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An Experimental Study of the Impact of Project-based Learning on Senior High Students' 4C Abilities

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Abstract

This experimental study investigates the impact of project-based learning (PjBL) on students' capacities for critical thinking, communication, creativity, and collaboration (i.e., the 4Cs). This study adopted a two-group experimental design comprising an experimental group, which received PjBL pedagogy, and a control group, which received traditional pedagogy. Of the 113 tenth graders from an agricultural and industrial vocational high school in central Taiwan, 55 were assigned to the experimental group, and 58 were assigned to the control group. The data were collected over one semester using scales to measure critical thinking, communication, creativity, and collaboration. Data were then analyzed using descriptive statistics, including distribution frequencies, percentages, mean values, standard deviations, and inferential statistics, including ANCOVA. The results revealed that the experimental group acquired significantly higher scores on the 4C scales than the control group, indicating that PjBL pedagogy is more effective than traditional pedagogy at improving students' 4C abilities. The experimental group students' post-test scores of 4C capacities were significantly higher than their pre-test scores, showing a significant enhancement in their 4C capabilities after receiving PjBL pedagogy. The study confirmed that PjBL pedagogy had a highly positive effect on students' 4C capacities.

Keywords: project-based learning; critical thinking; communication; creativity; collaboration

1. Introduction

With the popularity and rapid development of the internet, big data, digital manufacturing technology, urban intelligence, and other technologies, leading to an increase in the mobility of the social environment, the world has entered an age of rapid change. Cultivating students' abilities to cope with a rapidly changing environment has thus become an important issue for schools. In recent years, countries worldwide have successively proposed a framework of core literacy or critical competencies required in the 21st century. For example, in 2002, the U.S. 21st-Century Skills Partnership proposed a framework for developing core competencies that are essential for the 21st century, which consists of two parts: student learning outcomes and student support systems. The student learning outcomes comprise four dimensions: (i) learning and innovation skills, including critical thinking, creativity, communication, and collaboration (4Cs); (ii) core disciplines and 21st-century issues; (iii) information, media, and technology skills, including literacy in information, media, and information and communication technology (ICT); and (iv) life and career skills (Harper, 2014).

The European Commission (EC) also proposed a framework of eight core literacy qualities (i) mother tongue communication;(ii) foreign language communication; (iii)basic literacy in mathematics, science, and technology; (iv) digital literacy; (v) learning how to learn; social and civic literacy; (vi) founding and entrepreneurship cultural awareness; and expression literacy. The core literacy qualities identified by the EC have led to many repercussions in European education systems, with most European countries incorporating the core competencies of this architecture or similar concepts into national curricula (Harper, 2014). The Assessment and Teaching of 21st-Century Skills (ATC21S) project, a collaboration between Australia, Finland, Portugal, Singapore, and the United Kingdom, divides 21st-century skills into four main areas: (i) ways of thinking, including creativity and innovation, critical thinking, problem-solving and decision-making, learning how to learn, and meta-cognition; (ii) ways of working with communication and collaboration; (iii) tools for working with information and ICT literacy; (iv) skills for living in the world, including citizenship, life, and career, personal, and social responsibility (Griffin, Care, & McGaw, 2012). In response to the future development of the 21st-century, Taiwan has promoted the 12-year reform of national primary education (hereinafter referred to as the 12-year national education), emphasizing the cultivation of people-oriented "lifelong learners," whose core qualities are divided into three aspects: independent action, communication and interaction, and social participation (Taiwan Ministry of Education, 2014).

A review of the essential abilities or core qualities required in the 21st century by countries worldwide found that they all emphasize the importance of the 4C abilities. However, schooling continually focuses on teacher-centered teaching, which needs to encourage students' collaborative inquiry (Budiarti et al., 2021). Kokotsaki et al. (2016) claimed that traditional teacher-centered teaching can no longer meet future education needs and cannot effectively teach students the essential skills needed for the 21st century. Teachers must create a learning atmosphere in which students ask questions promptly; actively seek relevant information; apply information; are task-oriented, interdisciplinary, collaborative, and

technologically innovative; and, through mutual guidance from teachers, combined with learning programs inside and outside the school, effectively cultivate essential skills, including the 4Cs (Harper, 2014). Ravitz et al. (2012) claimed that project-based learning (PjBL) is the most commonly used and effective method for teaching students essential 21st-century skills, such as the 4Cs. One reason is that PjBL is interdisciplinary learning, meaning it can simultaneously respond to multiple disciplines, core competencies, and horizontal skills. It enables students to acquire in-depth content and knowledge consistent with 21st-century skills (Harper, 2014).

PjBL is an innovative and integrated student-centered learning orientation. Its advantages include improving collaborative skills through interactive learning, bringing intrinsic motivation by respecting differentiation, connecting students and courses with the real world, adopting effective assessment methods, and creating opportunities for students to succeed (Bell, 2010). In short, PjBL connects students, courses, real-world issues, and communities through a project inquiry process (Bell, 2010). During project inquiry, students take the initiative to think, plan, discuss agendas, formulate the work progress of particular topics, divide labor and cooperate, study intensely, reflect and create knowledge, control their self-learning progress, complete a series of tasks, propose problem-solving strategies, and become proficient communicators and advanced problem solvers. In the PJBL process, students can develop the 4Cs, which will bring unlimited benefits to their future lives and work (Bell, 2010; Harper, 2014; Larmer & Mergendoller, 2012).

Many empirical studies have confirmed that PjBL integrates a variety of learning areas through inquiry into real-world issues to help students acquire more profound knowledge and skills and enable them to develop from novices to experts in their field of knowledge and demonstrate the ability to learn in their fields of works (Grant & Branch, 2005; Tamim & Grant, 2013). PjBL can also trigger students' intrinsic motivation to learn, allowing each student to experience success. PjBL can also help students master their creativity and innovation, communication, critical thinking, and collaboration skills (Budiarti et al., 2021; Haniah et al., 2021; Tamim & Grant, 2013). PjBL is also an effective teaching strategy for students with no motivation and low achievement (Mergendoller et al., 2003).

PjBL emphasizes inquiry-based, integrated learning content from various disciplines and focuses on the problems relating to actual situations to cultivate students' 4C from inquiry skills. These skills are highly suitable for teaching the field of technology science. Therefore, this study applied the PjBL teaching method to a technology science class of vocational high school students to help them apply what they had learned to real situations and cultivate their 4C capacities. The aim was also to provide vocational high school students with the opportunity to engage in project inquiry related to environmental issues and to publicly present their outcomes of project inquiry to promote the importance of environmental conservation issues to the community.

This study adopted a two-group experimental design. The experimental group received PjBL pedagogy, whereas the control group received traditional pedagogy to determine whether

PjBL pedagogy is more effective than traditional pedagogy at improving students' 4 C abilities.

2. Methodology

2.1 Program participants

This study adopted a pseudo-experimental design. The participants included one instructor and 113 tenth graders from an agricultural and industrial vocational high school in central Taiwan. The instructor, qualified in information technology education, prepared the PjBL activities and conducted various project studies on teaching and learning approaches. Of the students, 55 (28 boys, 27 girls) were assigned to the experimental group and 58 to the control group (30 boys, 28 girls). The students' ages ranged from 15 to 16 years old, and their socioeconomic status (SES) in both groups was similar, with the majority of the students coming from low- to middle-SES families.

2.2 Research design

This study adopted a pseudo-experimental design, as shown in Table 1.

Table 1. Experimental design

Group	Pre-test	Treatment	Post-test
experimental	O_1	X	O_3
control	O_2		O_4

In this study, the dependent variables were critical thinking, communication, creativity, and collaboration capabilities, and the independent variable was the teaching method. Therefore, the pedagogy was the significant difference between the experimental and control groups. We used the following strategies to control interfering variables: (1) The experimental and control groups were from the same school and comprised students of the same grade with similar SES and life experiences. The number and gender distributions were also similar. (2) A homogeneity test conducted before the experiment showed that the two groups of students had similar 4C capabilities. (3) The same instructor taught the experimental and control groups to avoid any influence from the instructor's academic background or personal characteristics. (4) The same teaching units and teaching times were used for the two groups. (5) Pre-tests and post-tests of the two groups were administered in the same week. The instructor adopted the same testing procedures and guidelines to ensure consistency between the two groups.

2.3 Research hypothesis

The research hypotheses in this study are as follows:

1. Critical thinking abilities between the pre-and post-tests of the experimental group will be significantly different after the experimental treatment.

2. Communication capabilities between the pre-and post-tests of the experimental group

will be significantly different after the experimental treatment.

3. Creative capabilities between the pre-and post-tests of the experimental group will be significantly different after the experimental treatment.

4. Collaboration capability between the pre-and post-tests of the experimental group will be significantly different after the experimental treatment.

2.4 Experimental treatments

The experimental group received the PjBL pedagogy, which, based on a synthesis of scholars' views (Bell, 2010; Harper, 2014; Larmer, 2020; Larmer & Mergendoller, 2012), comprised the following steps: Entry event, assign tasks, provide resources, scaffolding guide, collaborative learning, inquiry and innovation, reflection, feedback, and revision, and public presentation. The experimental group of students was divided into five groups and followed the above steps of an inquiry project in one semester. The project topics were "Far away from PM2.5 air pollution" and "Magic music masters play together." In the topic "Far away from PM2.5 air pollution," the students applied their technological skills, including taking and editing photography of their works, using network video materials, and developing APP operations, to make air pollution prevention films and educate communities on how to reduce air pollution in the community. In the topic "Magic music masters play together," students combined network information in the field of science and technology with music theory in the field of art to create simple environmentally friendly musical instruments, play simple songs, and promote the concept of resource recycling and reuse in environmental education. The students shared the results and promoted ideas for environmental prevention with their families and communities.

The teaching process in the control group used traditional pedagogy with a teacher-centered orientation. Therefore, after receiving a lecture from the instructor on the concepts, the students carried out example exercises. The instructor assigned homework exercises to the students, which were reviewed in class to determine students' learning progress. The students finished their exercises individually, and there were no group discussions or assignments during the teaching process. Learning assessments included informal assessments, asking students questions at any time in the classroom, and formal assessments, implementing paper and pencil tests during teaching. The control group received the same information technology classes as the experimental group according to the school schedule; however, the experimental group spent more of their free time on collaborative inquiry for their projects.

2.5 Instruments

2.5.1 Critical Thinking Scale

Students responded to the items on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). This scale consists of 20 items in four subscales: reasoning (7 items), objectivity (3 items), curiosity (7 items), and inquiry (3 items). The factor analysis conducted on data obtained by the scale in the current application revealed that the factor loading of

each subject item of the scale was higher than .42, the value of each dimensional characteristic was between 1.01 and 8.50, and the cumulative total variation was 63.90%, indicating good validity of the items within this scale. The scale's overall internal consistency (Cronbach's α = .93) was good. Cronbach's α for the six subscales ranged from .75 to .87, indicating good internal consistencies of the items within each subscale.

2.5.2 Communication Scale

This scale consists of 10 items in two subscales: expression (5 items) and listening (5 items). Students responded to the items on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The factor loading of each item of the scale was higher than 0.43, the value of each dimensional characteristic was between 1.03 and 8.40, and the cumulative total variation was 52.11%, indicating good validity of the items within this scale. The overall internal consistency (Cronbach's α = .83) for the scale was good. Cronbach's α for the six subscales ranged from .73 to .76, indicating good internal consistencies among the items within each subscale.

2.5.3 Creativity Scale

This scale consists of 16 items in four subscales: curiosity (4 items), challenge (4 items), imagination (5 items), and adventure (3 items). Students responded to the items on a five-point Likert scale ranging from 1 (strong disagreement) to 5 (strong agreement). The factor loading of each scale item was higher than 0.45, the value of each dimensional characteristic was between 1.02 and 8.35, and the cumulative total variation was 56.16%, indicating good validity of the items within this scale. The scale's overall internal consistency (Cronbach's α = .86) was good. Cronbach's α for the six subscales ranged from .72 to .80, indicating good internal consistency among each item.

2.5.4 Collaboration Scale

This scale consists of 11 items in two subscales: introspection (6 items) and interpersonal (5 items). Students responded to the items on a five-point Likert scale ranging from 1 (not at all comforted) to 5 (highly comforted). The factor loading of each scale item was higher than 0.44, the value of each dimensional characteristic was between 1.03 and 8.40, and the cumulative total variation was 58.00%, indicating good validity of the items within this scale. The scale's overall internal consistency (Cronbach's α = .89) was good. Cronbach's α for the six subscales ranged from .80 to .82, indicating good internal consistencies among the items.

2.6 Data analysis

This study firstly used descriptive statistics to analyze the pre-and post-test scores for each group's responses to the 4C questionnaire. Second, a paired sample t-test was performed to determine whether a significant difference existed between the means of the pre-and post-test scores for students in the experimental group. Third, using one-factor covariance analysis, the main effects of the experimental treatment were directly analyzed to explore whether significant differences existed between the experimental and control groups in their 4C

capabilities due to the different teaching methods. All statistical tests in this study used .05 as the minimum alpha level.

3. Findings

3.1 Comparison of the differences between the experimental and control groups

The participants in this study consisted of 55 experimental group students and 58 control group students. A one-factor covariance analysis was used to compare the differences between the experimental and control groups. The independent variable included pedagogy, and the dependent variables were the post-test overall scores for the 4Cs.

3.1.1 Homogeneity of variance test

Table 1 shows the results of Levene's Test of Equal Variances, which showed that the p-value of the 4C scores did not reach a significant level (p＞ .05). Before treatment, the 4C capacities of the experimental and control groups were homogeneous.

Table 1. Summary of Levene's Test of Equal Variances

Dependent Variable	*F*	*df* 1	*df* 2	*p*
critical thinking	0.06	1	111	.81
communication	1.17	1	111	.28
creativity	0.62	1	111	.43
collaboration	1.12	1	111	.29

3.1.2 Homogeneity of regression coefficients test

Table 2 shows the results of the homogeneity of the regression coefficient test, which showed that the p-value did not reach a significant level (p ＞ .05). Specifically, the regression slope was the same and did not violate the assumption of the homogeneity of the regression coefficient within the group, so it was appropriate to conduct a covariance analysis.

Table 2. Summary of the Homogeneity of the Regression Coefficients Test

Dependent Variable	Sources	*SS*	*df*	*MS*	*F*	*p*
critical thinking	treatment ×pre-test	0.05	1	0.05	1.45	.23
	error	3.52	109	0.03		
	sum	1261.14	113			
communication	treatment ×pre-test	0.02	1	0.02	0.10	.75
	error	16.88	109	0.16		
	sum	823.76	113			
creativity	treatment × pre-test	0.06	1	0.06	0.52	.47
	error	11.56	109	0.11		
	sum	741.47	113			
collaboration	treatment ×pre-test	0.01	1	0.01	0.12	.73
	error	10.90	109	0.10		
	sum	836.98	113			

3.1.3 Analysis of one-way covariance

Tables 3 and 4 show the results of the one-way covariance analysis. Table 4 indicates that significant differences existed in the abilities of critical thinking ($F = 18.02$, $\eta 2 = .99$, $p < .001$), creativity ($F = 55.15$, $\eta 2 = 1.00$, $p < .001$), and collaboration ($F = 67.49$, $\eta 2 = 1.00$, $p < .001$) between the experimental and control groups. Specifically, PjBL pedagogy had a significantly greater impact on students' capacities for critical thinking, creativity, and collaboration than traditional pedagogy. However, the two pedagogies had no significant difference regarding the impact on students' communication abilities.

Table 3. Average of the Adjustment of the Pedagogy of the 4C Post-Test

Dependent Variable	Treatment	*M*	*SE*	95% CI	
				LL	UL
critical thinking	experimental	2.76	0.03	2.71	2.81
	control	2.61	0.03	2.56	2.66
communication	Experimental	2.71	0.05	2.62	2.80
	control	2.61	0.05	2.52	2.70
creativity	experimental	2.68	0.02	2.65	2.71
	control	2.50	0.02	2.47	2.54
collaboration	experimental	2.80	0.04	2.72	2.89
	control	2.30	0.04	2.22	2.38

Table 4. Summary Table of the One-Way Covariance Analysis of the Pedagogy of the 4C Post-Test

Dependent Variable	Sources	*SS*	*df*	*MS*	*F*	η^2
critical thinking	treatment	0.63	1	0.63	18.02***	0.99
	error	3.84	110	0.04		
	sum	851.17	113			
communication	treatment	0.26	1	0.26	2.20	0.31
	error	12.99	110	0.12		
	sum	844.01	113			
creativity	treatment	0.84	1	0.84	55.15***	1.00
	error	1.68	110	0.02		
	sum	793.67	113			
collaboration	treatment	6.88	1	6.88	67.49***	1.00
	error	11.21	110	0.10		
	sum	771.40	113			

***$p < .001$

3.2 Comparison of the differences between the pre-test and post-test of the experimental group

3.2.1 Critical thinking ability

The results of the paired t-test analysis shown in Table 5 indicated that the students' post-test scores in the subscales of reasoning (t = 1.97, p＜.05), objectivity (t = 2.28, p＜.05), curiosity (t = 2.41, p＜.05), inquiry (t = 3.39, p＜.001), and overall (t = 4.51, p＜.001) were significantly higher than their pre-test scores. These results indicated that PBL pedagogy enhanced students' critical thinking abilities.

Table 5. Results of the Paired *t*-test for the Experimental Group to Measure Critical Thinking

	Pre-test		Post-test		
Subscale	*M*	*SD*	*M*	*SD*	*t*
reasoning	2.66	.50	2.76	.61	1.97*
objectivity	3.04	.58	3.14	.69	2.28*
curiosity	2.77	.58	2.88	.61	2.41*
inquiry	2.75	.71	2.91	.80	3.39***
overall	2.77	.52	2.87	.54	4.51***

*$p < .05$. ***$p < .001$

3.2.2 Communication ability

The results of the paired t-test analysis presented in Table 6 showed that the students' post-test scores in the subscales of expression (t = 4.52, p＜.001), listening (t = 3.97, p

＜.001), and overall (t = 6.39, p＜.001) were significantly higher than their pre-test scores. These results indicated that PBL pedagogy improved students' communication abilities.

Table 6. Results of the Paired *t*-Test Measuring Communication in the Experimental Group

	Pre-test		Post-test		
Subscale	*M*	*SD*	*M*	*SD*	*t*
expression	2.58	0.59	2.75	0.71	4.52***
listening	2.74	0.58	2.91	0.71	3.97***
overall	2.66	0.53	2.83	0.60	6.39***

***$p < .001$

3.2.3 Creative ability

The results of the paired t-test analysis in Table 7 showed the students' post-test scores in the subscales of curiosity (t = 3.62, p＜.001), challenge (t =2.21, p＜.05), imagination (t = 3.64, p＜.001), adventure (t = 2.89, p＜.01), and overall (t = 6.51, p＜.001). The results showed that PBL pedagogy enhanced students' creative abilities.

Table 7. Paired t-Test Summary Table of Creativity Scale Scores for the Experimental Group

	Pre-test		Post-test		
Subscale	*M*	*SD*	*M*	*SD*	*t*
curiosity	2.70	0.51	2.86	0.62	3.62***
challenge	2.63	0.62	2.71	0.71	2.21*
imagination	2.70	0.63	2.85	0.73	3.64***
adventure	2.55	0.55	2.67	0.67	2.89**
overall	2.65	0.48	2.78	0.53	6.51***

*$p < .05$. **$p < .01$. ***$p < .001$

3.2.4 Collaboration ability

The results of the paired t-test analysis in Table 8 showed that the students' post-test scores in the subscales of introspection (t = 3.03, p＜.01), interpersonal (t = 4.38, p＜.001), and overall (t = 4.90, p＜.001) were significantly higher than their pre-test scores. These findings indicated that PBL pedagogy improved students' collaboration abilities.

Table 8. Paired t-Test of Collaboration Scale Scores for the Experimental Group

	Pre-test		Post-test		
Subscale	*M*	*SD*	*M*	*SD*	*t*
introspection	2.47	0.51	2.58	0.61	3.03**
interpersonal	2.69	0.57	2.85	0.73	4.38***
overall	2.56	0.49	2.71	0.59	4.90***

**$p < .01$. ***$p < .001$

4. Discussion

This study examined the impact of PjBL pedagogy on students' capacities for critical thinking, communication, creativity, and collaboration. The results showed that PjBL pedagogy significantly impacted students' capacities for critical thinking, creativity, and collaboration significantly more than traditional pedagogy. The finding is similar to those of several previous studies (Budiarti et al., 2021; Haniah et al., 2021; Tamim & Grant, 2013) that found that PjBL pedagogy has an impact on students' 4C capacities and can help students master creativity, critical thinking, and collaboration skills. A possible reason is that traditional pedagogy is teacher-centered, using textbooks compiled by experts as teaching materials. The teacher presents a lecture to deliver the concepts or principles of the textbooks, and the students only passively receive, rather than actively think about, the knowledge they acquire. Meanwhile, students repeatedly practice achieving the goal of proficiency. However, when faced with abstract knowledge content and formulas, some students feel uncomfortable and afraid and thus retreat, making it difficult to learn and apply the knowledge practically to live.

On the contrary, PjBL is a student-centered pedagogy. The teachers facilitate students' exploration of the project topic, design, production, explanation, and presentation of the outcomes. During this process, they fully respect the students' opinions, listen to their voices, provide opportunities for self-decision-making and innovation, and provide feedback mechanisms to help students make thoughtful decisions, revisions, and innovative works. In other words, compared with traditional pedagogy, PjBL pedagogy gives students more opportunities to explore and more time to think and ask questions; through peer communication and collaboration, PjBL pedagogy transforms the scientific concepts of understanding into practical experience, which not only deepens the content of learning but also improves students' self-confidence and sense of achievement. Therefore, compared to traditional pedagogy, PjBL pedagogy significantly impacts students' critical thinking, creativity, and collaboration capacities.

The findings also indicated that after treatment, the PjBL pedagogy significantly improved the experimental group students' capacities for critical thinking, communication, creativity, and collaboration. PjBL pedagogy is rooted in Dewey's experiential learning theory and Vygotsky's social constructivism. Experiential learning theory emphasizes learning by doing and gaining a change in judgment, emotion, knowledge, or skills (Dewey, 1938). Social constructivism claims that knowledge and meaning are constructed in the social context through interaction, communication, and collaboration (Vygotsky, 1978). PjBL pedagogy, rooted in experiential learning theory and social constructivism, is a student-centered pedagogy that encourages students to continuously engage in a collaborative inquiry by exploring particular topics to connect with the curriculum, real-world issues, and community. Students work together to apply what they have learned; discover answers to problems or propose solution strategies through active inquiry, thinking, division of labor, discussion of agenda, and formulation of notable topic work progress; and finally, complete a series of products or works (Bender, 2012; Buck Institute for Education, 2013; Harper, 2014; Tamim & Grant, 2013).

In the process of project inquiry, students are asked to raise vital questions and problems and formulate them clearly and precisely, to gather and assess relevant information and use abstract ideas to interpret it effectively, to come to well-reasoned conclusions and solutions, and test them against relevant criteria and standards, to think open-mindedly within alternative systems of thought, and to communicate effectively with others in figuring out solutions to complex problems. The demands are essential for cultivating students' critical thinking abilities (Ziegler, 2018).

According to Sword (2020), one strategy for developing students' communication skills is to create a safe learning environment with supportive relationships. When students feel supported, they are more comfortable expressing their thoughts and ideas in class discussions, attempting challenges, and asking when they need help. Additionally, providing students with more teamwork and group discussions will help make the classroom more comfortable. Working in small groups allows students to share their ideas more quickly and improve their communication skills. PjBL pedagogy stresses creating a safe learning environment in which students are divided into several groups to inquire about their project topics, which contributes to developing students' communication capabilities.

A safe environment is also beneficial for cultivating students' creativity skills. According to Davis (2018), creativity requires a safe environment to play, exercise autonomy, and take risks. In the PjBL classroom, an instructor establishes a supportive classroom, allowing students to present their ideas without hesitation or fear, which encourages autonomy. An instructor acts as a facilitator to give students direct feedback on their creativity to develop and nurture students' creativity. An inquiry process allows students to explore their creativity in relevant, engaging, and worthwhile ways and gives them space and a framework to be creative (Johnson, 2019).

Johnson et al. (2008) pointed out that if teachers want students to achieve real collaboration, they must intentionally design it as part of their learning activity. One strategy for encouraging effective collaboration is creating complex learning activities, which require positive interdependence. A situation in which attaining the goal, completing the task, being successful, and getting a good grade requires teamwork and knowledge sharing should be created. One way to do this is through rigorous projects that require students to identify a problem and propose a solution together (Burns, 2016). In the PjBL classroom, students were asked to conduct inquiry projects related to complex real-world questions, such as air pollution. They needed effective collaboration and positive interdependence to present a solution strategy.

To conclude, this study confirms that PjBL pedagogy can develop students' capabilities for critical thinking, communication, creativity, and collaboration abilities.

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