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DEVELOPMENT OF PLC AND MONITORING SYSTEM TRAINER KIT FOR PROJECT-BASED PRACTICE LEARNING, STUDENT CENTERED LEARNING, AND SCAFFOLDING IN VOCATIONAL HIGH SCHOOLS

Sukir

Yogyakarta State University, Indonesia
E-mail: sukir@uny.ac.id

Abstract

This study was aimed developing PLC and monitoring system trainer kits for project-based learning, student centered learning and scaffolding in vocational high schools, especially in Electrical Power Installation Engineering Expertise Program, that has a good level of feasibility.

The type of research used in this study is research and development, which has several stages: need assesment, design, manufacture, testing, validation, and revision. Data collection is gained by testing and observations, using check lists and observation sheets. Data were analyzed descriptively.

Findings of the study showed that the PLC and monitoring system trainer kit has been developed for project-based learning, student centered learning and scaffolding in vocational high schools, especially in Electrical Power Installation Engineering Expertise Program, with good feasibility, which is demonstrated by the results of black box testing showing that the system function properly, and the average total validation score of 3.01 showing a good feasibility. The recommendation given is that this study needs to be continued in the stage of implementation in learning and evaluation.

Keywords: PLC, trainer kit, project-based learning, student centered learning, scaffolding.

INTRODUCTION

Currently the development of science and technology applied in the industrial world is very advanced. One example of the advancement of science and technology in the field of electricity applied in the industrial world is the *Programmable Logic Controllers* (PLC). PLC are used in the industrial world and becomes more advanced and sophisticated from time to time, which serves as the control brain of various equipment or machines in the industry. Examples of the use of PLC in the industrial world, are: the use of PLC as the controller of elevators in buildings; controller of the conveyor system; the use in filling water into bottles, the use in welding and pressing car bodies; the controller in the sorting of industrial products; etc.

The latest development of PLC as the machine controller in the industry is the addition of a monitoring system on the control. The advantage of this monitoring system is that the control of industrial machines can be monitored continuously, so if there is any

disruption, it can be directly identified and corrected quickly and accurately. Moreover, the production process carried out by industrial machinery with PLC controllers can be monitored via a monitor placed in a comfortable monitoring room, so the employee can observe through the monitor in the room.

Seeing the development of the use of PLC as machinery controller which is equipped with a monitoring system as mentioned above, vocational high schools, especially the Installation Engineering of Electrical Power Utilization Expertise Package Program, which is an educational institution producing graduates to work in the industry, are required to equip competence of PLC and the monitoring system for its students. Providing competence of PLC and monitoring system for students is very important, so that when they graduate, they will not experience a PLC technology illiterate, and can handle jobs related to the PLC technological advances in the industry.

Based on preliminary studies conducted in SMK Negeri 1 Sedayu, Bantul, SMK Negeri 2 Pengasih, Kulon Progo, and SMK Negeri 2 Wonosari, Gunung Kidul, on the implementation of the 2006 curriculum for Competency of Expertise in Electrical Power Installation Engineering, the data showed that the competence of PLC is taught in eleventh grade 4th semester in the form of PLC practice learning through subject Assembly and Operation of Control System. In the 2013 curriculum, the competence of PLC is given in the form of PLC practice learning through subject Installation of Electric Motors in twelfth grade 5th semester. But until now the PLC practice learning in the 2013 curriculum through these subjects has not been carried out. This is because the 2013 curriculum is applied for vocational students in class 2013, while the current government took measures to exempt the application of the 2013 curriculum so that many Vocational High Schools returned to the application of the 2006 curriculum. Only vocational high schools with certain criteria can apply the 2013 curriculum. Thus it is estimated that most vocational high schools will continue to use the 2006 curriculum. In addition, if further examinated, the basic competence of PLC between the two curriculums is basically not much different.

Furthermore, preliminary studies conducted at the three vocational schools showed that the PLC competence achieved by students through PLC practice learning through subject Assembly and Operation of Control System is low. This is demonstrated by the data of students' learning results in the three vocational schools in the last three years, school year 2012/2013, 2013/2014, and 2014/2015, the average number of students who can achieve PLC competence, with a score of 70 to above, is still under 55%. In preliminary studies were also obtained data that in the three vocational high schools has

not been found PLC equipment equipped with monitoring systems as developed in the industrial world. Moreover, the available practice teaching material (job sheets) has not provided the competence of the monitoring system. Practice tools equipped with teaching materials such as job sheet or learning modules are referred to as a trainer kit. The presence of a PLC trainer kit which is not equipped with monitoring system caused the teachers to have not taught the development of PLC application in the industry.

Another result of the preliminary study indicates that the PLC practice learning process through subject Assembly and Operation of Control System at all three vocational schools still applies conventional learning, such as teacher-centered learning, and have not applied learning models developed in the 21th century, such as student centered learning, project based learning, etc. In addition, in the PLC practice learning, there have been no attempt made by the teacher to make the students active and independent therefore the learning process becomes effective. While in fact, there are learning that can encourage students to be active and independent, one of which is scaffolding based learning.

Based on the description above, a study needs to be done on the development of PLC and monitoring system trainer kit for project based practice learning, student centered learning, and scaffolding in Vocational High Schools. In this study, the development of PLC and monitoring system trainer kit is in the form of a PLC practice prototype unit, and practice learning module for the practice of Assembly and Operation of Control System, in vocational high school, in the Installation Engineering of Electrical Power Utilization Expertise Package Program. In this study, the PLC used is PLC Omron, while in developing monitoring system use Human Machine Interface (HMI).

This study aims to develop the PLC and monitoring system trainer kit for project based learning, student centered learning, and scaffolding in vocational high schools, especially in the Installation Engineering of Electrical Power Utilization Expertise Package Program, which has good feasibility. This study is particularly useful for students where students will gain competence provision of the development of PLC application in the industry, therefore when they graduate they will have a competitive edge in gaining employment opportunities that requires such kind of competence in the industry. Other benefits of the study is that the PLC and monitoring system trainer kit is developed for project based practice learning, student centered learning and scaffolding, therefore students will be encouraged to participate in the learning actively, creatively, and independently, impacting on the improvement of PLC competence achievement for the students.

A trainer kit is one form of a learning media. Rainer, et.al. (2008: 568), suggests that some types of learning media in terms of forms are learning media in the form of real objects and in the form of a model or an imitation. In line with these opinions, Anderson (1987: 38) suggests that one type of learning media is a physical object in the form of real objects or artificial objects that are very similar to real objects. Learning media in the form of a real object or artificial object equipped with the workings of the object is a trainer kit. Based on these opinions, it indicates that a trainer kit is a learning media in the form of real or artificial equipment equipped with job sheet or practice learning modules. In this study, the real object applied in the industry as a trainer kit is PLC Omron, equipped with a monitoring system using Human Machine Interface (HMI).

Bryan & Bryan (1997:4) suggests that Programmable Logic Controllers (PLC) or also called as Programmable Controllers, are equipments that are included in the computer family, which uses an integrated circuit to perform control functions. Another opinion is given by Festo (2004: 1) which states that the Programmable Logic Controller (PLC) is a digital electronic device that uses memory which can be programmed as an internal storage of a set of instructions to implement specific functions, such as logic, sequential, timing, calculation, and arithmetic. Based on the two opinions above, it can be concluded that a PLC is a digital electronic device, included in the computer family, which uses integrated circuit with a memory that can be programmed as an internal storage of a set of instructions to implement functions of logic, sequential, timing, calculation, and arithmetic to perform control functions.

According to Hidayat & Sumardi (2013: 1), to develop a monitoring system can use HMI (*Human Machine Interface*). HMI (*Human Machine Interface*) is an interface or a link display between a human and a machine. HMI is a place where users conduct surveillance or monitor processes in the system. In addition the user can also enter an input on the HMI display. These opinions shows that the HMI can visualize events or processes that is happening in real in the plant so with the HMI the operator is easier to do physical work. In addition HMI can also be used to indicate engine fault, the status of the machine, allows the operator to start and stop operations, and to monitor several parts on a production machine.

In this study, the PLC and monitoring system trainer kit is developed with reference to the project based learning, student centered learning, and scaffolding. Project-based learning, according to Bell (2010: 39), is defined as an innovative approach to learning that teaches many important strategies to be successful, with students pushing their own learning through investigation, and work together to research and create projects that

reflect their knowledge. Student centered learning, according to Cornelius-White and Harbaugh (2010: xxvii) is defined as an approach to teaching and learning that prioritizes the expertise, the uniqueness of each student, and the best instruction in the learning process to achieve success or achievement of students in a comprehensive manner. As for the scaffolding learning, according to Jingyan, Lajoie and Wiseman (2010: 284), can be defined as a technique of providing support to study in a structured manner, conducted at an early stage to encourage learners to learn independently.

RESEARCH METHOD

Type of research used in this study is Research and Development reffering to the ADDIE model, with stages: Analysis, Design, Development or Production, Implementation, and Evaluations. But in this study were taken limitations and modification of stages, including: requirements analysis, design, manufacture, testing, validation of reviewer, and improvement.

At the stage of needs analysis, literature studies and field studies was carried out by conducting observations, interviews, and distributing questionnaires to students and teachers of SMK N 1 Sedayu, SMK N 2 Pemgasih, and SMK N 2 Wonosari in the Installation Engineering of Electrical Power Utilization Expertise Package Program, about the problems and needs in PLC practice learning. At the design stage, designing of hardware and software of the trainer kit prototype units and learning modules is done. Design is done with reference to the results of the needs analysis. The next stage is manufacturing, which includes the manufacture of the trainer kit prototype unit and learning modules referring to the design. The testing stage is in the form of black box testing particularly to the manufacturing results of the trainer kit prototype unit to test the functioning of the system. The stage of validation is performed by 2 material reviewers, 2 media reviewers, and 2 learning model reviewers to the results of manufacturing the trainer kit prototype unit and learning modules. The next step is improvement to the trainer kit prototype unit and learning modules based on recommendations from the validation stage.

The means used to obtain data on the testing and validation stage is observation, while the instruments used were multimeter, checklists and observation sheet. Data were analyzed descriptively.

RESULTS AND DISCUSSION

Results

Through research stages including requirement analysis, design, and manufacturing, is obtained results of the development of PLC and monitoring system trainer kit for project based practice learning, student centered learning, and scaffolding in vocational high schools, in the form of trainer kit prototype and practice learning modules. The prototype for the PLC and monitoring system trainer kit is shown in Figure 1.

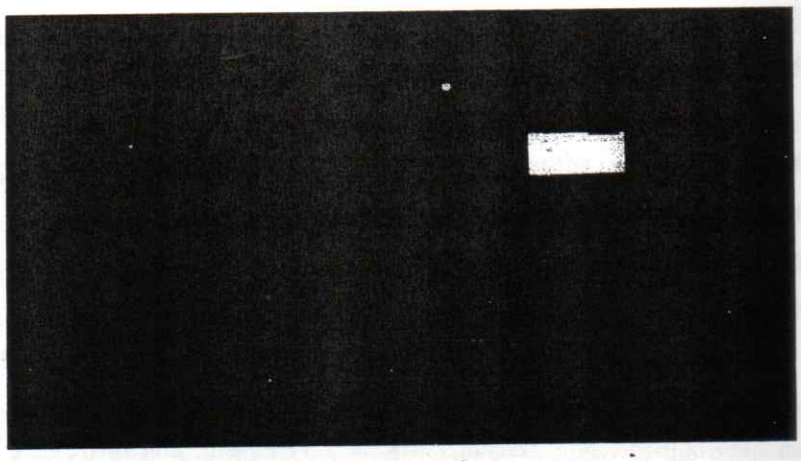

Figure 1. Prototype of the PLC and monitoring system trainer kit

The results of manufacturing the prototype of PLC and monitoring system trainer kit is then tested through the black box testing to examine the functioning of the system. The results of the black box testing on the prototype of PLC and monitoring system trainer kit is presented in Table 1.

Table 1. Results of black box testing on the prototype of PLC and monitoring system trainer kit.

No	Part/Block	Indicator	Test Results
1.	AC power supply	Scalable AC power supply voltage 220 Volt	Successful
2.	DC power supply	Scalable DC power supply voltage 24 Volt	Successful
3.	Input 0.00 – 0.11	Input indicator lights up when the corresponding input terminal 0.00 – 0.11 is On.	Successful
4.	Input 1.00 - 1.11	Input indicator lights up when the corresponding input 0.00 – 0.11 is On.	Successful
5.	Output 100.00 – 100.07	Output indicator lights up when the corresponding output terminal is On.	Successful
6.	Output 101.00 – 101.07	Output indicator lights up when the corresponding output terminal is On.	Successful

7.	PWR indicator light (green)	On, if the power is supplied to the PLC and Off, if the power is not supplied to the PLC.	Successful
8.	RUN indicator light (green)	On, if the PLC operates in the RUN or MONITOR mode and Off, if the PLC operates in PROGRAM mode or a fatal error occurs.	Successful
9.	COMM indicator light (yellow)	Blinks, if the data is being transferred via the peripheral port or RS-232C port and OFF, if the data is not being transferred via the peripheral port or RS-232C port	Successful
10.	ERR/ALM indicator light (red)	On, if a fatal error occurs, blinks in case of errors are not fatal, and off if the operation takes place normally.	Successful
11.	Software CX-Programmer	Can work for programming the PLC	Successful
12.	Software CX-Supervisor	Can work for programming the Human Machine Interface (HMI) as a monitoring system.	Successful
13	Push button	If pushed, the contacts are connected, if not pushed then the contacts are disconnected.	Successful
14.	Magnetic Contactor	If the coil is given working voltage, then the NO contacts are connected, NC contacts are opened, in the contrary, if the coil is not given voltage then the NO contact becomes open and NC contacts are connected.	Successful

The next step is validation of the prototype of PLC and monitoring system trainer kit and practice learning modules by the material reviewers, media reviewers, and learning model reviewers. The validation results conducted by the material reviewers to the prototype of PLC and monitoring system trainer kit are presented in Table 2.

Table 2. The results of validation conducted by the material reviewers to the prototype of PLC and monitoring system trainer kit.

No	Aspect	Assessment Indicators	Average Score
1	Benefit of the product	Benefit of the product in the learning process	3,25
2		The relevance of the product with the industrial world	3
3	Application difficulty level	Easiness in the application making	3
4		Variations of program that can be made	3,5
5		The suitability of the media with the ability of students	3
Total Average Score			**3,15**

The validation results conducted by the media reviewers to the prototype of PLC and monitoring system trainer kit are presented in Table 3.

Table 3. Results of validation conducted by the media reviewers to the prototype of PLC and monitoring system trainer kit

No	Aspects	Assessment Indicators	Average Score
1	Product design	Product design	3,25
2		The safety of material selection	3,25
3		Layout of components	3
4		Resilience of components	3,25
5		The realibility of product performance	3
6	Benefit of the product	The suitability of products in learning	3,5
7		Product benefits in the teaching and learning activity	3,25
Total Average Score			**3,21**

The validation results conducted by the material reviewers to the practice learning module of the PLC and monitoring system are presented in Table 4.

Table 4. Results of validation conducted by the material reviewers to the practice learning module of the PLC and monitoring system

No	Aspect	Assessment Indicators	Average Score
1	The relevance of the material	Suitability of the material with the syllabus	3,25
2		Suitability of the module with the media	3,5
3		Validity of the material	3,25
4		Sequence of the material	3
5	Components of the module contents	Benefit of the module	3
6		Conformity between the application example and the prototype	3
7		Clarity of working steps	3
Total Average Score			**3,14**

The validation results conducted by the media reviewers to the practice learning module of the PLC and monitoring system are presented in Table 5.

Table 5. Results of validation conducted by the media reviewers to the practice learning module of the PLC and monitoring system

No	Aspect	Assessment Indicators	Average Score
1	Contents	Conformity between the module and the competence	3,25
2		Ease of understanding the module material	3
3	Illustration	Clarity of illustration	3
4		Benefit of illustration	3
Total Average Score			3,06

The validation results conducted by the learning model reviewers to the practice learning module of the PLC and monitoring system are presented in Table 5.

Table 5. The results of validation conducted by the learning model reviewers to the practice learning module of the PLC and monitoring system.

No	Aspect	Assesment Indicators	Average Score
1.	Scaffolding	Characteristics of Scaffolding	2,75
2.		Steps of Scaffolding	3
3.	Student Centered learning	Characteristics of Student centered learning	2,75
4.		Steps of SCL	2,5
5.	Project Based Learning	Characteristics of PBL	2,75
6.		Steps of PBL	2,75
Total Average Score			**2,75**

Discussion

Results of the development of PLC and monitoring system trainer kit for project based practice learning, student centered learning, and scaffolding in vocational high schools in the Installation Engineering of Electrical Power Utilization Expertise Package Program, has two forms, the prototype of PLC and monitoring system trainer kit and practice learning modules of PLC and monitoring system. Because vocational students in Installation Engineering of Electrical Power Utilization Expertise Package Program has a moderate academic characteristic, oriented in the competence of strong current electricity or not weak current electricity, core competence and basic competence in PLC that is less deep, therefore the development of the prototype of PLC and monitoring system trainer kit, and the learning modules of PLC and monitoring system is carried out at a basic level. The main part of the prototype of PLC and monitoring system trainer kit is the PLC Omron CP1E-40SDR-A, equipped with other supporting parts which are the personal computer as a means to create the PLC program and the monitoring system program, and the screen of the personal computer as a place to display the monitoring system. Other supporting parts are the on and off button, emergency button, and a switch as part of the input support. While the output support include magnetic contactor and lights. The practice learning modules of PLC and monitoring system has been prepared based on project-based learning, student centered learning, and scaffolding, which refers to experiments on the prototype of PLC and monitoring system.

To find out the functioning of the system on the prototype of PLC and monitoring system trainer kit, a test has been done in the form of black box testing. The results of

black box testing to the prototype of PLC and monitoring system trainer kit shows that all parts of the system can function properly. This is shown in Table 1 that all indicators on the parts of the system succeeded in testing. Therefore, it can be said that every part of the system of the prototype can work synergistically so that the whole system can work well.

From the validation done by material reviewers, media reviewers, and learning model reviewers on the prototype of PLC and monitoring system trainer kit and the practice learning module of PLC and monitoring system, an average score of each aspects has been obtained. Furthermore, these scores are classified into several categories referring to the provision, which are: scores greater than 3.25 to 4.00 are categorized as having very good feasibility, scores greater than 2.50 to 3.25 categorized as having good feasibility, scores greater than 1.75 to 2.50 categorized as having unfavorable feasibility, and scores 1.00 to 1.75 categorized as having poor feasibility.

Results of validation conducted by the material reviewers on the prototype of PLC and monitoring system trainer kit shows the total average score of all aspects of 3.15, which is considered to have a good feasibility. This is supported by the overall indicator of each aspects which has a good or a very good feasibility. Results of validation conducted by the media reviewers on the prototype of PLC and monitoring system trainer kit shows the total average score of all aspects of 3.21, which is categorized as having a good feasibility. This is also supported by the overall indicator of each aspects which has a good or a very good feasibility. If the average of the validation results conducted by the material reviewer and the media reviewer is calculated, it obtained an average score of 3.18 which is categorized as having a good feasibility.

Results of validation conducted by the material reviewers on the practice learning module of PLC and monitoring system shows the total average score of all aspects of 3.14, which is categorized as having a good feasibility. This is supported by the overall indicator of each aspects which has good or very good feasibility. Results of validation conducted by the media reviewers on the practice learning module of PLC and monitoring system shows the total average score of all aspects of 3.06, which is considered to have a good feasibility. Results of validation conducted by the learning model reviewers on the practice learning module of PLC and monitoring system shows the total average score of all aspects of 2.75, which is categorized to have a good feasibility. This is also supported by the overall indicator of each aspects which has good feasibility, except for the indicator steps of student centered learning which is assessed as having unfavorable feasibility. If the average of the validation results conducted by the material reviewer, the media reviewer, and the learning model reviewer is calculated, it

obtained an average score of 2.98 which is categorized as having a good feasibility. In addition, if the total average between the validation results performed by the material reviewer, media reviewer, and the learning model reviewer is calculated, it obtained a total average score of 3.01 which is categorized as having a good feasibility.

CONCLUSION AND SUGGESTION

Conclusion

The development of PLC and monitoring system trainer kit for project based practice learning, student centered learning and scaffolding in vocational high schools has been generated, particularly in the Installation Engineering of Electrical Power Utilization Expertise Package Program, with a good feasibility. This is shown by the results of the black box testing that the system can function properly, and the validation results done by the material reviewers, media reviewers, and learning model reviewers which obtained a total average score of 3.01, categorized as having a good feasibility.

Suggestion

This study needs to be continued to the next research stage, that is the stage of implementation in the classroom, evaluation stage, and finishing.

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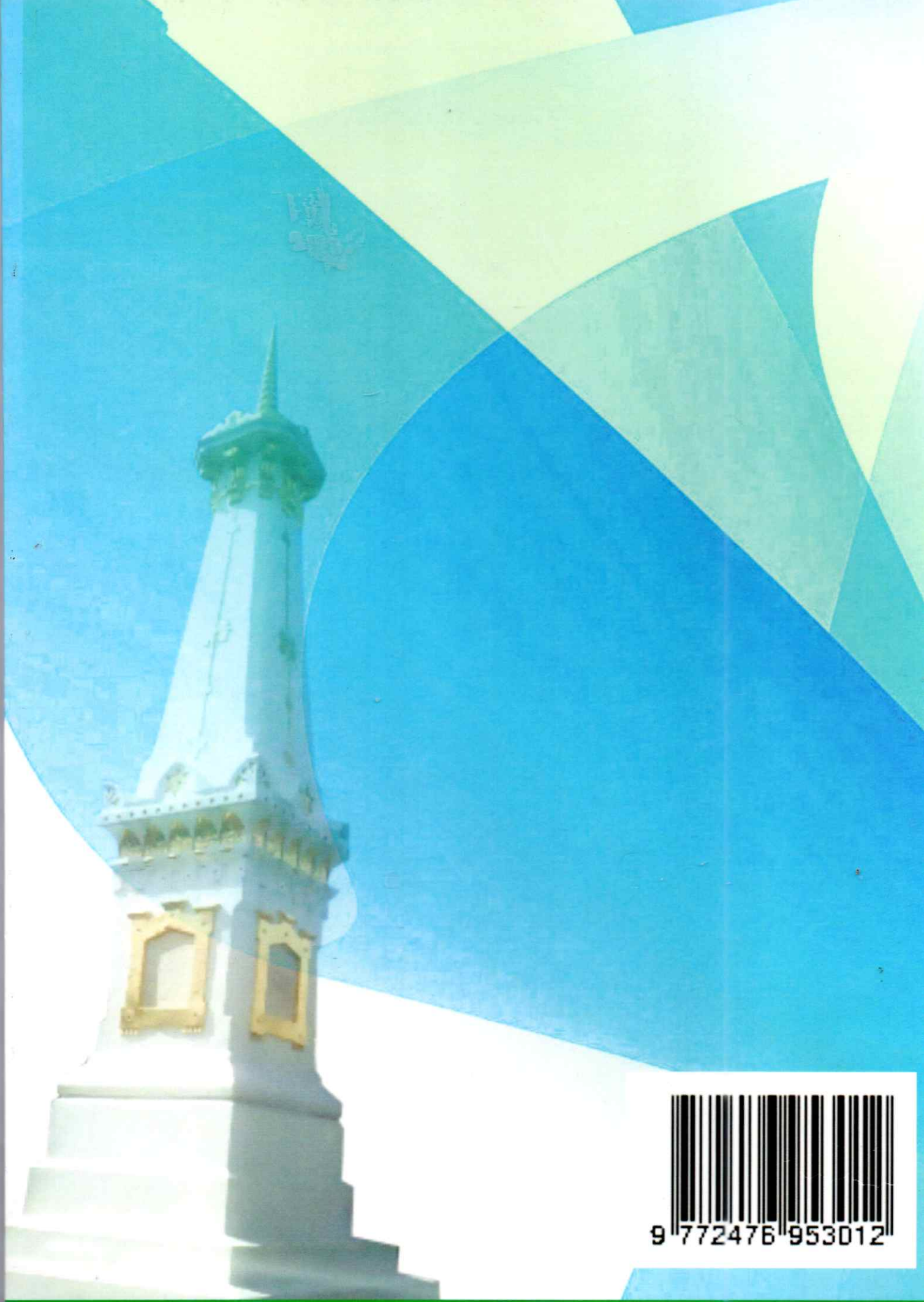

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