Journal of Engineering Education Transformations ,
Volume 38, No. 4 , April 2025 , ISSN 2349-2473, eISSN 2394-1707

10.16920/jeet/2024/v38i4/25100

Innovative Pedagogy: Project-Based Flipped Classroom in Computer Architecture for New Engineering Students

Anak Agung Gde Ekayana[1], Ni Nyoman Parwati[2], Ketut Agustini[3], I Gede Ratnaya[4]
[1]Institut Bisnis dan Teknologi Indonesia, Denpasar, Indonesia
[234]Universitas Pendidikan Ganesha, Singaraja, Indonesia
[1]gungekayana@instiki.ac.id;
[2]nyoman.parwati@undiksha.ac.id;
[3]ketutagustini@undiksha.ac.id;
[4]gede.ratnaya@undiksha.ac.id

Abstract— In today's rapidly evolving world, engineering graduates must have the necessary skills and knowledge to bring about significant changes in business, industry, and entrepreneurship. However, empirical evidence shows that engineering graduates have high levels of cognitive abilities that are still low, resulting in the achievement of suboptimal learning outcomes. The research design used a pseudo-experimental approach that analyzed the impact of project-oriented flipped learning models, direct flipped, and self-efficacy on higher-order thinking skills and learning outcomes. The study findings showed a marked difference in higher-order thinking skills and learning outcomes of students who participated in project-based flipped learning compared to those who participated in direct flipped learning. Students in the experimental group more fluently find new ideas in solving problems. The psychological aspect of students, namely self-efficacy, influences improving higher-order thinking skills and learning outcomes. The learning model applied accommodates students who have different levels of self-efficacy. Evidence shows that the project-based flipped learning paradigm improves learning outcomes in computer architecture materials by developing students' higher-order thinking skills.

Anak Agung Gde Ekayana
Institut Bisnis dan Teknologi Indonesia, Denpasar, Indonesia
gungekayana@instiki.ac.id

Keywords—computer architecture, higher-order thinking skills, learning outcomes, project-based flipped classroom.

I. Introduction

Higher-order thinking skills (next: HOTS) become the capital for every engineering graduate to collaborate with the work environment in the era of the Industrial Revolution 4.0 (Chaka, 2020; Pawar et al., 2023). Developing higher-order thinking skills is essential for training engineering students, which leads to optimizing learning outcomes to succeed in the corporate world, industry, and entrepreneurship (Purwanto et al., 2023).

Based on data in the field, recruitment requirements in a field of work are getting higher and more complex. Many companies set high enough standards to find competent personnel in the required fields. Therefore, higher-order thinking skills for engineering students need to be optimized so that in the future, they can compete and show their competence to society (Ali, 2021). Higher-order thinking skills are not an attitude but rather a skill that can be trained (Kocdar et al., 2021). There are many ways to practice thinking skills to reach a high level, such as guided training, research, innovative learning, and collaboration (Suherman et al., 2020). HOTS supports students in succeeding in their current field of work and trains them in real-life problem-solving (Yeung, 2015).

Currently, the government in Indonesia has made various efforts to be able to develop high-level thinking skills in engineering students, such as curriculum changes, adjusting learning outcomes, inviting practitioners to teach, empowering educational technology and internship programs directly to companies (Afikah et al., 2023; Widiawati et al., 2018). Higher education, as a unit of higher education, again adjusts the policy into academic regulations and operational standards so that it can be determined and applied following the regulations mandated by central policy.

The Informatics Engineering Study Program at the Institut Bisnis dan Teknologi Indonesia (INSTIKI) is one of the higher education institutions in Bali Province that routinely produces graduates every year. Engineering graduates from INSTIKI have been equipped with competencies following undergraduate learning outcomes, providing them with solid provisions to face challenges in the world of work. They hope they deeply understand Informatics Engineering and can apply their knowledge effectively in their work field.

However, there is evidence from the academic section that the higher-order thinking skills of engineering students are still low and need to be improved. Based on data on academic learning outcomes, it was revealed that the average score of the computer architecture course was still far from expected.

The computer architecture course has learning outcomes that enable students to analyze, evaluate, and design the architectural form of a computer. Strengthening the concept of computer architecture is important because this course is related to hardware, such as CPU, memory, storage, bus interconnection, cache, and number system. The competencies in the computer architecture course are the foundation for success in the next course. Computer architecture courses are programmed in the first-year curriculum, and the learning objectives are more geared towards higher-order thinking skills. The phenomenon of higher-order thinking skills is also researched by Sukatiman et al. (2020), which describes the higher-order thinking skills in the Central Java area as still low, which has a less than optimal impact on the learning process in higher education.

Higher-order thinking skills are thinking skills that give birth to new ideas as problem-solving solutions (Rati et al., 2023). HOTS is a skill that must be possessed by engineering students as a competency to be able to complete a project in the future. HOTS helps students find new ideas and think creatively and flexibly in different conditions (Rusli et al., 2024). HOTS competence moves from the ability to analyze, evaluate, and create work that can help solve problems (Agussuryani et al., 2022).

Based on these data, preliminary data collection was carried out to determine the factors that cause the problem of low high-level thinking skills in first-year students, which have an impact on learning outcomes that are not optimal. According to the data, the educational background of engineering students entering the early years varies. It is suspected that first-year students have not been able to adapt to the learning process in higher education, so it is not easy to find the best learning pattern. Teachers use more direct learning models during the learning process. This form of learning involves more teachers who provide material while students listen to the material being explained because less supportive learning patterns and lack of training in higher-order thinking skills are thought to cause not optimal learning outcomes.

According to Santyasa et al. (2019), the direct learning model provides fewer opportunities for students to explore knowledge from the material studied. The direct learning model is more than just listening to the lecture's material (Ariyati et al., 2021). There is a lack of space to practice problem-solving yet support higher-order thinking skills (Fanchamps et al., 2021). Research results by Pratiwi & Santyasa (2021) explain that the hands-on learning model lacks support for higher-order thinking skills. Direct learning provides fewer challenges for engineering students, which results in a lack of motivation to learn. According to Santyasa et al. (2020), the learning model is one of the factors from outside the student that affects the learning process and outcomes. Teaching practices that still use old ways only burden students and do not support higher-order thinking skills.

Based on this description, providing solutions to these problems is necessary. Utilizing educational technology that is developing today, one solution that can be done is to make changes to the learning process. The learning process must support and favor students as learners, provide more opportunities to explore knowledge, practice problem-solving, interact with friends, and support thinking skills. Learning practices in this technological era require active and creative learning models to transform learning in engineering. Learning methods must be able to involve students in understanding the material and practicing high-level thinking skills.

A learning model that is relevant to computer architecture learning outcomes to train and develop higher-order thinking skills is the project-based learning model. Previous research results from (2023) reveal that project-based learning improves student learning outcomes. Learning that provides project activities during learning can train problem-solving skills through the project being worked on (Bukit & Basuki, 2021). Previous research results from Darmayoga & Suparya (2021), Explaining project-based learning can improve critical thinking skills, learning achievement, and learning outcomes. Vega, (2012) also revealed the results of previous research that project-based learning provides opportunities for students to learn through real environment-based projects. Project-based learning can increase student productivity in learning (Acharya & Gayana, 2021). The use of project-based learning has been widely carried out by previous researchers from various worlds, such as models project STEAM (Lu et al., 2021), model project e-learning (Santyasa et al., 2021), Project model with props (Aisyah et al., 2020), model STEAM project (Suryaningsih & Ainun Nisa, 2021); project model based on Tri Hita Karana (Sutrisna et al., 2020); model project flipped learning (Pratiwi & Santyasa, 2021); and Project model with worksheet (Sobral, 2021). The proposed learning model that can support higher-order thinking skills and be relevant to the characteristics of engineering students is project-based learning that combines flipped classroom learning strategies (next: PjBFC). The project learning model combined with the flipped classroom strategy makes the learning process more optimal because the learning time in class is limited.

The PjBFC model provides readiness to learn to students earlier and in class, followed by more interaction, such as discussions, project reporting, and project monitoring, that leads to improved higher-order thinking skills. Applying a project-based learning model synergized with a flipped classroom strategy trains students to prepare better, understand, and plan the learning process. Previous research results from (Diana et al., 2023) explain that using flipped classroom strategies can improve understanding of concepts and HOTS. The flipped classroom strategy supports students' ability to divide time before, during, and after classroom learning. The PjBFC model is a blended learning model that is an active learning method that involves students before and during learning. This is supported by previous research that revealed the advantages of the PjBFC model over other learning models in improving critical thinking skills. Project-oriented learning in collaboration with flipped classrooms improves scientific thinking skills (Listiqowati et al., 2022), improves problem-solving skills (Yuniarsih et al., 2020), and drives better learning outcomes (Tang et al., 2020).

In addition to factors from outside students, such as learning models, factors from within students affect learning outcomes, namely, environment, motivation, confidence, attitudes, and self-efficacy. In this study, self-efficacy was the factor that was focused on in students. Self-efficacy in technical students relates to the student's belief in him or herself to succeed. Student confidence in following the learning process is an encouragement to be brave in every learning activity, such as explaining in front of the class, daring to ask questions without being pointed, and being able to give answers fluently. Previous research conducted by (Capron & Audrin, 2021) explains that self-efficacy in students' learning dramatically influences the learning process. Self-confidence can provide enthusiasm, self-efficacy, and strength to provide existing abilities to students. Because self-efficacy is thought to influence learning outcomes, it is essential in this study to analyze self-efficacy variables in students as moderator variables or sorting variables.

The effect of applying the learning model to HOTS needs to be measured as learning outcomes. Learning outcomes assess the learning process at a specific time (Ariyati et al., 2021). Learning outcomes relate to attitudes, knowledge, and skills carried out by individuals and groups (Ekayana et al., 2022). In the research, learning outcomes are limited to the cognitive realm. The cognitive domain adopted from Bloom and Anderson's taxonomy is adjusted to the learning outcomes in the computer architecture course.

This research is centred on applying the PjBFC learning model to first-year computer architecture students. The impetus for research is based on a prolonged gap in the use of learning methods that do not encourage the practice of thinking skills. This study aims to analyze the effectiveness of the PjBFC learning model compared to the DeFC model in computer architecture courses regarding students' self-efficacy levels. The application of innovative learning models is a fundamental step for educators in engineering to contribute to developing learning methods to improve the skills and competencies of engineering student graduates in the community.

2. Method

A. Research Design

A quantitative approach was used in this study. The research design used quasi-experiments involving a test group and a control group. The study population comprised 265 first-year engineering students studying computer architecture in the odd-numbered semester of 2023/2024. Two lecturers are involved as teachers in each class. Assistance was given to the two lecturers as instructions in applying each learning model. Sample selection uses group random sampling techniques to determine the control and experimental classes. The variables in this study are the PjBFC and DeFC learning models as independent variables, higher-order thinking skills (HOTS) and learning outcomes as bound variables, and self-efficacy as moderator variables. The study design is shown in Table 1.

Table 1 :
Research Design

Learning Model (A) Self-efficacy (B)	Model PjBFC (A_1)	Model DFC (A_2)
High (B_1)	$Y1(A_1B_1)$,$Y2(A_1B_1)$,	$Y1(A_2B_1)$, $Y2(A_2B_1)$
Low (B_2)	$Y1(A_1B_2)$, $Y2(A_1B_2)$,	$Y1(A_2B_2)$, $Y2(A_2B_2)$

B. Data collection

Data collection in this study used two instruments, namely Likert scale questionnaires to collect student self-efficacy data and tests to measure HOTS and learning outcomes. The self-efficacy questionnaire instrument is arranged based on the indicators used, namely the dimension of confidence, the dimension of difficulty, and the dimension of breadth. See Table 2.

Two forms of tests are used in this study and the first is an essay test to measure higher-order thinking skills (HOTS). The essay test adapted to Bloom's revised taxonomy has six levels: remembering, explaining, applying, analyzing, evaluating, and creating (Zainuddin, 2019). This study uses three levels that lead to HOTS: analysis, evaluation, and design. See Table 3.

Table 2 :
Self-efficacy Indicators

Dimension	Indicator
Difficulty Level	Confidence in solving a learning problem
Confidence Level	Confidence in self-potential in completing learning tasks
Breadth Level	Attitudes that demonstrate confidence in learning

Table 3:
Hots Measurement Instruments

Level	Indicator	Question Number
Analyze	Determine Linking	Question number 1
Evaluate	CompareChoose	Questions number 2 and 3
Designing	Designing Construction	Questions number 4 and 5

Computer architecture learning outcomes are measured using multiple-choice tests. The items on the test are adjusted to the learning outcomes and Bloom's taxonomy so that the competence of overall computer architecture learning outcomes can be measured. Indicators of learning outcomes are shown in Table 4.

Table 4 :
Computer Architecture Learning Outcomes

Expected Final Capabilities	Indicator
Students can use natural science, mathematics, engineering principles, and engineering science to design BUS and PCI system components, interconnection structures, and interconnections in computer system design media.	Explain the computer's leading parts and BUS path.
	Determine the main constituent components of computer architecture and interconnect paths.
	Determine the central computer architecture and interconnect features. Imagine data, control, and address bus interconnectivity lines.
Students conclude experimental data analysis of the computer bus system's primary structure and interconnection path.	Comparing data, address, and control bus interconnections
	Examine bus interconnect data transfer.
	Analyze the data communications utilized in connection pathways.
	Development of operational principles for bus interconnection lines

C. Test Internal Consistency of Grains, Validity and Reliability

The instrument used is first tested. The first test is related to the validity of the contents of each instrument. The content validity test is carried out by looking for two experts related to the variables to be studied. Each content expert's assessment and correction of instruments uses the Gregory formula to analyze instruments in the assessment range category (Candiasa, 2020). See Table 5.

Table 5 :
Content Validity Criteria

Range of Values	Criterion
0,00-0,19	Inappropriate
0,20-0,39	Not Appropriate
0,40-0,59	Quite Appropriate
0,60-7,90	Appropriate
0,80-1,00	Very Appropriate

The results of testing the validity of the contents for all instruments have a coefficient of 1.00. This means that the items on each instrument are by the indicators on each variable to be measured. The next stage is instrument trials using 102 respondents. The respondents were informatics engineering students who had received computer architecture courses. The esults of the instrument trial are continued by testing alidity and reliability. See Table 6.

Table 6 :
Research Instrument Reliability Test Results

Instrument	Cronbach's Alpha	N of Items
Self-efficacy Instruments	0.948	44
Instrumen HOTS	0.707	10
Learning Outcomes Instrument	0.703	15

The number of valid statement items is obtained based on the validity test results. There are 44 valid items on the self-efficacy instrument, ten questions on high-level thinking skills essay tests, and 15 on multiple-choice tests for learning outcomes. After all the testing processes are carried out, the next step is for the instrument to be distributed to each class group according to the learning stages.

3. Result And Discussion

A. Impact of Learning Models in Computer Architecture course.

The application of the PjBFC model to new students who take computer architecture courses is carried out for eight weeks. The researcher determined the eight weeks to ensure optimal treatment and reduce internal validity gaps during the study. See Table 7.

Table 7 :
Research Time Plan

	Week	
1	2-7	8
Socialization of the application of the PjBFC & DeFC learning model (Pretest)	Treatment of PjBFC models in experimental classes and DeFC models in control classes	Postest to the whole class group

The application of the PjBFC model uses three class conditions, namely before, during, and after

Table 8 :
PjBFC Learning Syntax

	Pre-Class	In-Class	After-Class
Lecturer	1. Share learning materials with students, including presentations, videos, research papers, and book excerpts. 2. Provide trigger questions related to learning materials 3. Provide project-based learning instructions	1. Review student readiness for learning led by each student 2. Lecturers act as facilitators for designing project activities and determining project schedule agreements 3. Lecturers monitor the progress of the project being worked on.	1. Interact with students through learning media related to project design progress. 2. Lecturers monitor project progress through learning platforms and guide if there are obstacles in project activities 3. Lecturers reflect on the results of learning projects that students have carried out
Student	1. Prepare answers to fundamental questions to be presented in class 2. Ensure project activities run according to the agreed schedule 3. Prepare work from project activities to be presented in front of the class.	1. Students design real-world-based project activities that are linked to learning .materials 2. Students Develop a schedule of project activities 3. Interact with friends and communicate the process of project activities 4. Students present the results of the project to all friends and discuss the project	1. Students work on project activities in groups 2. Students interact with group mates to complete projects 3. Students design reports on the results of project activities after being presented in class as an evaluation of learning experiences. 4. Provide follow-up responses and conclusions

class. This flipped classroom strategy modifies the results of the study (Chiang & Wu, 2021). Modifications are made to each class condition by integrating the syntax of the project-based learning (PjBL) model. Each stage in the PjBL model is tailored to each condition, from trigger questions to evaluation of learning experiences. This learning strategy is optimally applied to overcome project-based learning time limited to the classroom. The syntax of learning with the PjBFC model is shown in Table 8.

As for the DeFC model, class time conditions are adjusted as with the PjBFC model. The difference lies in the learning activities applied. In the DeFC model, activities before class include distributing materials, presentation materials, videos, books, and preliminary exercises carried out by students. Learning activities are usual in class: material presentations by lecturers, questions and answers, student presentations, and exercise work. When outside the classroom, he continued with assignments to students. See Table 9.

Both learning models were given the exact timing, starting before, during, and after. This is important to ensure the differences are the result of the intervention, not other factors that caused the differences. Each teaching lecturer carries out the learning process in a predetermined class group. Researchers in this section observe how the learning process is carried out by teaching lecturers. After teaching time, each lecturer will provide notes about experiences and what things happened during the learning process.

Table 9 :
Defc Learning Syntax

	Pre-Class	In-Class	After-Class
Lecturer	1. Share learning materials with students, including presentations, videos, research papers, and book excerpts.	1. Review student readiness for learning led by each student 2. Ask students about completing homework the night before 3. Teaching new learning materials.	1. Give homework related to newly learned material in class as an additional activity outside class.
Student	1. Prepare and study the material that lecturers have shared. 2. Ensure that the assigned tasks have been completed according to the instructions.	1. Students work on assigned assignments, either independently or in groups. 2. Students listen to the material presented by the lecturer.	1. Students work on assignments given by lecturers. 2. Work together with friends to be able to complete the assigned tasks.

Before the treatment process is given to each group of students, the instruments that have been tested are then distributed to student groups, starting from self-efficacy instruments and pretests. Self-efficacy instruments are used to sort students into upper and lower groups, while the pretest measures early higher-order thinking skills and learning outcomes. This pretest will then be used as a covariate variable for further analysis. A post-test is given to each group of students in the eighth week. The results of the assessment process carried out are shown in Table 10.

Table 10 :
Summary of Descriptive Results of
Hots and Learning Outcomes

Variabel	Group	Sorting	N	M	SD
HOTS	Control Class Pretest	High	50	18.46	5.67
		Low		21.17	5.21
	Postest Control Class	High		26.15	3.96
		Low		22.23	3.32
	Experimental Class Pretest	High	50	25.87	5.73
		Low		22.09	5.82
	Postest Experimental Class	High		31.77	2.93
		Low		26.81	3.94
Learning Outcomes	Control Class Pretest	High	50	31.47	12.68
		Low		30.41	18.77
	Postest Control Class	High		57.61	15.20
		Low		38.68	14.51
	Experimental Class Pretest	High	50	47.22	10.91
		Low		32.52	11.61
	Postest Experimental Class	High		72.82	17,33
		Low		54.95	11.61

Table 10 shows a statistical analysis of the pretest and post-test results carried out in each class group. The average HOTS post-test in experimental classes with students with high self-efficacy (M = 31.77) was superior to that of students with high self-efficacy (M = 25.87). In the control group, the average HOTS of students with high self-efficacy (M = 26.15) was superior to the control class with high self-efficacy (18.46). An increase in the average post-test scores also occurred in each class for students who had low self-efficacy. Furthermore, the average post-test score of experimental class learning outcomes with high self-efficacy students (M = 72.82) was superior to the pretest score of students with high self-efficacy (M = 47.22). The average post-test score in the control class in students with high self-efficacy (M = 57.61) was superior to the pretest score of students with high self-efficacy (M = 31.47). The average score of students with low self-efficacy between the control and experimental classes also improved.

Table 11 :
Five Scale Conversion Guidelines

Range of Values	Kualitas
$X > (M_{id} + 1{,}5\ SD_{id})$	Very Good
$(M_{id} + 0{,}5\ SD_{id}) < X \leq (M_{id} + 1{,}5\ SD_{id})$	Good
$(M_{id} – 0{,}5\ SD_{id}) < X \leq (M_{id} + 0{,}5\ SD_{i})$	Good Enough
$(M_{id} – 1{,}5\ SD_{id}) < X \leq (M_{id} - 0{,}5\ SD_{id})$	Not Good
$X \leq (M_{id} – 1{,}5\ SD_{id})$	Not Good

In this regard, it can be justified that there is a difference in the average higher-order thinking skills and learning outcomes between the experimental and control groups of students.

The average results of the pretest and post-test are then converted using a reference scale of five scales, see Table 11 by processing the ideal mean (Mid) and ideal standard deviation (SDid) so that the number of scores in each category is obtained.

In Fig 1, it can be shown that the number of students studying with the PjBFC model from the HOTS assessment (62%) is more than the number studying with the DeFC model. Learning outcomes in the experimental group showed the most distribution in the excellent category (40%). In the control class for HOTS, the most extensive distribution is in the sufficient category (56%). In comparison, the learning outcomes of the control class are in a suitable category, as much as 18%. The distribution of research data also showed that there were still student scores in the experimental group that entered the category of less (HOTS = 6%; Learning Outcome = 8%) and control classes that fell into the category of less (20%) and significantly less (22%).

HOTS assessment can be revealed based on the test results that have been analyzed, and learning outcomes between pretest and post-test scores are

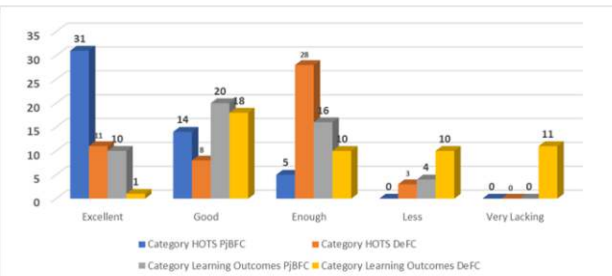

Fig. 1: Summary of test results by category

different, which the experimental class post-test results are higher than the control class post-test results so that the PjBFC learning model meets the requirements for effectiveness aspects in learning based on the results of higher-order thinking skills tests and learning outcomes.

B. Test Prerequisites and Hypotheses

Before testing the hypothesis, it is necessary to carry out a series of prerequisite tests, namely testing data normality, data homogeneity, linearity, and regression direction. Prerequisite testing aims to ensure that the data used follows the analysis techniques. All prerequisite test results were compared with a significance level of 5%.

The results of the normality test of pretest and post-test data on the HOTS variable and learning outcomes showed the value of sig. in each data source higher than =5%. This means that all data used in this study are typically distributed. See Table 12.

Table 12 :
Data Normality Test Results

Source	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest HOTS	.076	100	0.167	.974	100	0.047
Postest HOTS	.075	100	0.181	.976	100	0.070
Pretest Learning Outcomes	.086	100	0.066	.967	100	0.012
Postest Learning Outcomes	.080	100	0.114	.969	100	0.020

In Table 13, the value of sig. For the HOTS variable and learning outcomes, it is higher than =5%, meaning that the data variance between data groups used in this study is homogeneous. As for the homogeneity test results, Box's M test shows sig results. If it is higher than (=5%), then the covariance matrix tested jointly between HOTS variables and learning outcomes is homogeneous. See Table 14.

Table 13 :
Results of Homogeneity of Data Between Variances

Source		Levene Statistic	df1	df2	Sig.
HOTS	Based on Mean	.763	1	98	0.385
Learning Outcomes	Based on Mean	1.123	1	98	0.292

Table 14 :
Data Homogeneity Test Results Together

Box's M	1.410
F	.460
df1	3
df2	1728720.000
Sig.	0.711

In Table 15, the significance value in the deviation from linearity line > 5%, of which the significance value means that the regression direction between the covariate and the dependent variable is linear. Therefore, it can be concluded that the increase in covariate prices will align with the increase in prices on the dependent variable and vice versa. Furthermore, the linearity significance value < 5%, which means a form of linear regression (between the relationship of a covariate variable and a meaningful dependent variable). The regression linearity test results and the regression direction's meaningfulness show that the MANCOVA test can be continued.

Table 15 :
Results of The Linearity and Meaningfulness of Regression Direction Test

			Mean Square	F	Sig.
Postest HOTS * Pretest HOTS	Between Groups	(Combined)	29.891	1.036	0.435
		Linearity	167.769	5.815	0.018
		Deviation from Linearity	23.896	0.828	0.687
Postest Learning Outcomes * Pretest Learning Outcomes	Between Groups	(Combined)	649.084	1.989	0.050
		Linearity	2594.477	7.950	0.006
		Deviation from Linearity	405.910	1.244	0.283

The data analysis technique used to test hypotheses is Multivariate Analysis of Covariance (MANCOVA). The results of the hypothesis test are shown in Table 16.

The results of statistical calculations in Table 16 explain that the application of the learning model has a significant impact on HOTS (F = 53.066; ρ = 0.000) and learning outcomes (F=23.127; ρ=0.000). These results are reinforced by descriptive calculations that reveal the PjBFC learning model (M = 29.32) is superior to the DeFC model (M=23.20). Self-efficacy factors in students significantly impacted HOTS (F= 46.831; ρ =0.000) and learning outcomes (F=30.425; ρ= 0.000). This finding was reinforced by descriptive analysis, where students with high self-efficacy (M = 29.00 in both learning models) were superior to those with low self-efficacy (M=20.24). The statistical analysis results also revealed the influence of learning model factors and self-efficacy, that there was no interaction between the learning model and self-efficacy on HOTS and learning outcomes.

Table 16 :
Mancova Test Results Summary

Source	Dependent Variable	Mean Square	F	Sig.
Pretest HOTS	HOTS	.121	.010	0.922
	LO	163.127	.716	0.400
Pretest Learning Outcomes (LO)	HOTS	.500	.040	0.843
	LO	1.308	.006	0.940
Learning Model	HOTS	669.124	53.066	0.000
	LO	5266.231	23.127	0.000
Self-efficacy	HOTS	590.499	46.831	0.000
	LO	6928.923	30.425	0.000
Learning Model * Self-efficacy	HOTS	11.807	0.936	0.336
	LO	52.681	0.231	0.632

Pretest HOTS and learning outcomes were used as covariates in statistical analysis, and the results showed that the significance value was greater than 0.05, indicating no significant relationship between the pretest and the dependent variable after considering the pretest effect. In the context of this study, the pretest results did not significantly contribute to the dependent variable after control. Therefore, generalizations can be drawn that the difference between HOTS and learning outcomes is due to the treatment given during the learning process.

C. Impact of Learning Model on HOTS Quality and Learning Outcomes of Engineering Students

The research effectively applied the PjBFC learning model with groups of Informatics Engineering students throughout eight meetings. Applying the PjBFC learning model significantly enhances higher-order thinking skills (HOTS) and improves learning outcomes. Statistical analysis found that the engineering students in the experimental group outperformed those in the control group.

Based on the research that has been done, it can be reported that applying the PjBFC model has brought significant positive impacts in the context of learning processes and outcomes. This research is supported by the results of previous research by (Priyaadharshini & Maiti, 2023), which revealed that the implementation of flipped classrooms provides better learning strategies that have an impact on student performance that is increasing. One of its main successes lies in improving students' higher-order thinking skills. Through project activities with real problem-solving, this model encourages students to develop higher-order and contextual thinking skills. As a result of increasing HOTS, the PjBFC model has also been proven to improve the learning outcomes of computer architecture.

Higher-order thinking skills increase in students learning computer architecture. In the first dimension, students can improve their analytical skills, the basic structure of a computer system, or a particular computer architecture. An example of a project-based learning product related to analytical skills is the analysis of memory and storage components on computers analogous to the functions of tables and cabinets. Memory is like a table, which serves as a place to process applications and systems. The larger the table, the more applications can open at that moment. While storage is like a cabinet, which stores the results of work for a long time. See Fig 2. With the application of the flipped classroom strategy, students can learn basic materials, such as the basic principles of memory and storage in computer architecture, through materials that have been prepared before class sessions. In class, they can have in-depth discussions to analyze the work on projects about computer memory and storage systems that they have learned before.

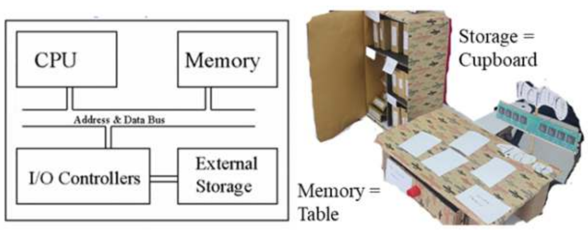

Fig. 2 :.Example of work on analytical skills in the PjBFC learning model

The second HOTS dimension is for students to improve their skills in evaluating a type of interconnection path in a computer system and comparing it with various types of architectures studied. With the PjBFC learning model, students can apply previously learned material to analyze critical aspects of various types of interconnection paths in computer architecture. In class, they can conduct evaluative discussions, such as evaluating the benefits and drawbacks of interconnecting paths of existing architectural systems as material for designing forms of real-world project activities related to the material. See Fig 3.

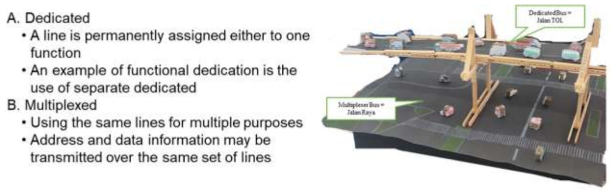

Fig. 3 : Example of work on evaluating skills in the PjBFC learning model

The improvement of design skills in the experimental group proves that implementing the PjBFC learning model can develop students' creative ideas to understand computer architecture material

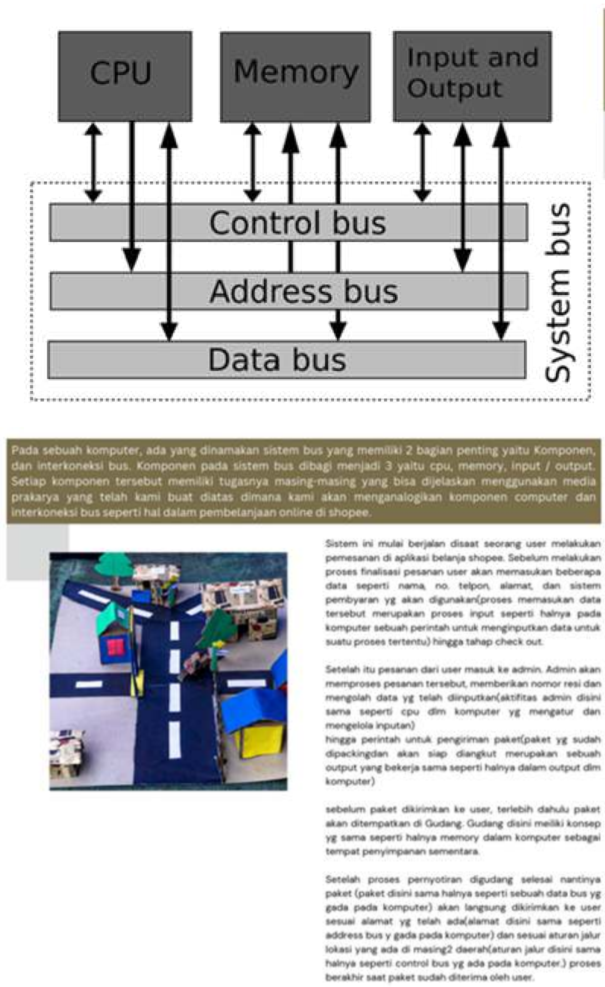

Fig. 4:Examples of work on design skills in the PjBFC learning model

through project activities based on real-life phenomena. Students in the experimental group demonstrated a deep understanding of BUS interconnection in computer architecture through project activities that created an analogy between the phenomenon of online shopping and the BUS interconnection system.

In this learning project, they linked roles in online shopping transactions with elements in computer systems. For example, CPU is likened to a store admin who coordinates operations, memory, and storage is formulated as a storage warehouse that stores goods, input and output are interpreted as warehouse guards who regulate the entry and exit of goods, data lines are interpreted as packages/goods stored, address lines are identified as the identity of the sender and recipient addresses of packages, and control lines are mapped as couriers or expeditions in charge of managing delivery of goods. Through the analogies they make, students can understand the concept of BUS interconnection in greater depth and relate the concept to real-world situations, enhancing a relevant and enjoyable learning experience. See Fig 4.

D. Impact of Self-efficacy on HOTS Quality and Student Learning Outcomes

The self-efficacy factor in students is very influential in improving higher-order thinking Skills (HOTS) and overall learning outcomes. Students with high levels of self-efficacy tend to be more proactive in contributing to the context of learning. They give new ideas to classmates more, can explain confidently, and tend to be more collaborative. On the other hand, students with low self-efficacy tend to be more passive, ask more of their peers for clarification, provide more corrections in project work, and wait for guidance from their peers. This research is supported by research results (Mitchell et al., 2021), which explain that the self-efficacy factor in each person influences the performance and success of that person. Therefore, it is essential to pay attention to the factors that influence the level of self-efficacy in individual students in the learning environment.

In learning, lecturers must motivate and encourage students to grow their self-efficacy. Students who have a high level of self-efficacy tend to have confidence that they can master the tasks assigned and can organize their way of learning. Through the PjBFC learning model, self-efficacy can be trained and improved in students. The PjBFC learning model provides opportunities for students with low levels of self-efficacy to interact more actively with classmates, ask questions, discuss incomprehension, and gradually learn to build confidence through project activities carried out together.

From the description above, it can be concluded, in general, that the self-efficacy factor has a significant influence on the ability of higher-order thinking Skills (HOTS) and student learning outcomes. Therefore, lecturers need to reinforce the learning process so that the self-efficacy of each student can grow over time (Luo et al., 2021). Thus, students are expected to be more prepared and confident to cope with various academic tasks, thus creating a more productive and supportive learning environment for their personal and academic growth.

Regarding interaction, research findings indicate that the learning model and the level of student self-efficacy do not significantly impact HOTS abilities and learning outcomes. Both learning models are well-suited for students of varying levels of self-efficacy. This indicates that the level of student self-efficacy does not directly impact the learning model's effectiveness. It suggests other factors are at play in developing higher-order thinking skills and improving student learning outcomes.

Research findings suggest that factors influence differences in higher-order thinking skills and student learning outcomes. One of the identified factors is the application of the PjBFC model. In addition, the findings in this study also show that psychological factors, such as self-efficacy in students, affect the HOTS (High Order Thinking Skills) ability and learning outcomes. In this context, students with high self-efficacy are proven superior in working on projects and more fluent in providing ideas for problem-solving. It is proven that this study's results consistently positively impact HOTS abilities and student learning outcomes. A project-based learning approach and a flipped classroom strategy optimize student learning time. Thus, it can be concluded that the PjBFC model is feasible and effective for engineering students in computer architecture courses to improve their higher-order thinking skills and learning outcomes.

Based on these research findings, future researchers must pay attention to the following things to generalize the results of this research to other times and subjects to ensure the meaningfulness of this learning model. If this learning model is to be generalized to a broader population, it is necessary to pay attention to sample characteristics, sample representativeness, and the sample size used, which has been done in this research. Furthermore, suppose this learning model is generalized to different situations related to variations in context, other subjects, and environmental conditions. In that case, ensuring that the research site has relatively similar learning environmental conditions, learning room facilities, teacher qualifications, and student characteristics is mandatory.

The study has limitations, especially concerning engineering students in the first year. They need additional time and adjustment to apply the PjBFC model optimally. This is because first-year students tend to be familiar with the direct learning model they obtained while still in high school. According to constructivist theory, students can form and understand the material learned at their own pace and use different methods depending on their cognitive structure. Another limitation is that this research was conducted quickly, so not all students could achieve the maximum target. The PjBFC model emphasizes simultaneous learning in groups with peers, which impacts the focus of material mastery. If a material is mastered, other less supportive materials can get less attention.

Conclusion

The results revealed that the PjBFC model effectively improved higher-order thinking Skills (HOTS) and learning outcomes of first-year engineering students studying computer architecture. Students in the experimental group showed excellence in finding ideas and explaining the concept of ideas more fluently than the control group. The research findings also highlight the critical role of student self-efficacy in influencing improved HOTS and learning outcomes. Therefore, it is recommended that lecturers provide space for students to dare to struggle and train self-confidence during learning activities. The PjBFC model can be effectively applied in classroom environments where students have varying levels of self-efficacy because research findings report no significant interaction between the learning model and self-efficacy on HOTS and learning outcomes.

This study offers valuable recommendations for engineering lecturers who teach engineering students at the start of the year. This suggestion highlights the importance of incorporating the PjBFC model as a learning tool to cultivate skills in higher-order thinking right from the start of lectures. This is anticipated to create a solid base for students to pursue more specialized courses in the coming year and, ideally, to produce graduates who are skilled, capable, and prepared to meet the challenges of a globalized world.

Acknowledgment

The author would like to thank the Institut Bisnis dan Teknologi Indonesia for providing permission for the research location and the Universitas Pendidikan Ganesha doctoral program for providing support until the completion of this research.

References

Acharya, S., & Gayana, M. N. (2021). Enhanced learning and improved productivity of students' using project based learning approaches for programming courses. Journal of Engineering Education Transformations, 34(Special Issue), 524–530. https://doi.org/10.16920/jeet/2021/v34i0/157205

Afikah, A., Rohaeti, E., Jumadi, J., & Perdana, R. (2023). Student's higher-order thinking skills and collaboration skills in online learning during pandemic. International Journal of Evaluation and Research in Education, 12(1), 23–33. https://doi.org/10.11591/ijere.v12i1.23797

Agussuryani, Q., Sudarmin, S., Sumarni, W., Cahyono, E., & Ellianawati, E. (2022). STEM literacy in growing vocational school student HOTS in science learning: A meta-analysis. International Journal of Evaluation and Research in Education, 11(1), 51–60. https://doi.org/10.11591/ijere.v11i1.21647

Aisyah, M. N., Fitriyah, L. M., & Indraswari, N. F. (2020). Pengaruh Model Project Based Learning dengan Alat Peraga Bokstik Terhadap Prestasi Belajar Matematika Siswa. Jurnal of Songke Math, 3(1), 1–7. https://unikastpaulus.ac.id/jurnal/index.php/jsm/issue/view/41

Ali, M. (2021). Vocational students' perception and readiness in facing globalization, industry revolution 4.0 and society 5.0. Journal of Physics: Conference Series, 1833(1), 0–7. https://doi.org/10.1088/1742-6596/1833/1/012050

Ariyati, P., Sukrawarpala, I. W., & Santyasa, I. W. (2021). Problem Based E-Learning dalam Pembelajaran Kimia Di SMA. In Kwangsan: Jurnal Teknologi Pendidikan (Vol. 9, Issue 1, p. 70). https://doi.org/10.31800/jtp.kw.v9n1.p70--89

Bukit, I. K., & Basuki, I. (2021). Analisis Pengaruh Pembelajaran Berbasis Proyek Dengan Arduino Terhadap Hasil Pembelajaran Siswa Pada Mata Pelajaran Teknik Pemrograman Mikroprosesor dan Mikrokontroler di SMK. Jurnal Pendidikan Teknik Elektro, 10(1), 35–39.

Candiasa, I. M. (2020). Analisis Data Dengan Statistik Multivariat. Undiksha Press.

Capron, P. I., & Audrin, C. (2021). Improving self-efficacy and creative self-efficacy to foster creativity and learning in schools. Thinking Skills and Creativity, 42(Desember), 100966. https://doi.org/https://doi.org/10.1016/j.tsc.2021.100966

Chaka, C. (2020). Skills, competencies and literacies attributed to 4IR/Industry 4.0: Scoping review. IFLA Journal, 46(4), 369–399. https://doi.org/10.1177/0340035219896376

Chiang, F. K., & Wu, Z. (2021). Flipping a classroom with a three-stage collaborative instructional model (3-CI) for graduate students. Australasian Journal of Educational Technology, 37(4), 51–67. https://doi.org/10.14742/ajet.6330

Darmayoga, I. W., & Suparya, I. K. (2021). Penerapan Model Pembelajaran Project Based Learning (PjBL) Berbantuan Media Visual untuk Meningkatkan Hasil Belajar IPS Siswa Kelas V SD N 1 Penatih Tahun Pelajaran 2019 / 2020. Jurnal Pendidikan Dasar, 2(1), 41–50.

Diana, Surjono, H. D., & Mahmudi, A. (2023). The Effect of Flipped Classroom Learning Model on Students' Understanding of Mathematical Concepts and Higher-Order Thinking Skills. International Journal of Information and Education Technology, 13(12), 2014–2022. https://doi.org/10.18178/ijiet.2023.13.12.2016

Ekayana, A. A. G., Putra, P. S. U., & Destiansyah, B. T. (2022). Android-Based Learning Media in Supporting the Recovery of Science Learning Class VII. JINOTEP (Jurnal Inovasi Dan Teknologi Pembelajaran): Kajian Dan Riset Dalam Teknologi Pembelajaran, 9(2), 197. https://doi.org/10.17977/um031v9i22022p197

Fanchamps, N. L. J. A., Slangen, L., Hennissen, P., & Specht, M. (2021). The influence of SRA programming on algorithmic thinking and self-efficacy using Lego robotics in two types of instruction. International Journal of Technology and Design Education, 31(2), 203–222. https://doi.org/10.1007/s10798-019-09559-9

Kocdar, S., Bozkurt, A., & Goru Dogan, T. (2021). Engineering through distance education in the time of the fourth industrial revolution: Reflections from three decades of peer reviewed studies. Computer Applications in Engineering Education, 29(4), 931–949. https://doi.org/10.1002/cae.22367

Listiqowati, I., Budijanto, Sumarmi, & Ruja, I. N. (2022). The Impact of Project-Based Flipped Classroom (PjBFC) on Critical Thinking Skills. International Journal of Instruction, 15(3), 853–868. https://doi.org/10.29333/iji.2022.15346a

Lu, S. Y., Lo, C. C., & Syu, J. Y. (2021). Project-based learning oriented STEAM: the case of micro–bit paper-cutting lamp. International Journal of Technology and Design Education. https://doi.org/10.1007/s10798-021-09714-1

Luo, T., So, W. W. M., Wan, Z. H., & Li, W. C. (2021). STEM stereotypes predict students' STEM career interest via self-efficacy and outcome expectations. International Journal of STEM Education, 8(1). https://doi.org/10.1186/s40594-021-00295-y

Mitchell, K. M., McMillan, D. E., Lobchuk, M. M., Nickel, N. C., Rabbani, R., & Li, J. (2021). Development and validation of the Situated

Academic Writing Self-Efficacy Scale (SAWSES). Assessing Writing, 48(April), 100524. https://doi.org/10.1016/j.asw.2021.100524

Pawar, R., Patil, S., & Kulkarni, S. (2023). Enhancing Product Development Skills of Engineering Students through Diversified Group Activities. Journal of Engineering Education Transformations, 37(1), 20–30. https://doi.org/10.16920/jeet/2023/v37i1/23128

Pratiwi, N. W. E., & Santyasa, I. W. (2021). Project-Based with Flipped Learning : A Challenge to Enhance Students 'Achievement on Chemistry. Advances in Social Science, Education and Humanities Research, 566(Aes 2020), 186–190. https://doi.org/10.2991/assehr.k.210715.040

Priyaadharshini, M., & Maiti, M. (2023). Learning Analytics: Gamification in Flipped Classroom for Higher Education. Journal of Engineering Education Transformations, 37(1), 106–119. https://doi.org/10.16920/jeet/2023/v37i1/23137

Purwanto, M. B., Hartono, R., & Wahyuni, S. (2023). Essential Skills Challenges for the 21st Century Graduates: Creating A Generation of High-Level Competence in The Industrial Revolution 4.0 Era. Asian Journal of Applied Education (AJAE), 2(3), 279–292. https://doi.org/10.55927/ajae.v2i3.3972

Rati, N. W., Arnyana, I. B. P., Dantes, G. R., & Dantes, N. (2023). HOTS-Oriented e-Project-Based Learning: Improving 4C Skills and Science Learning Outcome of Elementary School Students. International Journal of Information and Education Technology, 13(6), 959–968. https://doi.org/10.18178/ijiet.2023.13.6.1892

Rusli, N. S., Ibrahim, N. H., Hanri, C., & Surif, J. (2024). E-Module problem-based learning on chemical equilibria to improve students' higher-order thinking skills: an analysis. International Journal of Evaluation and Research in Education (IJERE), 13(1), 454. https://doi.org/10.11591/ijere.v13i1.25972

Santyasa, I. W., Agustini, K., & Pratiwi, N. W. E. (2021). Project Based E-learning and Academic Procrastination of Students in Learning Chemistry. International Journal of Instruction, 14(3), 909–928. https://doi.org/10.29333/iji.2021.14353a

Santyasa, I. W., Rapi, N. K., & Sara, I. W. W. (2020). Project based learning and academic procrastination of students in learning physics. International Journal of Instruction, 13(1), 489–508. https://doi.org/10.29333/iji.2020.13132a

Santyasa, I. W., Santyadiputra, G. S., & Juniantari, M. (2019). Problem-based learning model versus direct instruction in achieving critical thinking ability viewed from students' social attitude in learning physics. Advances in Social Science, Education and Humanities Research, 335(1), 633–644. https://doi.org/10.2991/icesshum-19.2019.101

Sobral, S. R. (2021). Project based learning with peer assessment in an introductory programming course. International Journal of Information and Education Technology, 11(7), 337–341. https://doi.org/10.18178/ijiet.2021.11.7.1532

Suherman, Prananda, M. R., Proboningrum, D. I., Pratama, E. R., Laksono, P., & Amiruddin. (2020). Improving Higher Order Thinking Skills (HOTS) with Project Based Learning (PjBL) Model Assisted by Geogebra. Journal of Physics: Conference Series, 1467(1), 1–9. https://doi.org/10.1088/1742-6596/1467/1/012027

Sukatiman, S., Akhyar, M., Siswandari, & Roemintoyo. (2020). Enhancing higher-order thinking skills in vocational education through scaffolding-problem based learning. Open Engineering, 10(1), 612–619. https://doi.org/10.1515/eng-2020-0070

Suryaningsih, S., & Ainun Nisa, F. (2021). Kontribusi STEAM Project Based Learning dalam Mengukur Keterampilan Proses Sains dan Berpikir Kreatif Siswa. Jurnal Pendidikan Indonesia, 2(6), 1097–1111. https://doi.org/10.36418/japendi.v2i6.198

Sutrisna, G. B. B., Sujana, I. W., & Ganing, N. N. (2020). Pengaruh Model Project Based

Learning Berlandaskan Tri Hita Karana Terhadap Kompetensi Pengetahuan IPS. Jurnal Adat Dan Budaya Indonesia, 1(2), 84–93. https://doi.org/10.23887/jabi.v2i2.28898

Tang, T., Abuhmaid, A. M., Olaimat, M., Oudat, D. M., Aldhaeebi, M., & Bamanger, E. (2020). Efficiency of flipped classroom with online-based teaching under COVID-19. Interactive Learning Environments, 0(0), 1–12. https://doi.org/10.1080/10494820.2020.1817761

Widiawati, L., Soetarno, ;, & Sudiyanto, J. ; (2018). Higher Order Thinking Skills as Effect of Problem Based Learning in the 21st Century Learning. International Journal of Multicultural and Multireligious Understanding, 5(3), 96–105. http://ijmmu.com

Yeung, S. yin S. (2015). Conception of teaching higher order thinking: perspectives of Chinese teachers in Hong Kong. Curriculum Journal, 26(4), 553–578. https://doi.org/10.1080/09585176.2015.1053818

Yuniarsih, Y., Hapsari, E. K., & Zakaria, M. (2020). Blended Learning Approach Using Flipped Classroom Model on Kaiwa III. Jurnal Kata, 1, 28. https://doi.org/10.22216/kata.v1i0.5064

Zainuddin, Z. (2019). Pengembangan Model Pembelajaran Flipped Classroom dengan Taksonomi Bloom pada Mata Kuliah Sistem Politik Indonesia. Jurnal Dimensi Pendidikan Dan Pembelajaran, 7(2), 109. https://doi.org/10.24269/dpp.v7i2.1809