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Development of critical and creative thinking skills to increase competence of PLC programming for electrical engineering education students

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Abstract. PLC learning emphasizes on teaching and learning activities as well as developing the concepts and skills of the students process with various teaching methods that are in accordance with the study materials being taught. PLC learning demands an active role for students, because PLC is a scientific process based on logical thinking based on supporting facts. The low ability of students thinking is caused by PLC learning so far only tends to hone aspects of remembering and understanding. Basically students have critical thinking skills in learning such as questioning skills, hypothesis, classification, observation and interpretation. Problem-based learning model (PBL) is a learning model designed on problem solving process that faced scientifically so that students get important knowledge. Thus expected students are adept at solving problems, have their own learning models and have the skills to participate in the team. Teacher's role as a trainer in problem-based learning is asking about thinking, monitoring learning, probbing (challenging students to think), keeping students engaged, organizing group dynamics, keeping the process going. This critical and creative thinking design aims to make students able to think critically and able to consider everything and be able to act on the decisions that have been considered and creative thinking that aims to learners are able to create ideas, or ideas and able to express the idea to solve a problem.

1. Introduction

Programmable Logic Controller (PLC) is a compulsory subject for the undergraduate students of Electrical Engineering Education. One of the goals of Electrical Engineering Education Unesa S1 is to produce competent teachers in electrical engineering. Among them as subject teachers on the competence of instrumentation and process automation skills on the spectrum of SMK 2016 and in accordance with the circular of the Director of Vocational Education on the Implementation of Vocational High School Curriculum Number 4540 / D5.3 / TU / 2017, dated June 22, 2017[1].

PLC learning emphasizes on teaching and learning activities as well as developing the concepts and skills of the students process with various teaching methods that are in accordance with the study materials being taught. PLC learning demands an active role for students, because PLC is a scientific process based on logical thinking based on supporting facts. The low ability of students thinking is caused by PLC learning so far only tends to hone aspects of remembering and understanding. Basically students have critical thinking skills in learning such as questioning skills, hypothesis, classification, observation and interpretation. However, these skills sometimes do not develop well, then there is an alternative method that is able to develop students' critical thinking skills in PLC

learning. One of them is through practicum or demonstration activities, because practicum or demonstration activities help students to understand an event, see an event more detailed than before and then remember the incident.

Wechsler (2017) says that creative or critical thinking is needed to develop problem-solving skills[2]. The results of his research say that there is differentiation and independence of creativity and critical thinking in cognitive performance, although both build small but complementary roles in different creative problem solving phases. As observed, the flexibility, ie the ability to consider the same information from different angles (Torrance, 1990), can improve critical thinking skills[3]. The ability of flexibility and critical thinking is considered a key ingredient to promote examination and resolution of problems in many professions (Hong & Choi, 2015)[4].

On the other hand, the creative process supports inductive reasoning, which is the ability to understand relationships. The importance of making connections through analogies and metaphors is an important characteristic of creative thinking (Wechsler, 2006) but intellectual critical functions can also contribute to this process[5]. With this in mind, creativity prefers inductive reasoning, especially in the identification of order and principle or conclusions about relationships, which do not occur in relation to logical reasoning, focusing on finding the best unique answer.

Dwyer (2016) says that critical thinking (CT) is a metacognitive process, consisting of a number of subclasses and dispositions which, when used appropriately, increase the chances of generating logical conclusions to the argument or solution to a problem[6]. There is potential to enhance the development of critical thinking by assessing effective writing with CACTiM tools (reflection) to provide formative and summative feedback to students and inform instructional strategies disclosed by Carter (2016)[7]. From Okan research (2012) stated that students' critical thinking skills vary between types of schools[8]. When students encounter situations or problems they are unable to cope with, to get help, they must communicate with their classroom teachers in primary school and with their counselors in high school. Thus, teachers should be prepared to perform services to help students optimally and approach the problem logically.

From these reviews, then made the problem formulation is how to develop the ability of critical and creative thinking? And how to improve the competence of PLC programming students Electrical Engineering Education?

2. Library Review

2.1. Critical Thinking

Thinking is a mental activity that a person experiences when they are faced with a problem or situation to be solved. Suryabrata (1990) argues that thinking is a dynamic process that can be described by process or path. The process of thinking that essentially consists of 3 steps, namely the formation of understanding, formation of opinions, and conclusions[9]. This view indicates that if a person is faced with a situation, then in thinking, the person will establish the relationship between the parts of the information recorded as the notions. Then the person forms opinions that are in accordance with his knowledge. After that, he will make the conclusions that are used to discuss or find a solution of the situation.

Ruggiero (1998) defines thinking as a mental activity to help formulate or solve a problem, make a decision, or fulfill the curiosity desire. This suggests that when a person formulates a problem, solves a problem, or wants to understand something, he performs an activity of thinking.

Thinking as a person's mental ability can be divided into several types, including logical, analytical, systematic, critical, and creative thinking. Logical thinking can be interpreted as a student's thinking ability to draw legitimate conclusions according to the rules of logic and can prove that conclusions are valid in accordance with previously known knowledge. Analytical thinking is the thinking ability of students to describe, itemize, and analyze information used to understand a knowledge by using logical reason and thought, not based on feelings or guesswork. Systematic thinking is the ability to think students to do or complete a task in accordance with the sequence, steps, steps, or planning the

right, effective, and efficient. The three types of thinking are interrelated. Someone to be said to think systematically, then he needs to think analytically to understand the information used. Then, to be able to think analytically necessary logical thinking ability in drawing conclusions to a situation.

Critical thinking and creative thinking is the embodiment of higher-order thinking. This is because the ability to think is the highest cognitive competence that students need to master in the classroom. Critical thinking can be viewed as a student's thinking ability to compare two or more information, eg information received from outside with information held. If there are differences or similarities, then he will ask questions or comments with the aim to get an explanation. Critical thinking is often associated with creative thinking.

Some of the thinking skills associated with critical thinking are comparing, differentiating, estimating, drawing conclusions, influencing, generalizing, specializing, classifying, grouping, sorting, predicting, validating, proving, linking, analyzing, evaluating and pattern-making. A student is said to be able to think critically if it has the ability to: 1) choose important words and phrases in a statement and will be carefully defined; 2) requires confidence to support a conclusion when he is forced to accept it; 3) (5) evaluating these assumptions, accepting only a few and rejecting others, 6) evaluating opinions, accepting or rejecting conclusions and (7) evaluating the assumptions, accepting or rejecting the conclusions; and 7) continually re-examining assumptions that have been made and believed previously.

Critical thinking processes include: 1) recognizing situations, 2) considering opinions according to evidence, data, or assumptions, 3) providing arguments beyond proof, 4) reporting and supporting conclusions / decisions / solutions, and 5) applying conclusions / decisions / solutions . One approach that can be used to increase students' sense of critical thinking is by creating a classroom atmosphere where students feel comfortable questioning something, challenging, suspending judgments, and demanding reason and justification because they are dealing with real-world contents and math. Ask questions that stimulate students to monitor, evaluate, and act on their own thinking. For example, Invite students to work in groups to (a) Discuss the situation below, (b) Brainstorming ideas to solve it. (c) Find solutions that all received, or this minority report, and (d) Discuss their thinking to arrive at a decision.

2.2. Creative Thinking

Creative thinking or creativity is often exchanged for its meaning. Weisberg (2006) defines creative thinking as referring to processes to produce a creative product that is a new work (innovative) derived from an activity / activity that is directed to the goal. Another sentence is said to think creatively involves intensive production that meets novelty, so that one can be said to be creative by producing something already known before. If you produce something new to you, but it has been generated by others, then you can still be said to be creative.

In looking at the link between creative thinking and critical thinking there are two views. The first view of creative thinking is intuitive in contrast to critical thinking based on logic, and secondly looking at creative thinking is a combination of analytical and intuitive thinking. Intuitive thinking means thinking of getting something by instinct or feeling suddenly without any general facts. The first view tends to be influenced by views of dichotomies of the right and left brain which have different functions, while the second view sees the two hemispheres working synergistically together that are not separated.

Creative thinking is a mental activity that considers authenticity and insight. Thinking critically and creatively allows students to study the problem systematically, bringing together many challenges in an organized way, formulating innovative questions and designing / designing original solutions. Creative thinking as opposed to destructive thinking involves searching for opportunities to change things for the better. Creative thinking does not explicitly organize processes, such as critical thinking. Creative thinking is a habit of sharp thinking with intuition, moving imagination, revealing new possibilities, unveiling amazing ideas and inspiring unexpected ideas. This understanding distinguishes firmly from creative thinking and critical thinking.

De Bono (in Barak and Doppelt, 2000) distinguishes between two types of thinking, ie lateral thinking and vertical thinking. Lateral thinking refers to the discovery of new clues in the search for ideas, while thinking vertically in the face of the development of ideas and examination of an objective criterion. Vertical thinking is selective and sequential that moves only when there is a clue in motion. Lateral thinking is a generative that can jump and move in order to build a new clue. Lateral thinking does not have to be true at every step and does not use category categorization, classification or fixed labels. Vertical thinking selects a very promising approach to a problem during lateral thinking building many alternative approaches. Creative thinking is a synthesis of complementary lateral and vertical thinking. This sense states that in creative thinking involves critical thinking (logical and analytical) as well as intuitive, as in the second view in terms of creative thinking.

2.3. Programmable Logic Controller

Programmable Logic Controller (PLC) is a computer specially designed for use on industrial machines. This computer has been designed for use in industrial environments, equipped with special input / output and a programming language for control.

2.3.1. Hardware

PLC is a type of control system that has input device, controller and output device. The equipment connected to the PLC which sends a signal to the PLC is called the input divice. While the controller is to perform the calculation, decision-making, control of the input to be issued in the output. How the PLC works can be explained through the block diagram in Figure 1 below. From Figure 1 shows that the PLC construction consists of CPU, input device, output device, supporting equipment, and power supply.

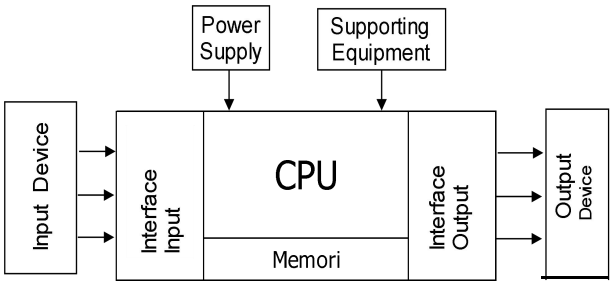

Figure 1. PLC block diagram

2.3.2. Basic Instruction

The basic instructions that exist in programming using PLC are LD (Load), AND, OR, OUT, AND NOT, OR NOT, TIMER (TIM), COUNTER (CNT).

2.3.3. Ladder Diagram and Mnemonic Code

To make it easy to write and insert program on PLC then needed some basic stage. Ladder diagram of a program is made first to facilitate the preparation of mnemonic code. The program form mnemonic code can be directly inserted into the CPU via a PC. The ladder diagram consists of a line extending downward from the left side with its branches towards the right. The line extending down on the left side is called the busbar. While the branches are called the instruction line. Along the lines of instruction are placed conditions leading another instruction line on the next right side. The logic combination of these conditions determines when and how the instructions on the right side are executed.

2.3.4. Software

There are five ways to program PLC: (1) Programming Console (PC), (2) Prompt Writer. (3) Sysmac Support Software + Personal Computer. (4) Factory Intelegent Terminal (FIT). (5) Graphic Programming Console.

3. Discussion

Science is a system of thinking about the empirical world. Therefore learning needs to develop rational thinking skills about the empirical world. From the taxonomic side of thinking, hence-learning means educating thinking at a certain cognitive level. With Bloom's taxonomy (2002), for example, critical and creative thinking lies at the level of analysis-synthesis-evaluation-creation, not at the lower levels of remembering, understanding, and applying[10]. When using the Merrillian taxonomy (1983), the thought lies at the level of finding, not at the lower level of remembering and using. In PLC learning where required to be able to do programming with the help of software through personal computer and or with programmable console that requires thinking not only remember it but must use logic through the knowledge of logic circuit[11]. Competencies to be met in PLC learning are hardware, basic instructions (LOAD, AND, OR, OUT, AND NOT, OR NOT, TIMER, COUNTER), ladder diagrams, mnemonic code, and software. To improve the PLC programming competence, it is necessary to improve the learning process through the application of variation of learning model and the use of appropriate learning media and cover affective, cognitive and psychomotor spheres. The ability to think critically and creatively to improve the competence of PLC programming is used problem-based learning model. Problem-Based Learning Model (PBL) is a learning model designed on problem solving process that is faced scientifically so that students get important knowledge. Thus expected students are adept at solving problems, have their own learning models and have the skills to participate in the team. Teacher's role as a trainer in problem-based learning is asking about thinking, monitoring learning, probbing (challenging students to think), keeping students engaged, organizing group dynamics, keeping the process going. Student roles as problem solver in problem based learning are active participants, directly involved in learning, build learning.

Generally problem-oriented learning can improve the ability of critical thinking and creative thinking. Such learning is like problem-solving, problem-solving, or problem-based learning. To judge creative thinking actually depends on the criteria or indicator of creative thinking formulated by the researcher or its users. Plucker, Beghetto, & Dow in Plucker and Makel (2010) recommend that "all examinations of creativity clearly define the authors' conception of creativity as used in that work"[12]. Guilford, Torrance, Wallach and Kogan, Getzels and Jackson use divergent thinking criteria to judge a person's creative thinking. While using varying content and instructions, diverging thinking equals multiple responses and is assessed using fluency criteria, flexibility, authenticity, and elaboration of ideas. According Dimyati (1996) one of the elements of science is the items, namely the science of tangible rational thinking[13]. The realization of rational thinking appears in the use of words, sentences, aleneas, problem solving formulas, or symbols. Prerequisites for realizing these items are the individual's ability to read, write, think and observe. In other words the requirement is the ability to think critically and creatively. The learning process of PLC with PBL model applied to the student of Electrical Engineering Education program class of 2015 cultivates creativity and critical thinking when solving the given problem shown in Figure 2.

Figure 2. Students are solving problems using a PLC training kit at the Unesa Electrical Engineering Control Laboratory.

With PLC media training kits and various problems given, it shows the learning outcomes with an average score of 73.83 with a scale of 100. Learning outcomes are shown in Table 1 below. The lowest score is 55.5 and the highest score is 85. Students whose value is above average is 21 and below the average is 15 out of a total of 36 students.

Table 1. Results of PLC courses in Electrical Engineering.

No	Student Number	Learning outcomes	No	Student Number	Learning outcomes
1	15050514002	72.5	18	15050514041	80
2	15050514006	80	19	15050514042	77.5
3	15050514007	77.5	20	15050514043	80
4	15050514008	77.5	21	15050514045	67.5
5	15050514009	60	22	15050514050	77.5
6	15050514011	75	23	15050514052	77.5
7	15050514013	55.5	24	15050514053	72.5
8	15050514015	77.5	25	15050514054	82.5
9	15050514022	70	26	15050514056	75
10	15050514023	77.5	27	15050514057	77.5
11	15050514028	70	28	15050514060	72.5
12	15050514030	75	29	15050514063	67.5
13	15050514031	80	30	15050514066	67.5
14	15050514034	77.5	31	15050514067	85
15	15050514036	77.5	32	15050514070	72.5
16	15050514038	77.5	33	15050514072	75
17	15050514039	72.5	34	15050514073	72.5
			35	15050514074	67.5
			36	15050514078	57.5

4. Conclusion

Critical and creative thinking are two inseparable sides and educational goals everywhere. Both are necessary skills in everyday life. To be applied depends on the ability and confidence of the lecturer to apply in the form lab in the laboratory. With the help of training kits, students will be more optimal in understanding the material being taught. Does not depend on difficult or difficult material. Simple problems can lead students to achieve that goal. The learning culture in the classroom that needs to be changed by giving students flexibility to argue and argue can create a critical attitude. By giving the opportunity to give other ideas or other strategies though not the same from the habit can create creative students. Then appreciate every wrong or true task result can make learning fun.

To improve the competence of PLC programming students Electrical Engineering Education, teachers apply problem-based learning model (Problem Based Learning). One of the learning design in order to make the atmosphere of learning activities fun and produce an effective and productive learning process that is critical and creative thinking. This critical and creative thinking design aims to make students able to think critically and able to consider everything and be able to act on the decisions that have been considered and creative thinking that aims to learners are able to create ideas, or ideas and able to express the idea to solve a problem.

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