

## PAPER

# Implementation of Project-Based Learning Computational Thinking Models in Mobile Programming Courses

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## ABSTRACT

This study focuses on investigating the integration of project-based learning with computational thinking (PjBL-CT) skills to enhance students' proficiency in learning mobile programming. The findings of the model provide an evaluation of cognitive aspects, affective aspects in the form of 4C soft skills, and psychomotor aspects. To measure the effectiveness of the model, we will test the differences in the quality of student learning outcomes between two groups: the control group and the experimental group. The cognitive test results showed a value of 80.85 for the experimental class and 73.21 for the control class. For the assessment of soft skill 4C, student creativity aspects are superior to other aspects. Whereas for aspects of enhancing the project's value, an important finding from the results obtained is the significant improvement in the quality of learning by incorporating computational thinking into the problem-based learning (PBL) model.

## KEYWORDS

problem-based learning (PBL), computational thinking (CT), control group, experimental group

## 1 INTRODUCTION

Education has undergone a paradigm shift since the inclusion of technology in learning. Changes are related to the learning environment in the 21st century, specifically graduates who are knowledgeable and skilled [1]. Furthermore, learning must incorporate the acquisition of 21st-century abilities such as creativity, communication, teamwork, and analytical thinking to solve issues (4C skills) [2]. Increasing knowledge and skills by enhancing assessment literacy among educational stakeholders [3]. Tertiary institutions, as higher education institutions, must have the courage to make decisions so that students can confront complex and highly challenging sustainability issues [4].

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Currently, knowledge is undergoing changes and reforms as a result of increased technology [5]. Preliminary observations indicate that students, often face a lack of enthusiasm when attending lectures. Professors not involving their students in the use of instructional strategies can lead to this outcome. In reality, students who should be at the center of the educational process, are often relegated to the background. According to a survey conducted by [6], 65% of students said lectures were boring. Observations were also made by [7] that the students' problem-solving skills have not improved as a result of the learning strategy employed. In particular, the ability to resolve coding issues [8].

It is necessary to apply teaching tactics by combining classic and contemporary strategies, as stated by [9]. In order to help make challenging procedures or ideas easier to grasp, visual models in learning serve as communication tools to summarize, generalize, or convey understanding [10]. Using project-based learning (PjBL), an approach can be utilized to create learning models [11]. PjBL can address fragile knowledge gaps because knowledge is contextualized [12]. This allows students to transfer knowledge and not rely solely on lecturers for learning [13].

Computational thinking (CT) in the digital age is indispensable for solving problems, designing systems, and understanding human behavior [3]. CT is a fundamental skill that everyone should possess for conducting analysis. According to constructivist learning theory [14], CT ability allows students to explore pre-defined problems and develop programming skills during the problem-solving process.

The term CT refers to the application of systematic thinking to produce results that align with the given input [14]. In order to address the challenges of the twenty-first century, computational knowledge must become more widely accessible. This is the goal of CT [15]. Findings [16] suggest that the use of student-centered CT can enhance understanding and learning. To overcome these challenges, a combination of CT and the PjBL learning model is required to address programming learning difficulties.

Previously, researchers had developed a PjBL model for learning that integrated the concept of CT into mobile development classes. The project includes components such as analytical thinking, cutting-edge technology, and the 4C aspects as learning concepts. Projects are loaded into groups consisting of 4–6 people. Algorithmic thinking involves thinking systematically with a process to monitor and evaluate project progress to identify and prove the success rate of the project design. Enhancing student competency in the Mobile Programming course. The resulting products come in the form of model books, mobile applications, application guidelines, and learning tools (modules, lesson plans, and syllabuses).

The developed model consists of six steps: 1) clearly stating the problem. 2) logically arranging and evaluating the evidence. 3) algorithmic reasoning. 4) Create a project schedule. 5) Track and assess the project's progress. 6) Assessment.

Research urgency: Using PjBL learning with technological components is challenging for lecturers, and their successes have not had the biggest influence on 4C. Researchers propose strategies for integrating CT components into the PjBL model, which are still relatively new in Indonesia. The purpose of this research is to enhance students' proficiency and 21st-century skills in vocational education through CT applications—in mobile programming classes.

## 2 LITERATURE REVIEW

The PjBL model creates a “constructivist” learning environment where students construct their knowledge based on the experiences gained during learning [17].

The PjBL model was initiated by an educational expert named John Dewey, who is famous for his concept of “learning by doing.” This concept involves achieving learning outcomes by engaging in specific actions to meet objectives, emphasizing the child’s mastery of tasks that require a series of behaviors to accomplish a goal [18]. Several studies recognize the enhancement of students’ science process skills through inquiry-based learning [19]. The PjBL model is an instructional approach based on the concept of learning activities in the form of real tasks that challenge students to solve problems [20]. This activity commonly reflects the types of activities or work done in daily life outside the classroom. This type of learning is generally carried out by groups of learners who cooperate to achieve common goals [21]. The implementation of the PjBL paradigm is based on challenging questions or tasks that necessitate students to participate in planning, problem-solving, critical thinking, or research activities [22]. The PjBL methodology allows teachers to monitor student learning while they are teaching by using projects [23]. PjBL strengthens acquired skills and knowledge through the creation of tangible outcomes [19].

In simple terms, PjBL is defined as teaching that aims to connect technology with everyday life problems that are familiar to students or with a specific project. The PjBL model is an educational approach that actively engages students in the learning process by involving them in research activities to collaborate on and accomplish a specific learning project [24]. PjBL generally involves guidelines or planning steps (*planning*), *creating*, and *processing*. One instructional approach that deviates from the traditional classroom setting is PjBL. Long-term PjBL experiences that are cross-disciplinary, student-centered, and deal with real-world issues are creative. They position teachers as facilitators and motivators while enabling students to independently construct their own learning [25].

The description above implies that through PjBL, students will be immersed in a learning environment where they work collaboratively in teams, demonstrating skills with a sense of responsibility for each task. It also highlights how information will be collected and presented in a scientific manner. The constructivist learning concepts that underpin the approach to PjBL are believed to have the capacity to cultivate the qualities inherent in soft skills, such as creativity, innovation, problem-solving, collaboration, interaction, and presentation abilities. CT is defined as problem-solving, designing systems, and understanding human behavior through the application of fundamental computer science concepts [14]. This concept implies that CT is a cognitive process that is not reliant on technology, and the solution can be implemented by either humans, computers, or both [26]. CT is about conceptualization, not programming. It deals with ideas, not artifacts. This is not a universal belief. CT patterns are alternatives that revolve around the Scratch language [27]. This can be interpreted as one of the challenges in integrating CT into the classroom. Another challenge in integrating CT in the classroom is the shortage of teachers.

Enrolling in courses or utilizing online platforms can help overcome challenges. Teaching and learning can be supported by these online courses and platforms. CT is applicable both inside and outside of the classroom, whether under instructor guidance or independently. Keep in mind that the concept of “online” is derived from the online learning consortium (OLC). Some online resources, such as courses, can help overcome these obstacles. You can enhance teaching and learning by utilizing online courses and platforms to develop CT skills independently or with instructor guidance, both in and out of the classroom. Be aware that the OLC is the source of the term “online” (Sener, 2015). Web-based courses are covered if the equipment is self-contained or if part of the instruction is offered online, meaning it may be

utilized without a teacher present. PjBL-CT is believed to be able to help resolve this issue in mobile programming courses.

### 3 METHOD

This study involved two test groups: the experimental class and the control class. The trials were conducted in the experimental group, while the control group served as a standard measure for improving the quality of learning outcomes. A randomized posttest control group design was used for the trial. This study employs a quasi-experimental design methodology and quantitative research methods. Although there is a control group in this design, it is unable to effectively regulate external circumstances that impact the execution of the research. Table 1 illustrates the usage of the post-testing only control methodology technique in the investigation's design.

**Table 1.** Research design of the PjBL-CT model in mobile programming courses

R	X1	X1
	X2	X2

*Notes:* X1 = posttest data for the treatment group, X2 = control group posttest data, X1 = model project-based learning CT (PjBL-CT), X2 = conventional model.

The design above aims to measure the effectiveness of the model by testing the differences in the quality of student learning outcomes in the two groups. To measure the trend of changes in the quality of learning outcomes following PjBL-CT learning and teaching through observation, questionnaires, and tests.

The effectiveness of the CpJBL-CT model can be measured using a tool to assess effectiveness, such as test questions. Test questions provided to students in advance must be analyzed first to determine the validity of the items, their discriminating power, question difficulty level, and test reliability. Measuring the effectiveness of the CpJBL-CT model in the Mobile Programming course through cognitive and affective measurements, focusing on 4C soft skills and psychomotor abilities. Test questions that have been validated will be used to assess student learning outcomes before and after the implementation of the CpJBL-CT model in the experimental class. This question was also tested in the control class during the pretest and posttest of the Mobile Programming course.

The CPjBL-CT model is used to generate scores for student learning outcomes. The results are then analyzed to determine the degree of achievement of the learning outcomes, and every pupil's score is translated into a numerical value between 0 and 100. Student learning outcomes can be categorized as follows:

**Table 2.** Categories of student learning assessment results

No.	Attainment Level	Category
1.	90–100	Very decent
2.	80–89	Healthy
3.	65–79	Sufficient
4.	55–64	Not sufficient
5.	0–54	Don't know

### Test requirement analysis

#### Normality

The normality test using the chi-square model can be conducted in two different ways to calculate the expected frequency ( $E$ , expected): by calculating the z-score area and by calculating percentages.

#### Formula

$$X^2 = (O - E_1)^2 + (O - E_2)^2 + \dots + (O - E_n)^2$$

$E_1 \qquad E_2 \qquad E_n$

In testing the normality of data using the chi-square formula, you must first calculate the expected frequency value ( $E$ ), while the observed frequency ( $O$ ) is automatically available. Apart from that, even though the data you want to use for a normality test is on an interval scale, the issue lies not in the magnitude of each individual data point ( $X$ ), but rather in the frequency of occurrence of each data point. Thus, the data processed in the normality test is nominal data.

#### Homogeneity

Proving that two or more sample information groups originate from communities with the homogeneity test aims to achieve the same variance. It is necessary for each group determined by the dependent variable to exhibit consistent variation in the regression results for regression analysis to occur. The hypothesis being tested is as follows:

$$H_0 : \tau_1^2 = \tau_2^2 = \tau_3^2 = \tau_4^2 = \tau_s^2$$

$H_1$ : One of the signs = not applicable

The testing technique used is the Bartlett test, which is conducted by calculating  $x_2$ . Price  $x_2$  obtained from the calculation ( $x_2$ count) is then compared with  $x_2$  from the table ( $x_2$ table). If  $x_2$ count <  $x_2$ table, the null hypothesis is subsequently accepted. This indicates that an evenly distributed population provided the information. The homogeneity test calculation using SPSS software is Levene's test for homogeneity of variances. The way to interpret the Levene test is that if the Levene statistic value is > 0.05, the data variation is homogeneous.

#### Population and sample

Thirty students enrolled in the Mobile Application Development course at Medan State Polytechnic of Informatics Study Programmer make up the population included in this sample.

## 4 RESULT AND DISCUSSION

Pre- and post-test findings from the t-test analysis were used to compare the efficacy of the PjBL-CT model with the conventional method. The effectiveness of the PjBL-CT model in learning implementation is measured based on cognitive aspects, affective aspects such as 4C soft skills, and psychomotor skills.

The effectiveness results are as follows:

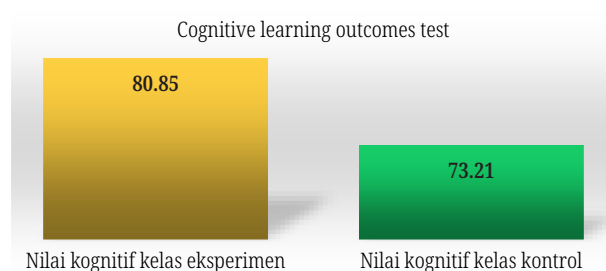
#### Cognitive test results

As for the average posttest cognitive learning outcomes of students in mobile programming, which have been calculated using statistical calculations in Excel, they can be seen as follows:

**Table 3.** Cognitive learning outcomes test

Information	Average Value
Experimental class cognitive value	80.85
Control class cognitive value	73.21

Can also be seen in the graph as follows:

**Fig. 1.** Student cognitive value

According to the students' post-test results for their cognitive learning in mobile programming, the experimental class's mean post-test score was higher than the control class's, with the former scoring 80.85 and the latter scoring 73.21.

The hypothesis testing data analysis used in this study is the difference test using an independent sample T-test.

1) Before analyzing the data, a prerequisite test for data analysis is conducted to determine if the information can be analyzed using an independent sample t-test. This preliminary test is essential. The uniformity and normalcy tests are the prerequisites.

#### Normality test

When a study's significance level is less than 0.05, the data is considered to be not normally distributed. The normality test is used to determine whether the data generated from the research results is distributed; if the value is greater than 0.05, the data is considered to be normally distributed.

The normality test was conducted using SPSS with the Kolmogorov-Smirnov statistic at a significance level of 0.05. The test results can be seen in the table below:

**Table 4.** Normality test posttest control class and experimental class

	Tests of Normality					
	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistics	df	Sig.	Statistics	df	Sig.
Pos_Test	.093	48	.200*	.980	48	.568

Notes: \*This is a lower bound of the true significance. Lilliefors Significance Correction.

A significance score of  $0.200 > 0.05$  in the normality test findings indicates that the data is normally distributed. Thus, it may be said that the posttest experimental group and control class data follow a normal distribution.

#### Homogeneity test

This is used to determine if the variance value of the research data is the same for the control and experimental groups. The data is considered to have a uniform

variant value if its statistical significance is greater than 0.05 and an irregular variant value if it is less than 0.05. The Levene test was used to assess the uniformity of the value of student learning outcomes using SPSS software. Table 5 presents the test results:

**Table 5.** Test the post-test homogeneity of the experimental class and the control class

Test of Homogeneity of Variances			
Post-Test			
Levene Statistics	df1	df2	Sig.
038	1	46	.847

The data exhibits homogeneous or equal variance, as indicated by the SPSS results presented in Table 5 above, with a significance value of 0.847, which is greater than 0.05. As a result, it was found that the outcomes from both the control and experimental groups were similar.

2) **Independent sample t-test:** The software SPSS was used to conduct the t-test. Table 6 displays the test results:

**Table 6.** T test post-test experimental class and control class

Independent Samples Test										
		Levene's Test for Equality of Variances		t-Test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Differences	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Score	Equal variances assumed	038	.847	4.876	46	.000	7.52917	1.54419	4.42087	10.63746
	Equal variances not assumed			4.876	45.953	.000	7.52917	1.54419	4.42078	10.63755

Based on the results of the t-test, the obtained t-count score of 4.876 and the t-table value at a significance value/P-value of 0.05, which is 1.725 (for 24 students), indicate that  $t\text{-count} > t\text{-table}$  ( $4.876 > 1.725$ ). Thus, it is concluded. There are differences in student learning outcomes between the experimental class using a PjBLmodel in the mobile programming course and the results of student learning in the conventional control class.

**Affective aspect**

In affective or attitude assessment, the goal is to determine the extent of student mastery of attitudes and behaviors in learning. The use of student observation sheets for assessing the 4C's through observation. The results are as follows:

**Table 7.** 4C assessment results from observer I

Project	Critical Thinking	Creativity	Communications	Collaboration
Project1	76.17	80.42	74.67	80.00
Project2	80.83	86.25	78.83	85.56



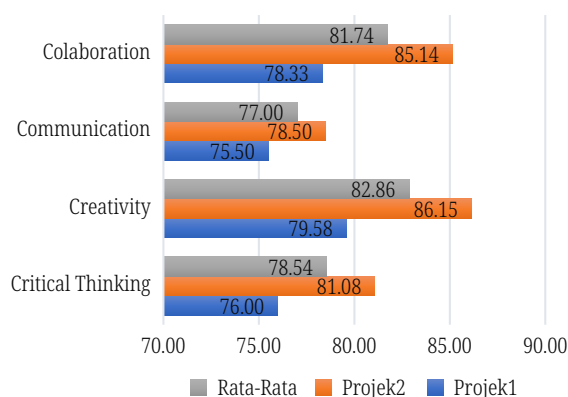
**Table 8.** 4C assessment result from observer II

Project	Critical Thinking	Creativity	Communications	Collaboration
Project1	75.83	78.75	76.33	76.67
Project2	81.33	86.04	78.17	84.72

**Table 9.** Recap of student 4C assessment results

Project	Critical Thinking	Creativity	Communications	Collaboration
Project1	76.00	79.58	75.50	78.33
Project2	81.08	86.15	78.50	85.14
Average	78.54	82.86	77.00	81.74

Based on the summary table of student 4C assessment results, it is evident that the 4C results include critical thinking, creativity, communication, and collaboration. Based on the outcomes of the two projects assigned to students, conclusions have been drawn regarding various aspects. 1) *Critical thinking* obtained an average score of 78.54. 2) Average creativity score: 82.86. 3) The communication average is 77. 4) The average collaboration score is 81.74. From these results, it can be seen that certain aspects of student creativity are superior to others. These results are also illustrated in Figure 2.



**Fig. 2.** Student 4C ability graph

**Psychomotor aspect**

The psychomotor aspect is evaluated through project assignments. For the assessment of student project results, two projects were conducted. Here are the results of the project.

**Table 10.** Recap of assessment of learning outcomes in project 1

Ket	Project Creation	Programming Competence	Product	Time	Report	Percentage
Exod 1	80	82.3	85.72	80	87	84.5
Exod 2	78	81.29	82.5	80	85	82.5
Exod 3	78	85.5	82.9	80	82	81.5
4th ex	82	86.5	84	82	80	80



The results of project 1 can be seen as follows:

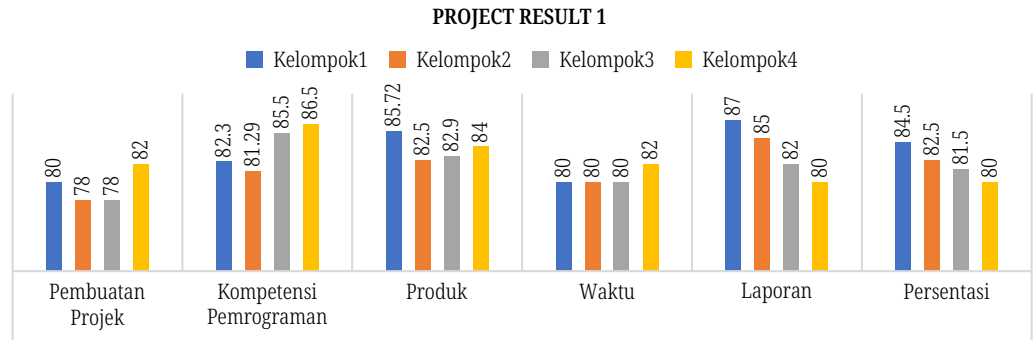


Fig. 3. Project assessment summary graphic 1 for each aspect

In the results of project 1, students were assessed on various aspects, including project creation, project competence, products, time management, reports, and presentations. The project results are presented in tables and graphs, showing that each group received good marks on different project aspects. As for the value of the second student project, it can be seen as follows:

Table 11. Recap of assessment of learning outcomes in project 2

Ket	Project Creation	Programming Competence	Product	Time	Report	Percentage
Exod 1	82	85	86	90	90	85
Exod 2	82	83.4	85	85.5	88	86
Exod 3	84	88.8	85	95.5	85.8	85
4th ex	83	90.2	86	87.5	85.5	84

The chart of project 2 can be seen in Figure 4.

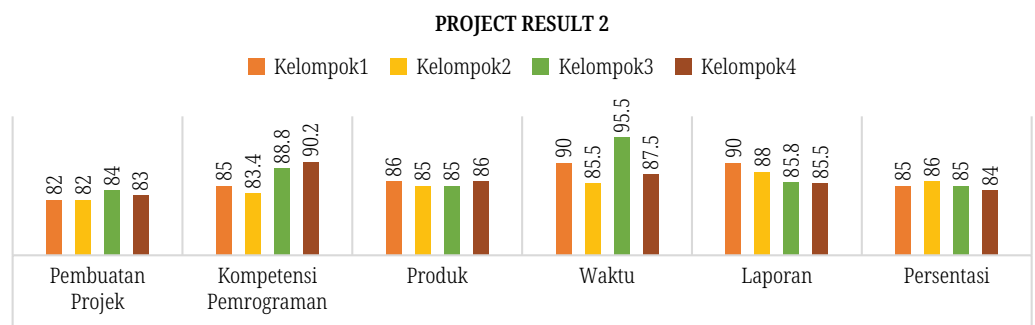


Fig. 4. Graph of project assessment summary 2 for each aspect

The results of the two student projects assessed various aspects, starting with project creation, project competence, products, time management, reports, and presentations. Tables and graphs present the outcomes of the projects in each group, showing that project aspects received good marks. It is evident that there was an improvement in the results from project 1 to project 2.

Teaching by applying the model PjBL-CT in the control class and the experimental class involves six steps: 1) Developing the problem’s focal point; 2) Logically

organizing and interpreting facts; 3) Algorithmic reasoning; 4) Create a project schedule; 5) Track and assess the project's progress; and 6) Assessment.

The efficacy of the model in the mobile programming course was determined by the following outcomes: The experimental class's average post-test score was higher than that of the control class, with scores of 80.85 and 73.21, respectively. It has been demonstrated that the data for the prerequisite exam is homogeneous and normally distributed. The results of the Independent Samples t-test show variations in the learning outcomes of students in the experimental class who used the PjBL paradigm for the Mobile Programming course compared to the academic achievements of students in traditional control classrooms.

Student 4C assessment results show that in terms of creativity, students outperform in other aspects. Meanwhile, psychomotor results from projects demonstrate project outcomes for two students across various assessed aspects, including project creation, project competence, products, time management, reports, and presentations. The project results are presented in tables and graphs for each group and project aspect, showing favorable ratings. An improvement in results can be observed from project 1 to project 2.

For academic achievement, students should possess the ability to analyze, solve problems, and evaluate effectively. The impact of the accompaniment after applying this model is that it can facilitate flexible learning based on the principles of CT, collaboration, and 4C capabilities and encompass social systems, responses, and support systems. Achievements generally aim to enhance the quality of learning.

This study supports the findings of [28], who discovered that PjBL can help students bridge the gap between abstract knowledge and practical application. The 21st-century educational framework is designed using the 4C criteria to provide students with the best possible opportunities to develop their artistic skills [29].

## 5 CONCLUSION

The CT teaching approach, combined with the PjBL model, can enhance the teaching of mobile programming courses. This study identified the implemented model as the most widely used approach to instructing CT. This verifies a modification in procedure; in this case, practicing CT can enhance constructionism. PjBL with a CT approach is also an important strategy that can enhance students' cognitive, affective, and psychomotor skills assessments. The key conclusion of this review is that in order to improve learning standards, digital thinking must be clearly defined.

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