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The Effect of Inquiry-based Learning (IBL) and Project-based (PjBL) on the Development of the Critical Thinking Disposition (CTD) of Prospective Teachers of Electronic Engineering Education at Universitas Negeri Jakarta, Indonesia

[1]Wisnu Djatmiko, [2]Suyitno Muslim, [3]Suyono
[1][2] Fakultas Teknik – Universitas Negeri Jakarta, [3]Fakultas MIPA – Universitas Negeri Jakarta
[1]wisnu.dj@unj.ac.id,[2]yitno.muslim@yahoo.com, [3]suyono@unj.ac.id

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Abstract:

Learning strategies are considered to have a facilitative effect or hinder the development of students' CTD. The purpose of this study was to determine the effect of IBL and PjBL on students' CTD development. 84-students study five electronic materials which are grouped using simple random sampling for each learning strategy. The pretest-posttest experimental design and paired sample and independent sample t-test were used to validate the effectiveness of each learning strategy. CTD instruments derived from California Critical Thinking Disposition (CCTD) are used to measure students' CTD data obtained at the end of each lesson. The results showed that the CTD of prospective teachers of electronic engineering education increased in the IBL and PjBL groups. In the IBL group (N = 42) the average value of students' CTD increased significantly (alpha = 0.05) from 163.24 (pretest) to 174.81 (posttest) with t-Statistic = 14.53 > t-Critical one-tailed = 1.68 with N-gain = 0.31. In the PjBL group (N = 42) the average value of students' CTD also increased from 162.52 to 168.38 with t-Statistic = 15.52 > t-Critical one-tailed = 1.68 with N-gain = 0.16.

***Keywords:** inquiry-based learning, project-based learning, development of critical thinking disposition, effect of learning strategies.*

I. INTRODUCTION

Traditionally, cognitive competence in critical thinking, analysis, and problem solving has been considered a key indicator for success, but changing economic, technological, and social conditions towards the 21st century have made interpersonal and intrapersonal competencies more important [1]. The Indonesian Ministry of Education and Culture has included 21st Century life skills in the learning process in the 2013 curriculum: (1) Critical Thinking and Problem Solving Skills; (2) Communication Skills; (3) Creativity and Innovation; and (4) Collaboration [2] to create a society that can compete in global challenges. The ability of critical thinking is needed in the process of reasoning, evaluating, problem solving, decision making, and analyzing thinking by humans in their lives [3][4]. Critical thinking has a cognitive dimension (critical thinking skill) and an effective thinking dimension (critical thinking disposition) [5][6]. Cognitive dimensions are skills that can be trained so that they can be improved using student-centered learning strategies [7]-[13].

Because the dimension of effective thinking or critical thinking disposition (CTD) is a combination of attitude and inclination [5], students' CTD scores cannot be significantly changed using the IBL and PjBL strategies [14]-[18]. Meanwhile, some researchers report that CTD scores can increase significantly through IBL and PjBL strategies [19]-[21], so research with the aim of knowing the effect of learning strategies (IBL and PjBL) in developing CTD is needed to answer how students CTD can be developed using the IBL and PjBL strategies?

II. METHODS

A. Study Design

The researcher used a randomized controlled experiment to compare CTD pretest-posttest scores of students after completing learning five Electronics-III course material (buffer circuits, inverting amplifiers, active low-pass filters, active high-pass filters, and active band-pass filters based on IC- LM741) grouped in experiment-class (IBL strategy) and control-class (PjBL strategy) with the research design shown in Table 1.

Table 1. Research Design

Class	initial conditions	Treatment	final condition
experiment	O_1	X_1	O_2
control	O_3	X_2	O_4

O_1: CTD pretest score for experimental clas
O_2: CTD posttest score for experimental class
O_3: CTD pretest score of control class
O_4: CTD posttest score for control class
X_1: Learning using the IBL strategy
X_2: Learning using the PjBL strategy

B. Participants

84 students of the Vocational Education program in Electronic Engineering, Faculty of Engineering, Universitas Negeri Jakarta, aged 23-24 years, participated in the research voluntarily. The 84 students were divided into two groups: (1) 42 students in the experimental class; and (2) 42 students in the control class.

C. Measurements

The CTD instrument has been successfully compiled based on The California Critical Thinking Disposition Inventory (CCTDI) [40] and refers to the CTD theory [3][5][22][23] [39]. The CTD instrument has been validated by two psychometrics experts (Rita Markus Idulfilastri from Universitas Tarumanagara and Zarina Akbar from Universitas Negeri Jakarta) and has been tested on 50 students of the Faculty of Engineering UNJ and has a reliability coefficient of 0.93 (very high). The CTD instrument consists of 50-item Likert-scale statements (with 4 answer options) and has 7 sub-scales: (1) Truth seeking (4-indicator with 6-item statements); (2) Open-mindedness (4-indicator with 5-item statements); (3) Analyticity (5-indicator with 11-item statements); (4) Systematicity (3-indicator 5-item); (5) Self-confidence (4-indicator 7-item); and (6) Inquisitiveness (5-indicator 6-item), and (7) Maturity of judgment (6-indicator 10-item) (see Appendix 1 and 2).

D. Procedure

The study began by dividing 84 students into experiment-class as many as 42 students and class-control 42 students using the Simple-Random Sampling technique. CTD pretest scores for all students were measured using the CTD instrument. Learning materials, student worksheets are designed and created for each material in the experimental-class and control-class. The lesson plan (facilitator and student learning activities) for each material is designed to refer to the learning objectives and the student's initial needs in the experiment-class and control-class. Facilitator observation sheets and student worksheets are created with the aim of ensuring all students in the experiment-class and control-class have completed all the learning steps (IBL or PjBL strategies) [24][25].

All students enter their respective classes to attend learning material 1 to 5. Each material takes 2x120 minutes for a period of 10-days in the laboratory with each class guided by a lecturer as a facilitator. Experiments-class using the guided-IBL strategy compiled with 6-syntax: (1) orientation; (2) determine the problem; (3) searching and obtaining data; (4) determine the hypothesis; (5) testing hypotheses; and (6) make conclusions [26]-[30]. The PjBL strategy implemented in the control-class is structured with 6-syntax: (1) making essential questions; (2) searching and obtaining data; (3) designing the project; (4) arrange steps and time to realize the project; (5) obtain and process data from the project's test results; and (6) conducting project evaluations [31]-[36]. The PjBL strategy implemented in control-class is a type of PjBL that forces students (in groups) to make a project that refers to the learning objectives of each material. At the end of learning the 5th material, CTD posttest scores for all students were measured using the CTD instrument.

E. Data Analysis

CTD pretest and posttest scores of 84 students are research data that will be analyzed using Microsoft Excel with three stages of testing: (1) comparing the average scores of pretest CTD class experimental and control class using the Independent Two sample t-test to get the p-value at a significance level of alpha =

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0.05. If the p-value (1-tailed) > alpha (0.05), the average CTD score of the experimental-class and control-class students is the same; and if the p-value (1-tailed) < alpha (0.05) then the average score of the experimental-class and control-class CTD is different; (2) calculate the N-Gain (Average Normalized gain Score) to interpret the increase or decrease in the average CTD score in each sub-scale in each class using the formula found by Hake [37] and then the average score of pretest and the posttest for each sub-scale of each class was compared using the Paired sample t-test which tested the p-value at an significance level of alpha = 0.05. If the p-value (1-tailed) > 0.05 then the average posttest score <= the average CTD pretest score; and if the p-value (1-tailed) < 0.05 then the posttest average score > CTD pretest mean score); and (3) comparing the mean scores of experimental and control CTD posttest using the Independent Two-sample t-test which tests the p-value at the significance level of alpha = 0.05. If the p-value (1-tailed) > 0.05 then the average score of the experimental class CTD posttest <= the average score of the control class posttest; and if the p-value (1-tailed) < 0.05 then the average score of the experimental-class CTD posttest > the control-class posttest CTD average score.

When you submit your final version, after your paper has been accepted, prepare it in two-column format, including figures and tables.

III. RESULTS

All students (experimental class and control class) have the same level of CTD scores before participating in the learning (see Table 1). The average CTD pretest score of the experimental class was 163.24 ± 12.44 and the control class was 162.52 ± 12.48 and statistically had the same significant value as t-statistic = 0.26 < t-critical (1-tailed) = 1.66 and has a p-value (0.40) > alpha (0.05).

Table 1. Comparison of CTD pretest score of students based on learning strategies

Learning Strategies	n	Mean ± SD	Variant	t-statistic	p-value
IBL	42	163,24 ± 12,44	154,77	0,26	0,40
PjBL	42	162,52 ± 12,48	155,67		

CTD scores of students increased after following the IBL learning strategy with an N-gain value = 0.31 (medium category) (see Table 2). At the end of the study, the average CTD pretest score was 163.24 ± 12.44 and the posttest average score was 174.74 ± 8.77 with a t-statistic value =14.53 > t-critical (1-tailed) = 1.68 and has a p-value (0.00) < alpha (0.05) so that the average posttest scores of all CTD sub-scale experimental classes are higher than the pretest average scores or have significantly increased because of the t-statistics of all sub-scales > t-critical (1-tailed) = 1.68 and p-values < alpha (0.05). "Open-mindedness" and "Maturity of judgment" sub-scales have N-gain values of 0.36 and 0.63 (medium category) higher than other CTD sub-scales.

Table 2. Comparison of N-gain scores of pretest-posttest CTD experimental class

CTD Sub-scales	Mean ± SD		N-gain	t-statistic	p-value
	pretest	posttest			
Truth-seeking	19,05 ± 1,58	19,79 ± 1,54	0,15	3,95	0,00
Open-mindedness	16,79 ± 1,51	17,95 ± 1,34	0,36	5,56	0,00
Analyticity	35,60 ± 3,75	37,45 ± 3,05	0,22	5,16	0,00
Systematicity	16,71 ± 1,63	17,43 ± 1,50	0,22	3,58	0,00
Self-confidence	21,90 ± 2,51	23,31 ± 2,27	0,23	4,18	0,00
Inquisitiveness	20,88 ± 2,54	21,67 ± 2,04	0,25	3,18	0,00
Maturity of judgement	32,31 ± 3,37	37,14 ± 1,47	0,63	10,94	0,00
Score TOTAL	163,24 ± 12,44	174,74 ± 8,77	0,31	14,53	0,00

Table 3. Comparison of N-gain scores of pretest-posttest CTD control class

CTD Sub-scales	Mean ± SD		N-gain	t-statistic	p-value
	pretest	posttest			
Truth-seeking	19,29 ± 1,80	19,19 ± 1,77	-0,02	-0,85	0,20

Open-mindedness	16,17 ± 1,50	16,71 ± 1,57	0,14	3,03	0,00
Analyticity	35,43 ± 3,70	37,93 ± 3,49	0,29	6,50	0,00
Systematicity	16,64 ± 1,83	17,48 ± 1,66	0,25	4,26	0,00
Self-confidence	22,12 ± 2,43	22,33 ± 2,40	0,04	1,94	0,03
Inquisitiveness	20,40 ± 2,15	20,43 ± 2,18	0,01	1,00	0,16
Maturity of judgement	32,48 ± 3,31	34,31 ± 2,76	0,24	5,84	0,00
Score TOTAL	162,52 ± 12,48	168,38 ± 11,91	0,16	15,52	0,00

Table 4. Comparison of CTD posttest student scores based on learning strategies

Learning Strategies	n	Mean ± SD	Variant	t-statistic	p-value
IBL	42	174,74 ± 8,77	76,98	2,79	0,00
PjBL	42	168,38 ± 11,91	141,80		

The PjBL strategy can also improve CTD scores but with an N-gain value = 0.16 (low category) (see Table 3). At the end of the study, the average pretest score of 162.52 ± 12.48 increased significantly to 168.38 ± 11.91 with a t-statistic value = 15.52 > t-critical (1-tailed) = 1.68 and p -value = 0.00 < alpha = 0.05. There are two sub-scales: (1) "Truth-seeking"; and (2) "Inquisitiveness" which statistically did not increase significantly because it has t-statistics < t-critical and has p-value > alpha = 0.05. The remaining CTD sub-scales increased but with a low N-gain category (< 0.03).

The IBL strategy can increase student CTD higher than the PjBL strategy (see Table 4). The average posttest score of the experimental class was 174.74 ± 8.77 higher than the CTD score of the control class at 162.52 ± 12.48 and statistically had significantly different values with the t-statistic value = 2.79 > t -critical (1-tailed) = 1.67 and has a p-value = 0.00 < alpha = 0.05.

IV. DISCUSSION

The IBL strategy has proven to be more effective in developing student CTD than the PjBL strategy. In the IBL strategy, the "Open-mindedness" and "Maturity of judgment" sub-scales can develop better than the "Truth-seeking", "Analyticity", "Systematicity", "Self-confidence", and "Inquisitiveness" sub-scales. Indicators in the "Open-mindedness" and "Maturity of judgment" sub-scales can be formed as a result of the 6-syntax of the IBL strategy that has been done using student worksheets. The sub-scale "Open-mindedness" of students can develop because the IBL strategy requires students to collaborate in groups so that 4-indicators can be formed (let other people voice their opinions, open minded, have an attitude of tolerance, and accept other people's opinions). The sub-scale "Maturity of Judgment" has also developed because the IBL strategy gives students freedom to develop their cognitive abilities to solve problems in the form of critical thinking skills, systematic, logical, and develop intellectual abilities (inductive and deductive processes) as part of mental processes [28] so that students can understand complicated problems, make timely judgments, study an event or phenomenon, make decisions with deep understanding, take into consideration before making a decision, and look at the evidence before making a decision.

In the PjBL strategy, all CTD sub-scales cannot effectively develop student CTD because the type of PjBL strategy used is the type of PjBL that requires students (collaborating in groups) to realize a project that has been given by the facilitator referring to the learning objectives (using steps contained in student worksheets), so students are not given freedom in developing their cognitive abilities. Differences in the effectiveness of students' CTD development using the IBL and PjBL strategies can be corrected by using the guided-PjBL type of strategy designed to give students freedom to develop their cognitive abilities to design and design projects referring to learning goals [38].

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Appendix 1. Blueprint of the CTD instrument

Sub-scale CTD	Indicator	Item number	
		favorable	unfavorable
Truth-seeking	1. Dare to ask	11	1
	2. Speak as is	7	-
	3. Look at the phenomenon objectively	4,9	-
	4. Looking for the right information through investigation	12	-
Open-mindedness	1. Let other people voice their opinions	22	-
	2. Open minded	14	23
	3. Have an attitude of tolerance	-	15
	4. Accept other people's opinions	17	-
Analyticity	1. Anticipating all the consequences of decisions made	32, 38	36
	2. Give reasons accompanied by evidence	30, 33	-
	3. Predict the presence of inhibiting factors	27, 34	-
	4. Show consistent performance	29, 39	-
	5. Analyze situations that could potentially be a problem	31, 37	-
Systematicity	1. Work systematically	42	-
	2. Using reason	52, 53	-
	3. Think thoroughly	40, 47	-
Self-confidence	1. Reflective thinking to solve problem	49, 58	-
	2. Confident about the outcome of his decision positively	64	-
	3. Influence others to solve problems rationally	56	-
	4. Explain what is the basic of the argument it produces	55, 57	54
Inquisitiveness	1. Has the nature of intellectual intolerance	61	-

	2.	Have the will to study	66	-
	3.	Have a desire to always get knowledge	67	70
	4.	Have the desire to be able to explain a phenomenon	68	-
	5.	Looking for information from many sources	65	-
Maturity of judgement	1.	Understand complicated problems	72, 75	-
	2.	Make timely judgments	74, 84	-
	3.	Study an event or phenomenon	77	-
	4.	Make decisions with deep understanding	78	-
	5.	Take into consideration before making a decision	79, 80	-
	6.	Look at the evidence before making a decision	81, 76	-
		TOTAL	44	6

APPENDIX 2. CTD instrument

No	Statement	Option			
		SA	**A**	**D**	**SD**
1.	I was afraid to ask when following the discussion.	SA	A	D	SD
4.	Only objective information can be processed.	SA	A	D	SD
7.	I am not ashamed to admit that I do not know.	SA	A	D	SD
9.	Objectivity is very necessary in getting information.	SA	A	D	SD
11.	Asking questions in discussions is normal.	SA	A	D	SD
12.	An argument can be accepted if it results from a scientific inquiry process.	SA	A	D	SD
14.	Every opinion must be heard and observed.	SA	A	D	SD
15.	The argument of the group leader **must b**e accepted by all members of the discussion.	SA	A	D	SD
17.	I enjoy working in heterogeneous groups.	SA	A	D	SD
22.	I support friends to voice their opinions.	SA	A	D	SD
23.	The amount of input or opinion makes me feel disappointed.	SA	A	D	SD
27.	I simulated a plan before implementing it.	SA	A	D	SD
29.	I always prepare scientific data related to the topic of discussion.	SA	A	D	SD
30.	Each argument must be supported by relevant evidence.	SA	A	D	SD
31.	I look at every component of the system that has the potential to cause problems	SA	A	D	SD
32.	The success of a plan is obtained through careful planning.	SA	A	D	SD
33.	I make sure to evaluate all the evidence or data before concluding.	SA	A	D	SD
34.	I always predict that there are inhibiting factors that can arise when implementing an idea.	SA	A	D	SD
36.	No need to make a backup plan.	SA	A	D	SD
37.	I always make sure all sub-systems can work before being assembled into a complete system.	SA	A	D	SD
38.	I prepare everything to anticipate the worst.	SA	A	D	SD
39.	I always remind discussion participants when the direction of the conversation is not relevant to the topic of discussion.	SA	A	D	SD
40.	The initial step to improve a system is to study the system as a whole.	SA	A	D	SD
42.	Need to design a work plan that is systematic.	SA	A	D	SD
47.	Need to think thoroughly before making conclusions.	SA	A	D	SD
49.	I can find ideas to solve problems in society	SA	A	D	SD
52.	Thinking activities must always be done in the process of getting a solution.	SA	A	D	SD
53.	Minds are needed to solve problems.	SA	A	D	SD
54.	There is no need for argumentation to decide conclusions.	SA	A	D	SD
55.	I can decide the matter fairly.	SA	A	D	SD
56.	I was trusted to find a solution to a problem	SA	A	D	SD
57.	I am responsible for the risks of the steps I choose.	SA	A	D	SD
58.	I can understand the problems that occur in a group	SA	A	D	SD
61.	Every information needs to be verified.	SA	A	D	SD
64.	I enjoy learning from various sources of information.	SA	A	D	SD
65.	A theory can be learned by asking more than one resource person.	SA	A	D	SD
66.	Learning something new is my pleasure.	SA	A	D	SD
67.	I have a high motivation to always learn something new.	SA	A	D	SD
68.	I like to help my friends learn something	SA	A	D	SD
70.	I feel enough with the knowledge that I have mastered.	SA	A	D	SD
72.	Finding variables that trigger complex problems is an activity that must be carried out	SA	A	D	SD
74.	A problem that arises must be able to find a solution quickly and precisely.	SA	A	D	SD
75.	I can understand a complicated problem.	SA	A	D	SD
76.	Decisions are obtained using relevant evidence and obtained from scientific methods.	SA	A	D	SD

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77.	It needs to be examined why a phenomenon can occur.	SA	A	D	SD
78.	A problem can be solved by understanding the root of the problem deeply.	SA	A	D	SD
79.	Every decision can be made by considering many inputs.	SA	A	D	SD
80.	Many things must be considered in deciding a plan	SA	A	D	SD
81.	Every evidence obtained must be tested for truth.	SA	A	D	SD
84.	It is important to make appropriate alternative solutions.	SA	A	D	SD

SA - Strongly Agree
A – Agree
D – Disagree
SD – Strongly Disagree