Development of Bioremediation Learning Materials based on Contextual Teaching and Learning (CTL)

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Abstract. Structured learning materials function as ground base for students to read and analyze topic related on deeper level. This succession in learning emerge as a problem in biotechnology course for bioremediation topic at Biology Education Department of Universitas Negeri Padang. Students had to read the latest research articles from national and international indexed journal. However, they had lacked basic concepts in the first place and compound by English as language barrier. This lead to problem of not achieving learning puporses. Thus, there was a need of structured basic concept learning materials of bioremediation. Bioremediation is a process of reducing organic and inorganic pollutants by organisms in the environment. Bioremediation is about real problems, therefore, learning materials of bioremediation will be integrated with Contextual Teaching and Learning (CTL) pedagogical model, to lead students achieve deep comprehension. This was educational Research and Development (R&D) using Plomp model which consists of three phases: preliminary research, development or prototyping, and assessment phase. Data gathered as qualitative and quantitative, through interview, questionnaire and paper based test to assess students’ comprehension of bioremediation. Result of this research showed that learning materials of bioremediation were valid from content, layout and presentation, graphics, and linguistic; practical in use for students and lecturer as users; and effective to improve students comprehension of bioremediation.

1. Introduction
University’s students should read the latest research articles to update their knowledge, likewise the Biology Education Department of Universitas Negeri Padang. The lecturer informs the students to read national and international indexed research articles before they attend lectures. This is especially for bioremediation topic, which is a part of biotechnology course. However, students had negative perception toward bioremediation topics because they did not understand about bioremediation as a whole. Based on preliminary research, data showed that the root problem of students’ negative perception toward Bioremediation topic were caused by lack of basic knowledge about bioremediation and English as language barrier. Basic knowledge is a must to have for students to understand bioremediation in deeper level when they read research articles. Even students who read many articles, it might not cover the objective of lectures [11], and it would get worse when they did not have basic knowledge.

Bioremediation is a process of reducing pollutants and other toxic chemical components from the environment by using organisms [31]. Bioremediation could be used for organic and inorganic...
pollutants contamination. For organic pollutants, bioremediation is basically the process of biodegradation, which mineralize organic pollutants into carbon dioxide, water and inorganic compounds by microorganisms. The organic components are hydrocarbons that come from an accident in petrochemical industry and spill the petroleum products into the environment \[10\]. Another hydrocarbon source is palm oil mill effluent (POME). The industry is common in Indonesia. It releases oil and other wastewater then pollute the environment \[4,33\] due to the high concentration of phenolic compounds and chemical oxygen demand (COD) \[15\]. Other contaminants are inorganic pollutants such as heavy metals. Heavy metals could uptake by plants \[18\] and microorganisms could alter chemical properties of heavy metals via array of mechanisms, because heavy metal cannot be destroyed \[7\].

There are no structured textbook or module that explain about the basic concepts of bioremediation as a whole process, because the topic need to explain about what the object is, what are types of pollutants that possible to reduce using bioremediation, and how the chemical process occurs. All of the data comes from preliminary research in 2016 by four universities in Padang, West Sumatera. One of the universities have biotechnology textbook and have a sub-chapter explaining bioremediation, however only half a page. These data show the need of bioremediation learning materials with structured basic concepts and many latest research articles included.

Bioremediation is not just a theory, it is discussing contextual cases. Bioremediation was first used commercially in 1960s for oil spill accident in Cat Canyon \[1\], highly influenced by Exxon Valdez oil spill in 1989 \[13\] and studies supported bioremediation as useful cleanup strategy when used by Exxon on large scale \[25\]. Back to 1940, microbiologist has studied the process of decomposed of hydrocarbons. The hydrocarbons are able to used by many microorganisms as source of energy in their metabolisms \[36\]. It is the history of bioremediation, thus, after the first chapter explains about basic concepts and process of bioremediation, there must be a chapter explaining about petroleum bioremediation, the next chapter about petroleum products, and the last about POME bioremediation. Bioremediation is a broad topic because the process linked to industries and its activities, thereby pollute the environment. Hence, learning materials developed with Contextual Teaching and Learning (CTL) pedagogical model as the basis.

The basis of CTL are interdependence, constructivism, and active learning \[14\]. Based on the three basis, the component of CTL are developed. There are seven components of CTL: constructivism, questioning, inquiry, learning community, modeling, reflection, and authentic assessment \[28\]. To achieve the CTL objectives, linked courses also needed \[16\] to connect a problem with many perspective of knowledge or courses. Thus, the research aimed to develop a learning materials of bioremediation based on contextual teaching and learning (CTL).

2. Method
Learning materials development used Research and Development Plomp model with formative evaluation by Tessmer \[24\] and criteria of interventions that adapted from Nieveen: validity, practicality, and effectiveness \[22\]. There were three phases of development, 1) preliminary research, 2) prototyping phase, and 3) assessment phase \[24\]. Preliminary research aimed to observe and collect data to discover the main problem and what were needed, through interview and paper based instrument questionnaire for lecturer and students from four universities in Padang. Followed by analyzing the syllabus of other universities in Indonesia that have bioremediation topic or course, and analyzing the content.

Based on preliminary research, the content of learning materials was systematically compiled and developed. It means research has entered the prototyping phase. Learning materials was evaluated from many aspects, and revised many times based on evaluation. The formative evaluation were self evaluation, expert review, one to one evaluation and small group evaluation, trough paper based instrument and interviews. In this phase, the experts’ review aimed to seek the validation of learning materials from four aspects: content egibility, layout and presentation, graphics and linguistic as four of that built the prototype of learning materials. One to one evaluation aimed to seek the first practical
evaluation of learning materials from students’ perspective, and the second practicality evaluation by the students in small group. One to one evaluation with three students and small group evaluation with six students, all of them vary in academic achievement. It is the most popular way to choose students population based on low, medium, and high academic achievement [34].

The last is assessment phase. In this phase, practicality of learning materials evaluated by lecturer as user. After the evaluation and revision, the field test was held. Field test is a process of learning in the classroom using the prototype of bioremediation learning materials. At the end of the second meeting, a test was conducted to assess the effectiveness of the learning materials in improving students’ comprehension.

The trial subject of this research was a class of undergraduates students from biology education department, thirty four (34) students who took biotechnology courses, on term period of July-December 2016. Data collected as qualitative and quantitative through interview, paper based questionnaires and test instruments for field test. Qualitative data analyzed with descriptive technique. Quantitative data from validity and practicality evaluation analyzed based on scores of four (4) Likert scale, and students’ assessment processed with score and letter grades as explained below.

The value obtained from validity and practicality evaluation were subsequently converted into criteria of validity and practicality shown in Table 1.

\[
\text{Value} = \frac{\text{Obtained scores}}{\text{Maximum scores}} \times 100\% \tag{1}
\]

| Percentage | Level of Validity | Level of Practicality |
|------------|-------------------|-----------------------|
| 0 – 20     | Invalid           | Practical             |
| 21 – 40    | Less Valid        | Less Practical        |
| 41 – 60    | Valid Enough      | Practical Enough      |
| 61 – 80    | Valid             | Practical             |
| 81 – 100   | Very Valid        | Very Practical        |

The learning materials met the valid and practical criteria when the percentage of its value at the valid and practical level as minimun.

Assessment of students’ comprehension based on paper tests used the criteria as shown in Table 2.

| No. | Score  | Letter Grades |
|-----|--------|---------------|
| 1.  | 85 - 100 | A             |
| 2.  | 80 - 84  | A'            |
| 3.  | 75 - 79  | B’            |
| 4.  | 70 - 74  | B             |
| 5.  | 65 - 69  | B             |
| 6.  | 60 - 64  | C’            |
| 7.  | 55 - 59  | C             |
| 8.  | 50 - 54  | C’            |
| 9.  | 45 - 49  | D             |
| 10. | 0 - 44   | E             |

The learning materials obtained the effectiveness from field test when \( \geq 75\% \) students test achieved B- (B minus) grades.
3. Results and Discussion

3.1. Preliminary research

Preliminary research data showed that the main problem was the unavailable of bioremediation basic concepts learning materials, whilst students at the same time have to read the latest articles of bioremediation from national and international indexed journal as the main resource of learning materials. Language barrier came as the next problem, it made the students were harder to get the main idea of articles. Bioremediation was a new topic for the class, therefore students needed to understand the basic concepts first, before being able to analyze the research articles systematically. Hence, there is a need for learning materials.

The design of learning materials required the syllabus analysis to include needed topics. Syllabus were analyzed from many universities in Indonesia that have bioremediation topic or course. Based on syllabus analysis, topics were arranged followed by content analysis. The process continued to the development of prototype, it would be developed into four chapters, included in many the latest research articles review, related pictures and links of videos. All of that integrated with syntax of CTL pedagogical model as the basis.

3.2. Development or prototyping phase

3.2.1. Self evaluation. After the prototype was ready, the researcher needed to do self evaluation with paper based checked to find obvious error and made revisions.

3.2.2. Validity evaluation. The next process was validity evaluation. The evaluation results were shown in Table 3.

| Table 3. Result of Validity Evaluation |
|---------------------------------------|
| Aspects                  | Percentage (%) | Criteria |
|--------------------------|----------------|----------|
| Content egibility        | 75             | Valid    |
| Layout and Presentation  | 87,5           | Very Valid |
| Graphics                 | 75             | Valid    |
| Linguistic               | 70             | Valid    |
| Mean                     | 76,9           | Valid    |

Validity evaluation of learning materials achieved valid mean. Within the evaluation process, the experts gave suggestions for improving the prototype including content improvement, layout and pictures proportion, and linguistic related to grammar. There were two experts for content evaluation, one for layout-presentation and graphics, and one for linguistic.

Valid criteria of content achieved because the prototype developed with Learning Outcomes (LO) which refers to Kerangka Kualifikasi Nasional Indonesia (KKNI) for bachelor degree, adapted from Peraturan Presiden No. 8 Tahun 2012. The rule explained about KKNI which is a framework level of qualification competence to juxtapose, equalize, and integrate between education, job training and work experience to give work competence recognition accordance with the job structure in various sectors. Learning outcomes were customized from syllabus and content analysis, to develop into learning materials. Learning materials included in many the latest research articles of bioremediation because the students should know it. The result of this research in the articles provided real examples for students because it helped them to understand research ideas, concepts and theories \[2\]. Research articles were placed as part of theory explanation and some articles reviewed as examples of bioremediation process as a research.

The prototype of learning materials integrated with CTL syntax that were blended in every chapter and some of the syntax could be identified. This help content egibility to achieve valid criteria. The need of CTL in this prototype was to built relation of theories and concepts of bioremediation with real world situations \[29\], for students to find meaning. Meaning gives them a reason to learn \[16\].
The basis of CTL are interdependence, constructivism, and active learning\(^{[14]}\). Syntax for CTL implement were developed based on it. There are seven syntax of CTL: constructivism, questioning, inquiry, learning community, modeling, reflection, and authentic assessment\(^{[28,20]}\).

Bioremediation concepts outlined and arranged systematically from basic to complex theories. Questions were inserted as part of inquiry syntax and as a question itself. Questions in theory parts function as a guide for students’ attention for concepts they need to comprehend\(^{[3,5]}\). Asking good questions are important because it encourages the students to think critically\(^{[5]}\). When a higher-order questions bring up, it gave students opportunities to develop deep explanation and learning is enhanced across content areas\(^{[8]}\).

In the learning materials, some questions as part of the inquiry were placed in material as a starting point before explanation for cases and theories, and some in special boxes on the page. What matter the most about inquiry is the initial query sparks students’ interest, provides the opportunity and resource for in-depth students’ investigations\(^{[32]}\). Inquiry required more than simply answering questions or getting the right answers. It espoused investigations, exploration, search, quest, research, pursuit, and study. It was enhanced by involvement with a community of learners, each learning from the other social interaction\(^{[17]}\). The process of answering the questions followed by inquiry and learning community to share knowledge and argument, indicate the contructivism syntax is running. Thus far, four syntax to implement CTL in learning materials already explained.

Modeling in learning process focused on expose the video related to bioremediation process and discussed about it, because bioremediation is just a part of topic on biotechnology course with only two meetings. Video related were put in the learning materials as a link in the box with explanation, and some have screenshot of it. After the students studied and watched the video, they would learn that bioremediation was not just about microorganisms and biology, but affect ecology, health and economy in broader perspective. CTL also need linked courses to link material from different sciences that overlapped or related\(^{[16]}\). Related material from different sciences needed because to solve a real problem of bioremediation need many perspective. It was linked to chemistry to understand the chemical reactions when there was a process of degradation of hydrocarbon or how could absorption of inorganic could occur. From physiology, it aimed to understand physiological process and effect on how hydrocarbon and heavy metal pollute the environment and harm organisms. Other links were on economics view, on why we could not stop the industries because we needed it. The only way was the industries needed to make it less harm to the environment.

After a chapter met the end, there was a reflection box. Students could write down about lesson they have just learned, including their feelings and new perception emerge after they understood new knowledge to save the environment. By describing their learning journey in reflection, students could personalize or contextualize the knowledge and transform it from implicit to explicit knowledge\(^{[6]}\). There was the last syntax, authentic assessment. It did not integrate in learning materials because this kind of assessment needed process of learning in the classroom to assess all of the learning process that students did. Though in every chapter ends, there was an evaluation parts with questions from low to high order thinking type of questions to evaluate the students’ comprehension. All of the process to implement CTL showed the interdependence, constructivism and active learning to connect the theories with real world problems.

The next validity content was layout and presentation. It obtained very valid criteria because learning materials had LO and LO indicator to achieve after learning, materials organized based on LO that arranged systematically, sub-chapter organize systematically, material presenent integrate with CTL syntax, components of learning materials information were clear, and learning materials as general met the standard of learning materials anatomy.

Validity from graphics evaluation obtained valid criteria. The aspects of evaluation from learning materials book cover had shown the identity of materials; the color selection that used in learning materials well blended, comfort the eye of readers and did not distract the focus. Font selection support the formal look of learning materials as scientific property and the size of fonts were
proportional. Pictures size, keyword and description were proportional, placed neatly and consistently. Description of pictures and link of videos followed by clear and functional keywords.

The last validity evaluation was linguistic aspect, obtained valid criteria. Learning materials developed based on Indonesian language rules, logic, effective and efficient sentences, and clearly communicate the ideas of learning materials.

3.2.3. One to one evaluation. The data of one to one evaluation were collected through interview from three students after they studied bioremediation with prototype of learning materials. Data obtained: 1) instructions on how to use the learning materials were clear so there was no obstacle, therefore easy to use; 2) some graphics colour were too strong and distract the focus; 3) typos were still found; 4) pictures and descriptions helped to understand the material however there was a description got cut; 5) pictures of polluted environment provoked students concern so they had good impression towards learning materials; and 6) it helped students to prepare themselves before lectures.

Therefore, points 2 and 4 were revised and the research was continued to practicality stage from small group of students and lecturer evaluation.

3.2.4. Small group evaluation. Small group of students studied bioremediation with learning materials prototype. After that, they answered the questions from instrument of practicality. The result are shown in Table 4.

| Aspects                        | Percentage (%) | Criteria       |
|--------------------------------|----------------|----------------|
| Practical in use               | 84             | Very Practical |
| Benefit obtained               | 86             | Very Practical |
| Efficiency of learning time    | 80             | Practical      |
| Mean                           | 84             | Very Practical |

All of the aspects of practicality learning materials achieved very practical and practical criteria, therefore the mean was very practical. Aspect of practical in use achieved very practical criteria because of students could learn the material easily due to its clear instructions for the use, material was described communicatively, and supported by the presence of pictures and video they could access to make easier to understand the concepts. The cognitive function of pictures and videos as media was intended to focus and direct students’ attention to the material for better comprehension [27]. The use of video media in learning affects learning outcomes, therefore it was worth to use for learning process [21].

The aspect of benefit obtained from the use of learning materials achieved very practical criteria. It means the students could learn bioremediation material independently with learning materials, able to connect real-world problems with materials discussed, facts from environment pictures and videos lead to meaningful learning, materials presented was relevant to current issues regarding bioremediation because it referred to the latest research articles. The research articles needed to broaden students’ insight to sparks the idea for their future research topics and current issues were important because it expanded the students’ comprehension of material when they could see and connect the materials with other aspects [22].

The last aspect was the efficiency of learning time using learning materials to study bioremediation, and it achieved practical criteria. It means that lectures on bioremediation topics using learning materials met time efficiency to understand the materials. In preliminary research, the problem was the unavailability of structured basic concepts of bioremediation, therefore students needed to read many articles to understand the concepts of bioremediation. This process took a lot of time and raised the possibility of not achieving learning outcomes because students could not find the proper articles and compounded by English as language barrier. Thus, the availability of structured
basic concepts of bioremediation learning materials could save the time and effort. Practical in time aspect also mean the students could adjust their speed of learning and reduced the time spent to explain the same concept.

3.3. Assessment phase

3.3.1. Practicality. Lecturer who taught biotechnology courses with the topic of bioremediation evaluating the learning materials. The result of practicality evaluation from lecturer as a user are shown in Table 5.

| Table 5. Result of Practicality from Lecturer as a User |
|-----------------------------------------------|----------|--------|
| Aspects                                | Percentage (%) | Criteria |
| Practical in use                        | 89       | Very Practical |
| Benefit obtained                        | 98       | Very Practical |
| Efficiency of learning time             | 79       | Practical |
| Mean                                   | 91       | Very Practical |

The three aspects of practicality component achieved very practical and practical criteria, thus the mean was obtained very practical criteria. Practical based on lecturer’s view meant that learning materials helping the lecturer in learning process because it helped students to improve and equalized the concept comprehension of bioremediation. When the users considered the learning materials to be usable and that was easy for them to use, the intervention of learning materials was largely compatible with the developers intentions, it means that learning materials achieved practical.

3.3.2. Field Test. After two meetings of bioremediation discussion in the class, students’ comprehension were tested. The test was in essay format with variety questions from low to high order thinking level based on Bloom cognitive taxonomy. Test result of thirty-four students’ comprehension are shown in Figure 1.

![Figure 1. Test Result of Students’ Comprehension of Bioremediation](image)

The figure showed the test result of majority students achieved good grades. The learning materials meets the effectiveness if > 75% students’ achieve B- grades as minimal on the test. The number of students who achieved grades A to B- were twenty-eight (28) and 82,3% in percentage, therefore learning materials were effective to improve students’ comprehension of bioremediation.

The good grades were related to students’ positive perceptions toward materials. They paid attention to stimulus of learning materials main purpose therefore they realized about damage caused by pollutant and how to remediate it with environmental friendly process, it was bioremediation.
Students received the stimulus and responded by showing the interest and active in discussion\textsuperscript{[12]}. It was a reflection of the effective learning process because of students’ active learning and enhanced by lecturer clarity to lead the learning process\textsuperscript{[9]}. High participation of students in lectures process would not happen if they did not have basic concept they studied before attending the class. Therefore, students who prepared themselves before the class assumed would achieve good learning outcomes\textsuperscript{[31]}.

Thus, it can be concluded that the learning materials met the effective criteria because of practicality and students assessment test passed the standard.

4. Conclusion

Development of Bioremediation Learning Materials based on CTL were valid, practical, and effective. The valid criteria achieved because of learning materials met the criteria of content egibility, proper layout and presentation, proper graphics arrangement, and proper of linguistic aspect by following the rules of Indonesian languages properly. The practical aspects achieved very practical criteria based on students and lecturer as the users. The learning materials was practical in use, giving benefit for students and lecturer because it helps in learning process, and time efficient for learning process. The effectiveness evaluation met the effective criteria because the learning materials obtained practical criteria from lecturer evaluation and succeed to improve students’ comprehension of bioremediation.

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