Scaffolding design to improve pedagogical competence of natural sciences for pre-service biology teachers

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Abstract. This research aimed to develop the curriculum and module of natural science curriculum development for junior high school subject. This work is a research and development study. The development model used in this research was ADDIE. The results of validator assessment for the suitability of teacher’s qualification standard for the content knowledge = 3.8 (extremely valid). The suitability of teacher’s qualification standard for the content of pedagogical = 3.9 (extremely valid). Then the curriculum is developed into a module. The design of module is according to the principle of scaffolding. The most basic level contains the most complete example of cross-disciplinary integration. The second level is about the integration between sub-disciplines in science, the completeness of the example is reduced. Scaffolding at the highest level, fewer examples. The third level concerns aspects of pedagogical skills. Examples are given in two forms namely Curriculum 2013. Module 2 and 5 gaining 100% responses liked by the students are categorized practical. The hardest one to be understood is module 4. Module 2 is the most effective one in which the students achieved the highest score of 96. Module 3 is the most difficult one to be completed; the students’ mean was 47.

1. Introduction
Integrated sciences subject was initiated in 1969 as a UNESCO program to be implemented in primary and secondary schools. All members of UNESCO are subject to such program. UNESCO has held six international meetings and conferences to discuss science and integrated science. In general, the results of the meetings show that there are many challenges in teaching the integrated science. Due to the research findings, each country is facing different challenges. [1] stated that it is crucial to prepare the natural science teachers in junior high schools. [2] strengthened such opinion by their results on various issues in primary and secondary schools teacher education and in designing an effective education program for integrated natural sciences teachers. [3] also pointed out the importance of preparing natural sciences teachers in the elementary school and junior high school so that they can teach socio-scientific issues in accordance with the curriculum demand in Turkey. [4] showed that through their research findings that it is significant to prepare teachers in order to have self-confidence in teaching natural sciences through inquiry.

Regarding the preparation of natural sciences teacher in many countries, one of the problems faced by Indonesia is the lack of elementary school and junior high school teachers. The Ministry of Education and Culture, the ministry that covers the primary and secondary education in Indonesia, mentions that the elementary school needs 460,542 teachers, junior high school needs 301,149 teachers, and the senior
high school needs 110,277 teachers. However, the Minister of Education and Culture states that the hiring of civil servant teachers will be prioritized out of Java which is greatly lacking the teachers [5].

The Department of Biology of the State University of Malang has double-field; the pre-service teachers have the chance to teach natural science in the junior high school for field practice lecture program. One of the subjects related to the enrichment of natural science competency is the development of natural science curriculum for junior high school. This work is a research and development aiming at arranging the curriculum and developing the teaching material for the subject of the development of natural science for junior high school in the Dept of Biology Education, Faculty of Mathematics and Natural Science, State University of Malang. That subject has not had the curriculum and teaching material developed in a module that is in accordance with the Regulation of the Ministry of National Education of Republic of Indonesia No 16 of 2007 on Academic Qualification Standard and Teacher’s Competency in Indonesia. Such regulation rules the educational qualification of teacher of preschool (PAUD) until senior high school, the competency that must be owned by teacher including pedagogical competence, professional competence, social and personality competences. The curriculum adopts the pedagogical, professional, and personality competencies for the natural science teacher for junior high school. This paper focuses on the pedagogical and professional competencies.

2. Methods

This research employed quantitative descriptive approach. The type of the research is research and development that is developing the curriculum and the module of the subject of natural sciences curriculum development for junior high school. The research questions are 1) how is the validity of curriculum developed? 2) How is the practicality of the module developed? 3) How is the effectiveness of the module developed?

2.1. Procedure and Data Analysis

The development used ADDIE Approach as its model or procedure. ADDIE approach consists of five cycles, namely analyze, design, development or production, implementation or delivery and evaluations [6]; the core of such five stages is evaluation. Every step could be evaluated and revised, and then continued to the next step. There are three phases of test namely validity, effectiveness, and practicality.

The first preliminary study was conducted in December 2014, the second one was in April 2016. The interview and questionnaire distribution were undertaken in April 2017 to strengthen the need analysis. The implementation stage to obtain the data of practicality and effectiveness was carried out in the Department of Biology, Faculty Mathematics and Natural Sciences, State University of Malang. The implementation step used two classes of the subject of the natural sciences curriculum development for junior high school (NSCD for JHS). This particular subject has two meetings in a week so there were four meetings for two classes in a week. The number of the students in each class is 13 people. The research was conducted for one semester, the semester of 2016/2017, started from the end of January 2017 – the end of May 2017.

2.2. Curriculum Validity

The validity of the developed curriculum and module was assessed by three experts. The first expert was from the Department of Biology, State University of Malang; he masters in learning. The second expert was from the Department of Physics, State University of Malang; he masters in the content of physics and biology. The third expert was from the Department of Physics, State University of Surabaya; he masters in the curriculum. The assessment of the material validity refers to A) the suitability of subject curriculum – in the form of lesson plan with the Regulation of the Minister of National Education of Republic of Indonesia Number 16 of 2007 on the Teacher’s Competency Standard in Indonesia. B) The suitability of curriculum with the module. The assessment technique was done by sending the material of the assessment in the form of 1) lesson plan, and module and 2) assessment instrument, to each expert. Every expert assessed individually. The assessment results were matched with the following table.
Regarding the assessment of validity and work product, the instrument must fulfill the requirement of reliability. The instrument is stated reliable if the gained R score = 70% < R ≤ 90% (referring to Table 2). The assessment of the instrument reliability was done by two people that assessed the same product using the similar instrument; the results are entered in the formulation:

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R = 1 - \left( \frac{A - B}{A + B} \right) \times 100\%
\]

\text{R = Instrument reliability (percentage of agreement)}
\text{A = Assessment from the first expert}
\text{B = Assessment from the second expert}

### Table 1. Criteria for Validity

| Interval Score | Criteria (Qualitative) | Note |
|----------------|------------------------|------|
| 3.25 < α ≤ 4.00 | Extremely valid | It can be used without revision |
| 2.50 < α ≤ 3.25 | Valid | It can be used with a few revision |
| 1.75 < α ≤ 2.50 | Moderate | It can be used with many revisions |
| 1.00 α ≤ 1.75 | Less | It cannot be used, need consultation |

#### 2.3. Practicality

Practicality was assessed based on the students’ responses to the module utilized. If the students’ responses result in the number = 70% < P ≤ 90%, the module is stated as practical [7]. see Table 2.

### Table 2. The Assessment of Practicality

| P Score | Criteria |
|---------|----------|
| 0.90 < P ≤ 1.00 | Very good |
| 0.70 < P ≤ 0.90 | Good |
| 0.50 < P ≤ 0.70 | Good enough |
| P ≤ 0.50 | Less good |

#### 2.4. Effectiveness

The effectiveness was assessed using the rubric of product (work result). The students are considered mastering the competency of knowledge and skill if they achieve the minimum score of C = 55% – 59% (based on the Guideline Book of Education of State University of Malang, ed. 2010).

### 3. Results and Discussion

#### 3.1 Validity, Practicality and Effectiveness

The results of validator assessment for the suitability of teacher’s qualification standard for the content knowledge = 3.8 (extremely valid). The suitability of teacher’s qualification standard for the content of pedagogical = 3.9 (extremely valid). Then the curriculum is developed into a module. The design of module is according to the principle of scaffolding. The most basic level contains the most complete example of cross-disciplinary integration. The second level is about the integration between subdisciplines in science, the completeness of the example is reduced. Scaffolding at the highest level, fewer examples. The third level concerns aspects of pedagogical skills. Examples are given in Curriculum 2013. Module 2 and 5 gaining 100% responses liked by the students are categorized practical. The hardest one to be understood is module 4. Module 2 is the most effective one in which the students achieved the highest score of 96. Module 3 is the most difficult one to be completed; the students’ mean was 47.
3.2 The Development of Module Material

The topic of the knowledge of the relationship of natural sciences with the other subjects taken are multidisciplinary, interdisciplinary, intradisciplinary, and transdisciplinary. This module already contains examples of Indonesian curriculum integration approaches written by researchers. The topic of understanding the correlation among natural science sub-disciplines are refers to Fogarty’s model, but only four models that were developed into complete example in Indonesian curriculum, the example of learning design until the development of concept and tool. The three models that were completely discussed are fragmented, connected, nested models and webbed.

The module applies the principle of scaffolding that is explained in Figure 3. The higher the module level, the assistance in the form of example is reduced. The module is chosen as the teaching material for some reasons: 1) The module compiles the material, 2) the module also provides the examples of integrated curriculum development in accordance with the applied curriculum in Indonesia, 3) the module is completed with the student worksheet, 4) the module is completed with the rubric of work product evaluation as well.

3.3 Scaffolding Design for Module

[8] clearly described the procedure of providing scaffolding to students of the education in developing e-Portfolios in the course of ICT for education. Masters supervised his students to write electronic portfolios and provided gradual assistance. On the initial stage, the students were guided to be able to develop electronic portfolios which present the students’ learning journey. The guidance was gradually stopped. The students who could develop electronic portfolio were given the chance to learn independently. Those who could not develop were still guided. This research was conducted in three years.

Figure 1 shows the design of module scaffolding in this research. The higher the stage, the lesser the assistance. The most basic level compiles the most complete example. The first example is the topic of combining. The most complete example is based on various literatures stating that the crucial thing in preparing the natural sciences pre-service teacher is by giving the understanding of the integrated curriculum. What a teacher brings to the classroom is based on his/her previous knowledge the teacher’s previous knowledge, beliefs, and ideas, as well as experiences in his/her previous study, affect what he/she will learn and what he/she will teach. As the students in general, teachers are required to have the integrated knowledge.

The basic stage of scaffolding was also compiled based on the validator’s suggestion. The first validator, as the expert of learning field, gave input in term of concept expansion to clarify the scaffolding during the learning process. The scaffolding was required especially in the examples of integrated model and approach until the development of the concept. NSCD for JHS is a difficult course subject according to the lecturers who teach it. The lecturers should use alternative supports in guiding the students to do the tasks.

In the second stage, the example completeness is reduced but the example of the sequence of intradisciplinary topic that compiles the topic of physics and the connection physics and biology is completely provided. This case is based on many research reports showing that the biggest difficulty of biology and natural science students is understanding the physics concept [9][2]. The results of physics test for the first try out on December 2014 reached the mean of 33.23. The physics test in the second test on April 2016 obtained the mean of 61. [2] stated that in 1990/1991, Department of Integrated Natural Sciences is available in all universities of education in Nigeria. However, the reports of research show that this program is not yet successful. One of the causes is the less harmony relationship of lecturer and students. Besides, the students are afraid and dislike to physics, and they think that the course of physics is too mathematic and abstract.

Back to the assistance that will be provided in the module. The completeness of the scaffolding in the highest stage has decreased. In this stage, the students will develop the transdisciplinary using problem base learning - PBL. The assistance in this step is based on the qualification pedagogic
competence of junior high school teachers. The pedagogic competence is related to the mastery of educational skill and junior high school learning. The examples are provided in Indonesian curriculum.

Modules can indeed help students understand the material and do the task well. The module can be categorized as scaffolding because it contains worksheets with easy-to-understand instructions. One form of scaffolding is writing step-by-step instructions to guide students in completing tasks. The following research uses modules as scaffolding and making students able to do the task well. Researchers from Thailand developed 4 modules in a computer programming course. The four scaffolding modules consist of metacognitive scaffolding, conceptual scaffolding, strategic scaffolding, and procedural scaffolding, each of which is represented by a 3-D animation cartoon to attract students' attention. Scaffolding module can be used to complete the task successfully collaborative PBL [10]. Research from Malaysia also uses modules as scaffolding. This research is about remedial learning in English for low level elementary students. The researcher developed a ScafoLIT module (scaffolding literacy) that can be used by teachers for remedial learning in English at the elementary level [11].

3.4 Scaffolding Model for Student

The assistance in this research was given by the lecturer in some models. First is verbal explanation and the second is giving example and explaining the procedure to finish the task. The third is the lecturer also guides and provides solution if there is a group that is difficult or not able to accomplish the task. The help in this research is in accordance with the description of scaffolding by Vygotsky. Another form of scaffolding is in the form of task related to the students’ contextual knowledge. This help is called bridging. Bridging is the way to connect the students’ pre-knowledge and the new information or new concept by organizing the knowledge and understanding [12]. The difference in conventional learning and scaffolding is the intensity of mentoring to the learners. The next form of scaffolding is reviewing and highlighting important things in the task. Students can discuss individual ideas in group discussions.

![Scaffolding Design for Module](image-url)

**Figure 1. Scaffolding Design for Module**
assisted by lecturers. The lecturer will help to analyse individual ideas, then students choose the right idea according to the task and evaluation standards in the module. This kind of assistance includes reviewing, students asked to understand the task and see the assessment rubric to find out the standards evaluation for the student's work. Engin [13] conducted discussions between trainers and preservice teachers to assess good teaching methods. This assessment is understood and agreed upon by both parties. Understanding of the expected evaluation standards also includes scaffolding.

4. Conclusion
The assessment result from the validators regarding the curriculum was extremely valid. Based on the implementation result of module 2 and 5, both of them were 100% preferred by the students. Module 2 and 5 are categorized practical with the very good response. They could do the task without any significant difficulty. Module 2 is the most effective module where the students gained the highest score of 96. Module 3 is the hardest one to do; the students’ outcome was 47. The most difficult to understand is module 4 where the students must improve the connection tool between physics and biology.

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