Creating kit and plc application with industrial applications for practice learning of plc technology in electronics

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Abstract. The purpose of this research was to develop PLC technology lessons so that they would be more easily practiced and so students could more easily master PLC Technology Studies, so that after graduation it is not difficult to find work, especially in the PLC field. The subjects of this research were students who studied PLC Technology were taken as samples and then given a pretest and their grades, they were given training that was taken from the module, after that, they were given appropriate module lessons from the introduction of the Kit, PLC and HMI themselves, inputs and outputs, their functions and the application, then ladder diagram and finally the wiring and the application. Methods for this research is research and development with steps of 1) Problem Analysis, 2) Data collection, 3) Product Design, 4) Design Validation, 5) Design Revision, 6) Product Testing, and 7) Analysis and Reporting. The feasibility of the PLC trainer and job sheet that had been made were obtained from the validation results by 5 validators and students responses to determine students responses to the media. The results of the study are in the form of KIT and PLC applications for industry, video tutorials, and modules and also outputs that were accredited and national journals. From the result, it can be seen that student made progress from grade from mean 53 from pretest to mean 86 from the post-test.

1. Introduction

Nusa Putra University was established in Sukabumi Regency, which is the only major campus that has Electronics Diplomas and bachelor of Electronics Study Programs. Automation is one of the most significant things nowadays because, with that, everything changes from manual to automatic from human power to machine. In the area where Nusa Putra University is located there are many industries that use PLCs to control their machines. Be it a beverage factory, an ice cream factory, and many more such as IndoLacto, Krating Daeng, Aqua, Indo Eskrim, Pocari Sweat, UC 1000, Mercy, Mayora, Yakult and many more and they all use PLCs, both ordinary brands such as Siemens, Omron, Mitsubishi or, brands that can handle large inputs and outputs such as Allen Bradley and others. The need for PLC skills is inevitable, In Nusa Putra University is taught PLC technology lessons because based on the needs of the industry above, because they always ask the question whether the alumni can PLC both hardware and application software, but the facilities are still lacking, especially for applications and outputs and cards for outgoing connections, whereas now there is a lot of outside communication or monitoring, as well as HMI and SCADA.

At present, we do not have a proper PLC KIT. There is also a PLC Omron Compact CPM 1 E with push-button selector switch input and lamp as output. So that if we have practiced it is difficult and
takes a long time so it is not practical whereas if only simulation alone is not enough, sensors that we have especially not much output. Therefore, we made this for the proposal of novice lecturers, so if there is this tool, the learning process will be smoother and more helpful

2. Reference

Programmable logic controllers (PLCs) are a specialized type of system used to control machines and processes. They have been introduced in the early 1970s to replace the existing relay control logic that became obsolete and expensive for implementing systems at that time. On the other hand, PLCs have offered flexibility, higher reliability, better communication possibilities, faster response time, and easier troubleshooting. So far, PLCs have been mainly of interest for industrial control engineers that introduced, developed, and standardized their own design methods and programming languages [1].

Research so far presented expensive, less portable, less interactive PLC trainers in the form of prebuilt hardwired kits and simulators. The expensive and less portable PLC trainers are however not affordable to the masses of PLC users. Prebuilt hardwired kits, in particular, do not provide a more interactive system for the novice PLC user who needs it most. This is because they are pre-fabricated in a casing making it inaccessible to observe the interfacing between the controller and the I/O modules. These reasons contribute to the rising gap between the industry endowed graduates and the industries [2].

Portable concept Portable concept can be limited by taking the standard size and weight of the kit. To be brought by car transport or shipping in general, no special standards are applied. However, kits containing electrical and electronic components must be carried with special care and caution so as not to damage the working function of the apparatus [3].

Basic Theory on Human Machine Interface A Human Machine Interface (HMI) is a device for providing the means of controlling, monitoring, managing and visualizing device processes. With controls and readouts graphically displayed on the screen, the operator can use either external buttons or the touch screen to control the machinery HMI can also be system and an operator. The interaction is presented by a screen with dynamic icons, figures, and text. An operator can monitor the production and control it to a certain level by the help of an HMI panel or PC [4].

The aim of the new proposed training system is to support the sub-disciplines of software engineering, computer programming and panel wiring. Meanwhile, the basic system must support digital I/O. It should be expandable to support analogue handling and non proprietary networking. The system should have components from multiple users – it should not be seen as favouring a particular manufacturer. The detailed objectives being that it must: 1. Be safe; 2. Be portable; 3. Fit comfortably on a desk; 4. Incorporate an industrial standard PLC ; 5. Interfaces to a PC; 6. Support Ladder Logic and at least two of the other IEC 6-1131 defined Languages; 7. Interface with common industrial electrical components; 8. Be low cost as continuing transportation will likely result in the need for frequent component replacement ; 9. Be expandable to facilitate analogue handling; 10. Be expandable to facilitate Ethernet networking [5].

Meredith D. Gall, Joyce P. Gall, dan Walter R. Borg (2003: 569) divined “Educational R & D is an industry-based development model in which the findings of research are used to design new products and procedures, which then are systematically field-tested, evaluated, and refined until they meet specified criteria of effectiveness, quality, or similar standards”[6].

3. Methods

The Methods for this research is R & D Methode ( Research and Development ) Methode. Place and time of this research is in Nusa Putra University which located on B Building at B3G room from August until October 2019 with the student who learns automation industry.
The process begins with observation looking for a problem, after meeting a problem namely the lack of PLC KIT facilities, then the data were collected in the kit trainer as desired, what components were needed after searching - it was found that the KIT PLC was simple but it could be used to learn basic with HMI (human machine interface), which is the best learning tool, then product design was tried, that is by simple means, then validated, then print stickers at the printing press, after that, a module was made for both PLC and HMI, then the device was tested in the lab. First 85.4, the connection was not right, then it was corrected, and then we tried everything until everything was okay, and was all in accordance with the module until it was finally considered feasible. And then, it was tried to the respondents who were given training and modules. After several trials with PLC and HMI and the respondents were considered to have mastered the skill, it was considered complete and could help respondents in learning PLC.

PLC AND HMI KIT dimension is:
53X16X30cm(length, height,.wide)
WEIGHT BEFORE:4kg
WEIGHT AFTER PLC HMI KIT :7 kg

4. Result and Discussion
Result of this research:
1. Trainer KIT PLC and HMI
2. Modul
3. Video from the student
4. Journal in accredited national/international journal
Plc cpm1A was used because it was simple and basic for beginners who only had 10 I/O. HMI NB7W was used because the brand was good and the same brand-suitable with PLC CPM1A. Previously, we used weintek but then we changed cause programming and knowing about HMI was good for the student. We made this PLC KIT with aluminum case because it is strong and practical and we could take it to the class or make practical basic in another place for the public. If we want to make another advance practice we can go to the lab and use another PLC KIT like CJM KIT (without H85.4MI) or another CPM2A kit with HMI weintek and the application in advance is automatic racking system 85.4, water system for the plant, etc.

KIT Modul consists of:
1. Trainer Kit specification and part
2. Ladder Diagram basic and command
3. CX Programmer
4. NB designer
5. Wiring
6. Application basic and industry

Table 1. Condition part of the PLC and Kit HMI.

| No | Tested Component | How to test | Result |
|----|------------------|-------------|--------|
| 1  | PLC Omron CMP1A  | Power, i/o and operation | Power can turn on and off, input status good, program can connect to PLC with cable connector RS232 to USB |
| 2  | MCB 2 A          | Can turn on and off | MCB working good |
| 3  | Power Supply 24 V | Giving 24 V power supply | Can give the 24V to the PLC and HMI |
| 4  | HMI Omron NB7W  | Touch screen, power, and operation | All doing fine and touch screen is doing good programming the HMI by NB designer |
| 5  | Input and Output | Wiring and program | Input and output in this KIT working good trying by wiring them and by program in CX programmer |
| 6  | Relay 24 V       | Connect with wiring | Relay working good and can connect |
| 7  | Power in         | Connect to the power in to power on the KIT PLC | Power in working good |
| 8  | Voltmeter DC     | Show the Voltage in 24 V DC | Can show the voltage in 24 VDC |

From the table shown above, all parts of the PLC trainer KIT worked well. PLC input and output were good, HMI also had good touch screen, voltmeter for 24 v also worked well even when sometimes it showed 24,1V. The cable connection for PLC to PC worked well; all relay all worked well; push-button was good. The pilot lamp was at first good, but then the connection inside needed repair, and then it became good again, and also banana jack and connector need some repair and the student repaired the jumper and connection and then all became fine.
When we tried HMI Omron Nb7W, we used another PLC CPM2A which cause input and output port from the kit insufficient. From the experiment, it showed that all the program PLC and HMI worked well. Because the heater power was only 15 watts then to make the water 35°C it need 30 minutes tp heat. If the heater had higher power, it would heat the water faster because in industry they usually use 100°C temperature for heating the water beverage.

![Figure 5. Testing HMI with PID Application process layout.](image)

![Figure 6. Manual Process.](image)

Here we also made the application for mixing and heating the beverages inspired by the beverage industry in Cicurug, Sukabumi.

The process of the system is as follows. The first pump takes water from the water storage, and then it fills the tank raw water, until the tank for raw water is full. After that pump no. 2 is turned on to supply water from tank raw water to the water tank storage. Then, the water is processed with heater. The motor agitator moves the agitator inside the tank. And then pump is turned on and supply water to the filling water. In this process we use PLC Omron CPM2A because the kit does not have enough input and output, but then we still use the HMI and power supply 24v from the PLC and HMI kit. This process is adapted from the industry, although the adaptation was not a 100% similar due to limited component.

| No | Part of component | How to test | Result |
|----|-------------------|-------------|--------|
| 1  | PLC CPM2A 30 CDR | Power, i/o and operation | Power can turn on and off, input status good, program can connect to PLC with cable connector RS232 to USB |
| 2  | Sensor temperature Azbil SDC 36 | Show the current temperature and set point | Can show the current temperature and also set point temperature |
| 3  | Motor 1, Motor 2, Motor 3 as pump, motor agitator to move the agitator | Pump water from water source, motor agitator run well | All pumps can run well, motor agitator run well |
| 4  | Heater as water heater | Warm the water to a certain temperature | Heater can work well |
| 5  | Limit switch 1, 2, 3 | Detect to a certain depth of water | Can detect the water |
6. Pilot lamp  
   Show the status by turn on and off  
   Can work well

7. Selector switch  
   rotate in the specified direction and light  
   Can work well

8. Power supply  12 V  
   Give the 12 v power  
   Can work well

4.1. Step of How the student study in this research

1. Students study without the trainer, just theory
2. Students have the pretest
3. Students learn the module PLC and kit
4. Students go to Rumah PLC and learn from the expert
5. Students try to learn about PLC kit and HMI
6. Students learn from the practician from the factory in the beverages
7. Students learn about kit and wiring
8. Students learn about command in the ladder programming
9. Students practice from modul and trainer also application
10. After 2-month practice students get used to trainer KIT PLC an HMI.
11. Students have another test after treatment

| NO | PRETEST | POST TEST |
|----|---------|-----------|
| 1  | 45      | 95        |
| 2  | 52      | 76        |
| 3  | 49      | 99        |
| 4  | 56      | 78        |
| 5  | 60      | 85        |
| 6  | 54      | 78        |
| 7  | 60      | 79        |
| 8  | 45      | 88        |
| 9  | 53      | 89        |
| average | 52,66 | 85,55 |

The average value of after treatment was 85.55, with the smallest pre-test value was 45, and the largest value was 60. This was because they could not answer the questions related to ladder and wiring. After they practiced using the tools, assembling, and fixing the tools, they were given another test. The average score was 86, the highest score of 99 was 76. Because their ability was much improved, they were happy with PLC lessons, and almost every day they played with the PLC, making PLC videos. Even though they were still basic, every day their knowledge of PLCs and wiring increased. It took a lot of practice for the student to master this PLC and HMI Trainer. They study almost every day. They also asked practicioners. They learned how to make videos. They had a lot of discussions together.

Validation Results obtained from 5 validators were 3 lecturers from Nusa Putra University and 2 practitioners from industries around Sukabumi. From the results of validation by lecturers and practitioners, striking results were obtained. From PLC and HMI: the value of HMI for development was above 90, while the PLC development for CPM1A type was indeed lacking due to lackings in the
basic and input-output. So if you want to develop it, the PLC must be replaced. The HMI was good enough for development because it had a 7-inch size and was also supportive for many developments.

Table 4. Validasi Validator.

| NO | Display of the Hmi PLC kit | Suitability of the media with the curriculum | HMI Development | PLC development | Ease of understanding |
|----|-----------------------------|---------------------------------------------|-----------------|-----------------|---------------------|
| Val 1 | 89                          | 86                                          | 90              | 69              | 90                  |
| Val 2 | 88                          | 88                                          | 98              | 75              | 89                  |
| Val 3 | 86                          | 90                                          | 95              | 78              | 98                  |
| Val 4 | 79                          | 89                                          | 98              | 72              | 89                  |
| Val 5 | 85                          | 92                                          | 87              | 76              | 89                  |
| average | 85.4                       | 89                                          | 93.6            | 74              | 91                  |

Table 5. Validation Result From the Student Who Learns PLC

| NO | Display of the Hmi PLC kit | Suitability of the media with the curriculum | HMI future Development | PLC future development | Ease of understanding |
|----|-----------------------------|---------------------------------------------|------------------------|------------------------|---------------------|
| 1  | 90                          | 90                                          | 90                     | 78                     | 90                  |
| 2  | 96                          | 95                                          | 92                     | 79                     | 90                  |
| 3  | 90                          | 90                                          | 95                     | 78                     | 98                  |
| 4  | 88                          | 88                                          | 98                     | 72                     | 89                  |
| 5  | 90                          | 90                                          | 87                     | 76                     | 89                  |
| 6  | 90                          | 90                                          | 90                     | 80                     | 97                  |
| 7  | 89                          | 89                                          | 99                     | 78                     | 90                  |
| 8  | 93                          | 88                                          | 98                     | 80                     | 97                  |
| 9  | 91                          | 87                                          | 90                     | 78                     | 93                  |
| Average | 90,78                      | 89,67                                       | 93,2                  | 77,67                 | 92,5                |

From validation result of 9 students who learn PLC from the kit PLC HMI, it was revealed that the student like the display of the HMI. It can be seen from the average score, where the average suitability score was 89.67. It means the HMI was good. The HMi future development score is very good 93.2, PLC future development show low score 77,67 it means to have to upgrade the PLC later time so don't have to change plc in application use lot of input/output, ease of understanding have high score 92,5 it means that kit plc is easy to understand and they enjoy using it.
5. Conclusions and Suggestions

5.1. Conclusion

- All the parts of PLC KIT worked well. At first, it did not work well due to several causes, like problems with cable connection. But then the students repaired and connected the connection again.
- The students had significant better grades after using PLC kit, treatment, and exercise. Before treatment and practice, the average was 56, after using PLC trainer KIT and treatment the average was 86. So it was worthed.
- We made KIT plc portable because it would be easy to take everywhere and cheaper than to buy in an online shop.
- The kit was only for basic using PLC PCM1 A focusing for command and also HMI lesson, but later, it had to be upgraded for better development.
- If we want to use many input-output, we have to use another PLC, while still using power supply and HMI.
- HMI is quite good for development. The students like the PLC kit because it is easy to learn with module and HMI and also application, and they can also make a creation with it.
- To get a better score, the student has to take many steps and processes, using trainer and modul, and practice ladder and wiring, few times, so the kit PLC HMI. In this research, it is good for education for learning PLC.

5.2. Suggestion

- More input and output for PLC for advance application
- Make another PLC portable kit with advance specification
- Future works can consider obtaining more samples of input and output devices to be interfaced with the trainer. Considering the Supervisory Control and Data Acquisition (SCADA), applications can be considered in future research as well.

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