The learning tool for electric circuit and mathematics logic integration

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Abstract. This research is motivated by the lack of the primary teacher education students’ critical thinking skills. This problem occurs because the learning model given by the lecturers cannot improve the students' critical thinking skills. This study aims to improve critical thinking skills of the primary teacher education students and develop learning tools in the form of the lesson plan (RPS), lesson instructions (SAP), and instructional materials based on Problem Based Learning for the subject ‘Basic Concepts of Science in Primary School 1’. This study uses ADDIE development model and the participants of the study are the first semester students in Educational Institution (LPTK) Region A and B. The practicality is seen through the results of SAP implementation, the students’ and lecturers’ response to the questionnaire in the LPTK PGSD region A and B. The effectiveness is seen through the process of assessment, observation, and critical thinking ability tests. The collected data are analyzed descriptively. The results showed that the developed RPS, SAP, and teaching materials for the integration of electric circuit and mathematics logic using Problem Based Learning with a mean of 96%, 95%, and 96% can be stated in a very valid category in terms of content, language, and graphics. The result of SAP implementation observation is 84%, the students’ response to the questionnaires is 83%, and the lecturers’ response to the questionnaire is 91%. These results indicate that the learning tool developed is practical. The results of the critical thinking skills process assessment in the A region is 83%, while B is 84%, the observations of critical thinking activities in region A is 82.2%, while B is 81.9%, and the critical thinking skills tests in which N-gain scores for regional A is 0.6, while B is 0.7. In conclusion, the tools are effective to improve the students’ critical thinking skills.

1. Introduction

The development of science and the demand of the work environment must be accompanied by the development of students' abilities and skills as future educators [1]. One of efforts to achieve it is by integrating one scientific discipline with another. This integrated disciplines are expected to develop the depth of their content and their strong relationship. In general, fundamental disciplines in elementary education are science and mathematics which are interrelated to one another. The integration of these two disciplines in a learning will improve and broaden their content and discussion [2]. In addition, the two disciplines can complement one another. One of the advantages of integrated science and mathematics is it can provide students with relevant experience to the real world and can improve their critical thinking skills as well as stimulate them [2].

Critical thinking is one of the most important things students must fulfill in the learning process [3]. If students have the ability to think critically, they will be able to compete each other. Conversely, if they are unable to think critically, it will be difficult for them to compete [4]. The concept of critical
thinking from western countries focuses on critical thinking as a skill to convey logical reasons and to identify things relevant to solving problems. This definition includes the ability to think in a logical way [5].

Critical thinking will increase students’ or prospective teachers’ ability in solving problems and expand their insights during the discussion. [6] From critical thinking, a prospective teacher can also focus and be wise in using the information [7]. Critical thinking directs them to be more active in finding information and finding solutions to problems encountered in the learning process [8].

The phenomenon the field also shows that students' critical thinking was not optimal. This condition was seen when the researcher conducted observation in one of the LPTK (Institute of Teachers’ Education) in Padang especially first semester students of PGSD (Elementary Teacher Education) department. This lack of critical thinking was seen through the following phenomena. First, students were not able to determine the relationship between the learning material of heat with their daily life. When the lecturer gave questions to them, they cannot connect heat to their daily life. Second, it was difficult for students to determine the conclusions and to give their opinions. When the lecturer appointed one student to conclude the material, he explained the conclusions of the material, but it was not based on their own thoughts. Third, when the lecturer gave problems, students were still confused in determining the cause and effect of the problem. In addition, students did not have a handbook. The lecturing process is only done by group discussion, in which each group discussed one topic. In each meeting, one or two groups would present each of their topics. The RPS (semester lesson plan) used was still conventional because it had not employed appropriate learning strategies.

Critical thinking ability is defined as (1) an attitude of willingness to think deeply about problems within one's experience; (2) knowledge of logical methods and reasoning; and (3) a skill to apply the method [9]. Critical thinking requires hard effort to examine every assumptive belief or knowledge. One of the efforts to improve critical thinking skills is using problem-based learning model. This model can indirectly help students improve their critical thinking skills in dealing with problems quickly and accurately. The problem-based model that will be used in this research is Problem Based Learning (PBL). PBL learning models center on students, so they are trained to think critically and familiarize themselves to solve problems in their own way [10]. PBL is a learning model that provides opportunities for students to explore authentic experiences, to encourage them to learn actively, to construct knowledge, and to integrate the context of learning in school with real life condition [10]. Students do not only listen, take note, and memorize the material delivered by the teacher, but also think, search, analyze data, and communicate them, in the learning process. PBL learning models can only occur if the teacher is able to create an open classroom environment and guide the exchange of ideas [11]. The learning process with PBL is that of student-centered learning in which students will solve the problems they get in the learning process [12].

In addition to critical thinking skills, students will also be encouraged to add their insights about the material discussed and relate it to the existing reality in the surrounding environment. Thus, students’ learning activities that will integrate the two concepts of disciplines require instructional documents, such Semester Lesson Plan (RPS), Course Unit (SAP), and Instructional Materials. The instructional documents are designed by combining science and mathematics, which are the material of electrical circuit and logic by using a problem based learning model. The electrical circuit is the material on the subject of elementary concept of science for SD1 while logic is the material on the subject of mathematics for elementary. This research was conducted on the subject of basis concepts of science for SD1 for first semester students of PGSD.

2. Methods
This research is developmental research using descriptive qualitative and quantitative descriptive data analysis [13]. The selection of a good development model will produce an effective and efficient product. The accuracy of the model selection will produce the right product. One of the characteristics of such accuracy is that the product can be applied properly and provide benefits to its users. The good developed product will improve students' critical thinking skills to gain deeper knowledge of the
material presented. In addition, products developed from integrated learning material on electrical circuit and logic using problem-based model can overcome learning problems that often arise in the learning process.

One of simple and easily understandable media development design is the ADDIE model. The ADDIE model is the term used to describe a systematic approach to the development of learning. ADDIE is an abbreviation that refers to the main processes of the learning system development process, namely: Analysis, Design, Development, Implementation, and Evaluation [14]. The research will also involve experts’ assessment as validator, so the product trials can be conducted and is revised based on assessment, suggestions and input from validators.

3. Results and Discussion
3.1. Analysis Stage.
The analysis phase was divided into two aspects namely document analysis and needs analysis. Document analysis focused on the analysis of electrical circuit materials and mathematical systems, for more details, see the following table. Need analysis was designed to improve students' critical thinking skills. It was obtained from two perspectives, namely lecturers and students. The results of lecturers' needs analysis obtained instructional documents on integrated learning of electrical with mathematical logic using problem based model (PBL) to improve students' critical thinking skills on the subject of basic concepts of science for SD 1. Instrument used in the analysis of student needs is the questionnaire distributed to 28 first semester PGSD students on Monday, October 2, 2017. The contents of this questionnaire is related to the instructional documents that will be developed. The following figure 4.2 presents the results student needs analysis. The results of students’ needs analysis obtained instructional documents on integrated learning of electrical with mathematical logic using problem based model (PBL) to improve students' critical thinking skills on the subject of basic concepts of science for SD 1. The conclusion from the results of this analysis reveals that students and lecturers agree that instructional documents that integrate science and mathematics with good quality and attractive designs can stimulate students to think critically. In addition, it can also facilitate lecturers in conducting the teaching process.

3.2. Design Stage
The designed RPS is that of mathematics and science integrated learning using problem-based on undergraduate students of PTE. The developed RPS shows the exposure of the learning stages on the topic of classification of living things combined with the concept of the sets. The characteristics derived from this RPS design are more detailed and easy to understand. It also helps to understand the classification of living things. The fundamental principle in RPS design is that the lesson material presented has fulfilled the scientific truth; the order of the article adjusts to the level of student development, and the preparation of the RPS adapt to the established components. The SAP is compiled entirely and systematically regarding the developed RPS. Based on the analysis of the material, the achievement of competency indicators is implemented in 3 lectures with the allocation of time for each lecture 6 x 35 minutes. Each address is conducted in a structured way by collaboration the stages of Problem Based Learning [15]. Learning materials are designed by the curriculum and presented using the learning steps of the PBL model. Its development adapts to the needs and characteristics of students’ progress [16]. These materials develop regarding the results of material analysis and formulated indicators.

3.3. Development Stage
3.3.1. Validation Result
a. RPS (Semester Lesson Plan)
The RPS is revised based on the advice of the content and language expert validator. The following table shows the general results of the RPS validation.
Table 1. The Results of RPS Validation by Expert Validator

| No | Validated Aspect     | Score Number | Percentage | Category |
|----|----------------------|--------------|------------|----------|
|    |                      | V1 | V2 |          |          |
| 1  | Content Feasibility  | 43 | 44 | 97       | Very Valid |
| 2  | Language             | 19 |    | 95       | Very Valid |
|    | Total Number         | 106|    |          | Very Valid |
|    | Percentage           | 96 |    |          | Very Valid |

Table 2. The Results of SAP Validation by Expert Validator

| No | Validated Aspects     | Score Number | Percentage | Category |
|----|-----------------------|--------------|------------|----------|
|    |                       | V1 | V2 |      |          |
| 1  | Content Feasibility  | 43 | 43 | 95   | Very Valid |
| 2  | Language              | 19 |    | 95   | Very Valid |
|    | Total Number          | 105|    |      | Very Valid |
|    | Percentage            | 95 |    |      | Very Valid |

b. SAP (Course Unit)
The SAP is revised based on the advice of the content and language expert validator. The following table shows the general results of the RPS validation.

c. Instructional Material
The validation of instructional materials focuses on several aspects, namely the feasibility of content, language and graphics. Similar to RPS and SAP, instructional materials are also revised by expert validators before the real assessment.

3.3.2. Mathemathic Practicality Test of Instructional Document on Integrated Learning of Electrical with Logic
a. The Observation Results of SAP Implementation
The observation on SAP implementation focuses on seeing whether the learning is carried out in accordance with the SAP and whether there are any obstacles in its implementation. The observation data was recorder in observation sheet. Observations were conducted by using indicators in accordance with PBL steps.

b. Students’ Respons on the Practicality of Instructional Documents
The assessment of student responses was conducted to find out students’ opinions about the level of practicality of instructional documents. The data from students’ responses were obtained from student response instruments. The results of students’ responses can be seen in

The results show that students feel their level of critical thinking increase, and it is helpful in understanding the material on the integrated electrical circuit with mathematical logic. Students also get new experiences with the instructional documents used because they are different from the ones used previously.

c. Lecturers’ Response on the Practicality of Instructional Documents
The assessment of lecturers’ responses was conducted to find out lecturers’ opinions about the level of practicality of instructional documents. The data from lecturers’ responses were obtained from student response instruments. The results of students’ responses can be seen in the following table.[}
Table 3. The Results of Lecturers’ Response on the Practicality of Instructional Documents

| No | Assessed Aspects                  | Assessment | %   | Category   |
|----|-----------------------------------|------------|-----|------------|
| 1  | Concept Accuracy                  | 5 5 10 100 | Very Practical |
| 2  | Concept Depth                     | 5 4 9 90  | Very Practical |
| 3  | Concept Extensibility             | 4 5 9 90  | Very Practical |
| 4  | Instruction on Problem Solving    | 5 4 9 90  | Very Practical |
| 5  | Presentation Structure            | 4 4 8 80  | Very Practical |
| 6  | Presentation Flow                 | 4 4 8 80  | Very Practical |
| 7  | Writing Language                  | 5 5 10 100| Very Practical |
| 8  | Narrating Language                | 4 5 9 90  | Very Practical |
| 9  | Creativity                        | 4 5 9 90  | Very Practical |
| 10 | User Practicality                 | 5 4 9 90  | Very Practical |
| 11 | Clarity                           | 5 5 10 100| Very Practical |
| 12 | Relevancy                         | 5 5 10 100| Very Practical |
| 13 | Organization                      | 5 5 10 100| Very Practical |
| 14 | Attractiveness                    | 4 4 8 80  | Very Practical |
| 15 | Trustworthiness                   | 5 4 9 90  | Very Practical |
| 16 | Satisfaction                      | 4 4 8 80  | Very Practical |
| 17 | Outcome                           | 5 5 10 100| Very Practical |
|    | Total                             | 78 77 155 | Very Practical |
|    | Percentage                        | 91        | Very Practical |

Based on all of the above explanation, it is known that the use of integrated learning material on electrical circuit and mathematical logic using problem-based model is effective. Based on the effectiveness of instructional documents at the trial stage, it can be concluded that the integrated learning material on electrical circuit and mathematical logic using problem-based model is effective to be used in improving students' critical thinking skills.

3.3.3. The Effectiveness Test on Instructional Documents of Integrated Learning Material on Electrical Circuit And Mathematical Logic Using Problem-Based Model

Product quality or development results are determined by validity, practicality, and effectiveness of the learning tools developed. The effectiveness aspects can be achieved if the product has been declared valid and practical. The effectiveness of integrated learning material on electrical circuit and mathematical logic using problem-based model can be seen through the assessment of critical thinking processes, critical thinking activity observation sheets, and critical thinking tests. Instructional documents are said to be effective, if the assessment of the process of critical thinking skills, observation sheets of critical thinking activities, and critical thinking tests are categorized as high. For more details, the effectiveness of instructional documents can be described as follow.
a. The Assessment of Critical Thinking Process  
Based on the results of data analysis on the assessment of critical thinking that the integrated learning material on electrical circuit and mathematical logic using problem-based model has run optimally and as it is expected.

b. Observation of Critical Thinking Ability  
Observation of critical thinking activities focuses on observing students' thinking skills throughout the learning process. The observation data on critical thinking activities was taken from observation sheet done by two observers at each meeting. Observations focuses on five indicators of critical thinking ability according to Ennis (1985), described into six critical thinking sub-abilities.

Based on the explanation above, the effectiveness of learning in terms of observing students' critical thinking activities can be said to run very well. In other words, students can participate in integrated electrical circuit learning mathematical logic using the developed instructional documents. Thus, it can be concluded, that the instructional documents developed can be used in different situations and conditions and can improve students' critical thinking skills.

c. Critical Thinking Test  
The critical thinking test in this study focuses on five indicators of critical thinking ability. The average score of the pretest and posttest is obtained.

| Table 4. Pretest and posttest Score for each Indicator of Students’ Critical Thinking during the Trial Phase |
|---------------------------------------------------------------|
| No | Indicators of Critical Thinking | Average Score of each Indicator | Average Score |
|----|--------------------------------|---------------------------------|---------------|
| 1  | Giving simple explanation      | Pre Test 1,5                      | Post Tes 3,35 | N-Gain Category 0,74 | Average |
| 2  | Establishing basic skills      | Pre Test 2,47                     | Post Tes 3,82 | N-Gain Category 0,88 | High |
| 3  | Making Conclusion              | Pre Test 3,07                     | Post Tes 3,9  | N-Gain Category 0,89 | Average |
| 4  | Making detailed Information    | Pre Test 0,63                     | Post Tes 2,32 | N-Gain Category 0,50 | Average |
| 5  | Determining Strategies and Tactics | Pre Test 1,58                    | Post Tes 2,62 | N-Gain Category 0,43 | Average |

Based on the above table, instructional documents for integrated learning material on electrical circuit and mathematical logic using problem-based model is classified into effective category seen pre-test and post-test on the aspect of critical thinking ability.

3.3.4. Implementation Stage  
The implementation phase can be carried out in other classes, other LPTK, or other instructors. The implementation phase in this study was carried out to the first semester PGSD LPTK students in region B. The aim was to test the effectiveness of the use of these devices on different objects, situations, and conditions. There are three main things that need to be considered at the implementation stage, namely the assessment of the process of critical thinking skills, observation of critical thinking activities, and tests of critical thinking skills in the electrical circuit material integrated with mathematical logic based on PBL. The following are the results of the implementation phase.

The implementation phase can be done in other classes, other LPTKs, or other teachers. The implementation phase in this study was carried out to the 1st semester students of PGSD LPTK in region
B. The aim was to test the effectiveness of using these devices in different objects, situations, and conditions. There are three main things that need to be considered in the implementation phase, namely the assessment of the process of critical thinking skill, the observation of critical thinking activities, and the test of critical thinking skills in integrated learning material on electrical circuit and mathematical logic using problem-based model. The following explained the results of the implementation phase.

a. Assessment of the Process of Critical thinking
Based on the results of the assessment of critical thinking skills, it can be concluded that instructional documents of integrated learning material on electrical circuit and mathematical logic using problem-based model runs optimally and can achieve the expected results.

a.1 Observation of Critical Thinking Activities
The observation of critical thinking activities focuses on seeing students' thinking skills during the learning process. The observation data on critical thinking activities were taken from the observation sheets of critical thinking activities by two observers at each meeting. The observation focused on five indicators of critical thinking ability, which then were divided into six critical thinking sub-abilities.

Observational data on critical thinking activities
The critical thinking skills of students as a whole have an average percentage of 81.9% in the very high category. Thus, it can be said that students' critical thinking skills when following the learning process of integrated learning material on electrical circuit and mathematical logic using problem-based model was developing. The following table described the more details.

a.2 Critical Thinking Test

| No | Indicators of Critical Thinking         | Average Score | Average    | N-Gain | Category |
|----|----------------------------------------|---------------|------------|--------|----------|
| 1  | Giving simple explanation              | 1,73          | 3,43       | 0,75   | Average  |
| 2  | Establishing Basic Skills              | 1,25          | 3,8        | 0,93   | High     |
| 3  | Making Conclusion                      | 2,02          | 3,87       | 0,93   | High     |
| 4  | Making Detailed Information            | 0,7           | 2,48       | 0,54   | Average  |
| 5  | Determining Tactics and Strategies     | 0,77          | 2,62       | 0,57   | Average  |

3.4. Evaluation Stage
Evaluation is the last stage of the ADDIE development model. The evaluation stage is the process of giving value to the developed instructional documents. Giving this value is based on the results of the practicality and effectiveness of the developed instructional documents.

Formative evaluation is an evaluation obtained from the results of applying the developed instructional documents. The results of the application of instructional documents in this formative evaluation can be seen from the process assessment, activity observation, and critical thinking skills tests. Process assessment, activity observation, and students’ critical thinking skills tests were obtained during the trial and implementation stages. The trial phase for the 1st semester students of PGSD LPTK
was carried out in region A, and the implementation phase was carried out for the 1st semester students of the LPTK PGSD in region B.

Based on the assessment process, activity observation, and critical thinking skills test for the 1st semester students of the LPTK in Region A at the first meeting until the third meeting, it is seen that students can follow the learning well and get maximum results. Assessment of the process of critical thinking skills is based on the results of activities and evaluations 79% at the first meeting, 83% at the second, and 86% at the third. The observation of critical thinking activities based on five indicators of critical thinking ability according to Ennis (1985), which are described into six critical thinking sub-abilities is 78.7% at the first meeting, 81.3% at the second, and 83.3% at the third. The average score of the pre-test class is 46.3 smaller than the average post-test score of 80, with an average gain score of 0.6 with medium category. Thus, there is an increase in the ability to think critically after using an instructional documents of electrical circuit integrated with mathematics logic. The increase of critical thinking skills is inseparable from problem-based learning activities, so that the instructional documents of electrical circuit integrated with mathematics logic support students' critical thinking skills.

This means that when the learning process takes place, students' critical thinking skills increase in understanding and using the developed instructional documents, even though there are some students who lack of comprehending and understanding. However, after getting further explanation, they can understand the products that have been developed and students can follow the steps contained in the teaching materials

The effectiveness of the instructional documents obtained in the 1st semester of students in PGSD LPTK in B region and in accordance with its consistency in implementing them in the different environments found that the 1st semester students of PGSD LPTK in B region were able to follow and carry out the subject of electrical circuit learning activities integrated with mathematical logic well. It can be seen from the results of the assessment of the process of critical thinking skills based on the results of activities and evaluations that students have answered at the meeting I which achieved 80%, in the meeting II was 84%, and in the meeting III was 86%. Observation of critical thinking activities at meeting I was 80.7%, meeting II 83.7%, and meeting III 87.3%. The average score of pre test (32.3) was smaller than the average score of post test (81), which the average gain score was 0.7 categorized into medium category. So that there is an improvement in critical thinking skill after implementing the instructional documents of electrical circuit integrated with mathematical logic. The improvement of critical thinking skills cannot be inseparable from problem-based learning activities, so that the instructional documents of electrical circuit integrated with mathematical logic support students' critical thinking skills.

It proves that integrated electrical circuit integrated with mathematical logic which was based on PBL are indeed effective to be used in helping and improving the 1st semester students' critical thinking skills in PGSD LPTK. Based on the result of the two classes and the consistency of the results shown in the development of the instructional documents, it can be concluded that electrical circuit integrated with mathematical logic based on PBL can be used to improve the 1st semester students' critical thinking skills in PGSD LPTK.

4. Conclusion

The development of instructional documents of electrical circuit mathematical logic based on PBL used the ADDIE development model which focused on the preliminary study phase, the trial phase, and the implementation phase that has been successfully implemented. The instructional documents had been tried on the 1st semester students PGSD in one of the LPTKs in A region in Padang which a number of students were 30 students, and it had been implemented in the 1st semester students of PGSD LPTK in B region Padang with a total of 30 students. The discussion of the results of the research can be further elaborated especially relating to the characteristics of instructional documents, students’ responses, and the achievement of students' critical thinking abilities.
References
[1] Van Seters J R, Ossevoort M A, Tramper J and Goedhart M J 2012 *Comput. Educ* **58**(3) 942
[2] Kurt K and Pehlivan M 2013 *Int. J. of Educ. in Math. Sci. Tech.* 1(2) 116
[3] Li X and Ma L 2017 *Saeme* **105** 1994
[4] Istianah E 2013 *Infinity* 2(1) 43
[5] Ahmatika D 2016 *J. Euclid* 3(1) 394
[6] Stoica A 2015 *Procedia-Soc. Behav. Sci.* **180** 702
[7] Suyun X 2018 *Adv. Soc. Sci. Educ. Hum. Res.* **238** 754
[8] Wang X and Zheng H 2016 *Theory and Practice in Language Studies* 6(6) 1323
[9] Alrahlah A 2016 *Saudi Dent. J.* **28**(4) 155
[10] Lo F 2015 *Proceedings of the 2015 Conference on Education and Teaching in Colleges and Universities* (Atlantis Press)
[11] Gurses A, Dogar C and Geyik E 2015 *Procedia-Soc. Behav. Sci.* **197** 2390
[12] Mohd K, Ahmad S, Syed H and Zamry M 2012 *Ictlhe* **56** 223
[13] Deljavan R and Norouzi D 2016 *Procedia-Soc. Behav. Sci.* **229** 354
[14] Petranová D and Hossová M 2015 *International Conference on Applied Social Science Research (iCASSR)* pp 244-248
[15] Chiu A, Price A and Ovrahim E 2015 *NARST 2015 Annual Conference* (Museum of Science and Industry)
[16] Mumu J, Prahmana R C I and Tanujaya B 2018 *J. Phys.:Conf. Ser.* 943 012011