selected the sample classes, arranged the implementation schedule, and prepared the module, LKPD, and research instruments. The instruments were then trialed and revised based on validity, reliability, difficulty level, and discrimination analysis using Anates V4.

In the implementation phase, both classes completed the pretest to identify baseline ability. The experimental class learned through Canva-supported PjBL, whereas the control class learned through conventional instruction using lecture and question-and-answer activities. The PjBL learning process followed six stages: determining an essential question, designing a project plan, arranging a schedule, monitoring progress, assessing outcomes, and evaluating learning experiences. During the lessons, the appointed biology teacher observed teacher implementation and student activities.

In the finalization phase, both classes completed the posttest, and the experimental group completed the student response questionnaire. The collected data were then organized for descriptive and inferential statistical analysis using SPSS. The procedural flow of data collection is presented in Figure 1.

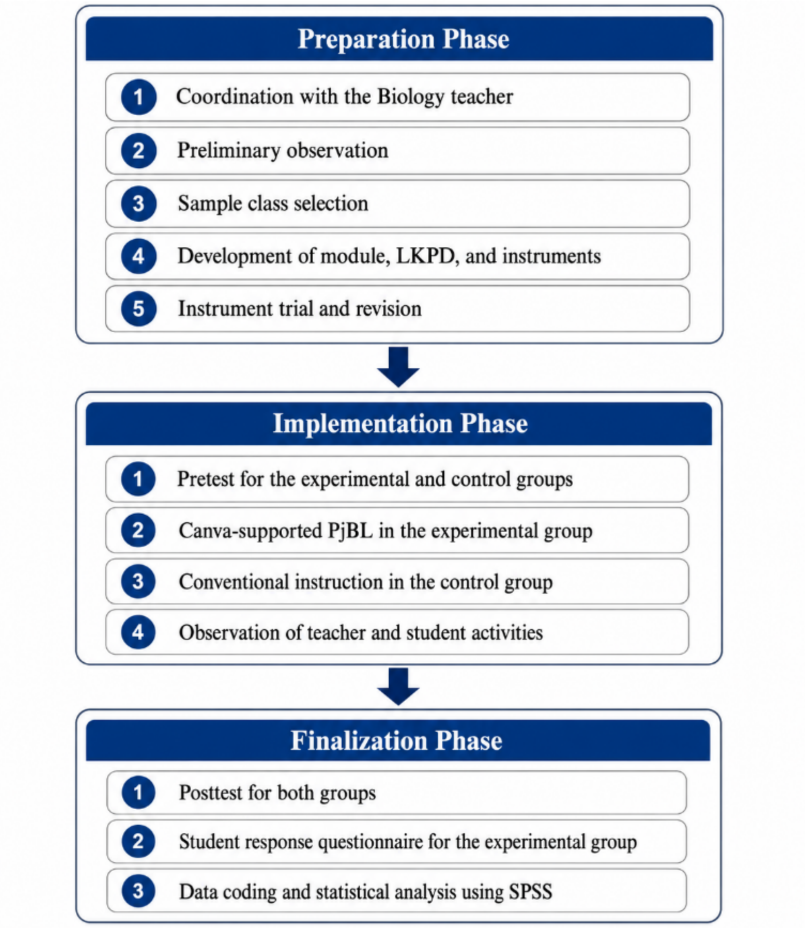

Figure 1. Procedural Flow of Data Collection

As shown in Figure 1, the data collection process was organized from preparation to final analysis. The pretest and post-test generated quantitative learning data, observation sheets documented implementation fidelity, and the student response questionnaire provided supporting data on students' perceptions of Canva-supported PjBL.

Data Analysis Techniques

Quantitative pretest and posttest data were analyzed using descriptive and inferential statistics. Descriptive statistics included the mean, minimum, maximum, and standard deviation. Before hypothesis testing, normality was assessed with the Kolmogorov-Smirnov test, and homogeneity of variance was assessed with Levene's test. After these assumptions were met, an independent-samples t-test compared the experimental and control groups at an alpha level of .05. Learning improvement was calculated using normalized gain following Meltzer (2002) and interpreted as an indicator of the magnitude of improvement (Hake, 1998). Observation and questionnaire data were summarized as percentages and interpreted using predetermined criteria, including the student-response criteria of Riduwan & Akdon (2015).

Table 6

Summary of Data Analysis Techniques

Data Source	Analysis Technique	Purpose of Analysis
Pretest and posttest scores	Descriptive statistics	To describe students' initial and final performance.
Pretest and posttest distribution	Kolmogorov-Smirnov test	To test data normality before inferential analysis.
Group variance	Levene's test	To test homogeneity of variance between groups.
Experimental and control group scores	Independent-samples t-test	To determine whether there was a significant difference between groups.
Pretest-posttest improvement	N-Gain (Meltzer, 2002)	To measure the magnitude of improvement in critical thinking skills and cognitive learning outcomes.
Observation sheet	Percentage analysis	To describe teacher implementation and student activity during instruction.
Student response questionnaire	Percentage analysis using predetermined criteria	To describe students' perceptions of Canva-supported PjBL (Riduwan & Akdon, 2015).
Test items	Anates V4, KR-21, and discrimination index	To evaluate item validity, reliability, difficulty level, and discrimination (Arikunto, 2011).

As shown in Table 6, each data source was analyzed according to its function. Test scores were used to determine treatment effects, while observation and questionnaire data supported the interpretation of the learning process. This combination strengthened the analysis by connecting learning outcomes with implementation evidence.

RESULTS AND DISCUSSION

The findings indicate that Canva-supported Project-Based Learning (PjBL) produced greater improvements in students' critical-thinking skills and cognitive learning outcomes than conventional instruction. This outcome is consistent with evidence that PjBL can strengthen achievement when students investigate meaningful problems, develop products, and receive structured support (Chen & Yang, 2019; Markula & Aksela, 2022; Guo et al., 2020). The interpretation extends beyond numerical posttest differences. In this study, PjBL required students to investigate digestive problems, organize biological information, construct digital representations, and defend their explanations through peer discussion. These activities are relevant to human digestive physiology because the topic requires students to connect organs, enzymes, nutrients, absorption processes, and digestive disorders as an integrated biological system.

The experimental group's stronger performance suggests that students benefited from activities that required them to externalize abstract biological processes into visible products. Digestive physiology requires more than anatomical identification; students must explain why and how digestive processes occur, such as how bile supports fat digestion, how enzymes act on nutrients, and how absorption occurs in the small intestine. This mechanism is consistent with research on systems learning and learner-generated representations, which emphasizes that students refine understanding when they explain causal relationships through diagrams and other externally visible models (Hmelo-Silver & Pfeffer, 2004; Boersma et al., 2011; Quillin & Thomas, 2015; Bobek & Tversky, 2016).

Implementation fidelity and classroom engagement

Before interpreting the outcome data, implementation fidelity and classroom engagement should be considered. The observation results showed that the PjBL process was implemented consistently, and students were actively involved in project planning, product development, discussion, and reflection. Guided implementation is central to PjBL because differences in student outcomes may otherwise reflect uncontrolled variation in classroom activity rather than the learning model itself (Lazonder & Harmsen, 2016; Markula & Aksela, 2022).

Student response data also provided important insight into the implementation process. Overall, students responded positively to Canva-supported PjBL, but the scheduling indicator obtained the lowest score, namely 76.14%. This finding should not be interpreted as a failure of the intervention. Instead, it shows that students still needed stronger support in managing project timelines and coordinating group workflow. In PjBL, time management is not only an administrative task, but also part of self-regulated learning. Students must plan tasks, divide roles, complete research before design, prepare scripts before narration, and revise products before presentation.

This scheduling challenge indicates that students were still adapting from teacher-paced instruction to student-centered project work. In conventional instruction, the teacher usually controls the sequence and rhythm of learning. In contrast, PjBL transfers part of this responsibility to students. Future implementation should therefore include milestone calendars, progress checklists, role allocation, and teacher approval of content before students proceed to Canva design. Such guidance is consistent with evidence from inquiry-based learning showing that scaffolds can structure planning and reflection without taking over students' cognitive work (Lazonder & Harmsen, 2016; Furtak et al., 2012).

Effects on students' critical thinking skills

The summary of students' pretest, posttest, and normalized-gain scores is presented in Table 7. The table shows group differences in final achievement and the pattern of improvement from pretest to posttest.

Table 7

Summary of Pretest, Post-test, and N-Gain for Both Groups (N = 66)

Outcome Variable	Group	Pretest	Posttest	N-Gain	Category	Sig.
Critical Thinking	Experimental (PjBL)	55.50	82.52	0.61	Moderate	$p < 0.001$*
Critical Thinking	Control	53.99	73.08	0.41	Moderate	
Learning Outcomes	Experimental (PjBL)	50.10	82.62	0.65	Moderate	$p < 0.001$*
Learning Outcomes	Control	47.87	73.13	0.47	Moderate	

As shown in Table 7, both groups started from relatively similar baseline scores. For critical thinking, the pretest mean was 55.50 in the experimental group and 53.99 in the control group. For cognitive learning outcomes, the pretest mean was 50.10 in the experimental group and 47.87 in the control group. This baseline similarity is important because it indicates that the two groups had comparable initial ability before the intervention. Therefore, the higher post-test and N-Gain scores in the experimental group can be interpreted with greater confidence as the effect of the Canva-supported PjBL intervention.

The experimental group achieved a higher post-test mean on critical thinking (82.52) than the control group (73.08). The experimental group also obtained a higher normalized-gain score (0.61) than the control group (0.41). Although both gains were categorized as moderate, the difference indicates that the PjBL class experienced stronger development in reasoning ability. This pattern is plausible because the learning process required students to clarify problems, select relevant information, infer relationships among biological concepts, and defend their explanations during project presentation. The interpretation aligns with meta-analytic evidence that critical thinking improves when students analyze information, evaluate evidence, articulate explanations, and receive support for the reasoning process (Abrami et al., 2015; Niu et al., 2013; Huber & Kuncel, 2016).

Cognitive learning outcomes showed a similar pattern. The experimental group achieved a posttest mean of 82.62, whereas the control group achieved a mean of 73.13. The experimental group's normalized-gain score was 0.65, higher than the control group's 0.47. Thus, Canva-supported PjBL was associated not only with stronger critical thinking but also with more coherent conceptual understanding of the human digestive system. This finding is consistent with evidence that active, inquiry-oriented learning can improve conceptual understanding in science, although the exact effect depends on task design and facilitation (Freeman et al., 2014; Deslauriers et al., 2019; Michael, 2006; Minner et al., 2010). The improvement is educationally meaningful because digestive physiology requires students to connect structure and function, not merely memorize organ names or enzyme lists.

The p-value $< .001$ for both outcome variables indicates statistically significant differences between the experimental and control groups. Statistical significance alone, however, does not explain the educational meaning of the findings. The deeper implication is that the PjBL model gave students repeated opportunities to transform information into digital artifacts, discuss the accuracy of their biological explanations, and revise products in response to feedback. These activities support conceptual integration and critical reasoning, as generative learning research predicts that when learners construct and revise external representations (Fiorella & Mayer, 2016; Van Meter & Garner, 2005).

Visual Interpretation of N-Gain Improvement

Figure 2 presents the normalized-gain comparison between the two groups. It complements Table 7 by showing the consistency of the gain advantage across critical-thinking skills and cognitive learning outcomes.

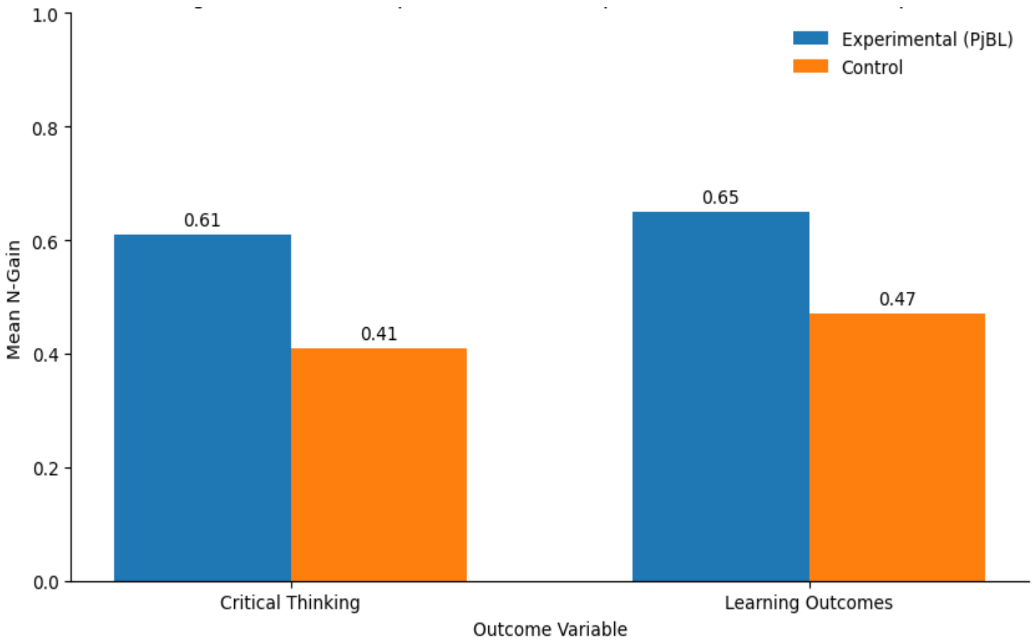

Figure 2. N-Gain Comparison Graph

As illustrated in Figure 2, the experimental group achieved higher N-Gain scores than the control group in both measured variables. The N-Gain for critical thinking was 0.61 in the experimental group and 0.41 in the control group. Meanwhile, the N-Gain for cognitive learning outcomes was 0.65 in the experimental group and 0.47 in the control group. The visual pattern confirms that the learning gain was consistently stronger in the Canva-supported PjBL group.

The interpretation of Figure 4 should not be limited to stating that one bar is higher than the other. The consistent gap across both variables suggests that Canva-supported PjBL influenced two related dimensions of learning: reasoning and conceptual mastery. Students who engaged in project development were required to think critically about the accuracy of biological content while also deepening their understanding of the subject matter. This indicates that critical thinking and cognitive achievement developed together during the intervention.

This finding is consistent with the logic of student-centered learning. When students are actively involved in inquiry, product construction, and peer explanation, they not only receive information but also reorganize it into meaningful knowledge. In this study, students had to decide how to represent digestive organs, enzymatic reactions, nutrient absorption, and digestive disorders in Canva artifacts. This process required analysis, evaluation, and synthesis, which are central to higher-order learning.

Analysis and Synthesis of the Findings

The findings show that Canva-supported PjBL enhanced students' understanding of the human digestive system as an integrated process rather than a simple linear movement of food. Conventional instruction can leave gaps in students' understanding of biochemical and functional relationships among organs, enzymes, and nutrients. By creating digital artifacts, students were required to represent these relationships explicitly, making their reasoning more visible. The higher critical-thinking gain in the experimental class is therefore linked to the need for scientific justification during project work. Students explained processes such as fat digestion by connecting the roles of bile, lipase, emulsification, and nutrient absorption, which reflects mechanistic reasoning. This interpretation fits biology systems-thinking research, which frames understanding as the coordination of levels of organization and causal processes (Boersma et al., 2011; Gilissen et al., 2020; Verhoeff et al., 2008).

Cognitive gains were reinforced through repeated engagement with the concepts: reading modules, preparing scripts, designing visuals, discussing with peers, revising content, and presenting projects. Canva supported this process by allowing students to externalize abstract processes into visual forms, helping them identify relationships that were previously difficult to articulate. The educational value lies not in the software alone, but in the intellectual work required to select, organize, compare, and explain representations (Ainsworth, 2006; Rau, 2017; Brame, 2016).

Challenges and Practical Implications

Although Canva-supported PjBL improved students' critical thinking and cognitive learning outcomes, the scheduling score of 76.14% indicates that students still faced challenges in managing project time and coordinating group work. This issue is common when students move from teacher-paced instruction to self-regulated project activity. Evidence from PjBL implementation studies indicates that task interdependence and learner autonomy require explicit scaffolds rather than open-ended access to tools alone (Blumenfeld et al., 1991; Heo et al., 2010; Markula & Aksela, 2022). Future implementation should therefore provide clear milestones, brief progress conferences, defined roles, and content checks before students invest time in visual design. These supports can preserve student agency while reducing avoidable workload and scheduling problems.

CONCLUSION

Canva-supported Project-Based Learning (PjBL) produced significantly greater improvements in Grade XI students' critical-thinking skills and cognitive learning outcomes than conventional instruction in human digestive physiology. The experimental group achieved higher posttest scores in critical thinking (82.52 vs. 73.08) and cognitive learning outcomes (82.62 vs. 73.13), along with stronger normalized gains in both variables. These findings indicate that the combination of project inquiry, collaborative digital artifact construction, peer explanation, and reflection supported students in connecting digestive organs, enzymatic reactions, nutrient absorption, and physiological functions as an integrated system. The contribution of Canva-supported PjBL lies not in the use of a digital design platform alone, but in its role as a medium through which students externalized, evaluated, revised, and communicated biological explanations. Such activities encouraged learners to move beyond recalling isolated facts toward mechanistic reasoning and conceptual integration. High implementation fidelity and positive student engagement further indicate that the intervention was feasible for classroom application. Project scheduling remained the main implementation challenge, indicating a need for stronger support for students' self-regulation and group coordination. Teachers should therefore incorporate explicit milestones, progress-monitoring tools, clear deadlines, and structured group responsibilities throughout the project cycle. Future research should examine the retention of learning gains, the scientific quality of student-generated digital artifacts, and the effectiveness of Canva-supported PjBL across different Biology topics, learner characteristics, and longer instructional durations.

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