Design and validation of general biology learning program based on scientific inquiry skills

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Abstract. Scientific inquiry is highly recommended to teach science. The reality in the schools and colleges is that many educators still have not implemented inquiry learning because of their lack of understanding. The study aims to 1) analyze students’ difficulties in learning General Biology, 2) design General Biology learning program based on multimedia-assisted scientific inquiry learning, and 3) validate the proposed design. The method used was Research and Development. The subjects of the study were 27 pre-service students of general elementary school/Islamic elementary schools. The workflow of program design includes identifying learning difficulties of General Biology, designing course programs, and designing instruments and assessment rubrics. The program design is made for four lecture sessions. Validation of all learning tools were performed by expert judge. The results showed that: 1) there are some problems identified in General Biology lectures; 2) the designed products include learning programs, multimedia characteristics, worksheet characteristics, and, scientific attitudes; and 3) expert validation shows that all program designs are valid and can be used with minor revisions. The first section in your paper.

1. Introduction
The curriculum in Indonesia emphasizes that all courses should contribute to the formation of attitudes, skills and knowledge while learning in the classroom [1,2], especially in the science subjects [3]. The learning process in developing active students require longer time to conduct observation, inquiry, association, care, and communication [4]. Among those, inquiry is the main learning standard in teaching science [5]. Science contributes many things in improving the ability of scientific work (scientific inquiry), critical thinking, problem solving and communicate that are needed by students as the preparatory provision to be effective future workers and excellent people in the 21st century [6]. Scientific inquiry refers to students’ activities in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world [5]. Scientific inquiry is a multiphase activity involving observation; asking question; creating hypotheses; checking references and information sources to see what is already known; planning an investigation; reviewing what is already known in experimental evidence; using tools to collect, analyze and interpret data; proposing answers; explaining using graphs or statistical data, predictions; and, communicating the results [5,7]. The scientific process through scientific inquiry also shapes students' attitudes such as curiosity, scepticism, cooperation, and accepting criticism [6].
The research of Jeffery, Nomme, Deane, Pollock, & Birol [8] on the investigation of the role of inquiry-based Biology laboratory courses indicates a positive correlation to students' attitudes and views towards Science course, where there was found an increased confidence and interest in scientific inquiry. A study conducted by Famlari, Da Silva, Rayner, Young, Cross and Blanksby[9] in a Biology class stated that scientific inquiry can improve understanding of biological contents (100%), developing skills such as collecting and interpreting data and drawing conclusions accurately (92%), and communicating these results in the form of scientific reports (95%). Furthermore, the results of Thoron and Myers’ [10] study adds that inquiry-based learning can improve the scientific reasoning, a process connection generates science based on evidence/data. In general, the learning of Biological Science Inquiry is more effective than conventional biology learning approach [11].

Biology as a science may decrease that ability, where Biology education at schools and universities has not been provided satisfactory results among science courses. Similarly, there are still many teachers and lecturers who have not implemented inquiry learning in teaching science. Their reasons, among others, are the difficulty in the implementation, the impracticability of which making it suitable for high-achieving students, and requiring a lot of time [6]. The main thing that becomes the problem is the teacher’s lack of understanding in developing proper instruments based on scientific inquiry skills. Therefore, the exposure of instruments is needed to enhance the measurement of the scientific inquiry skill [7]. The responsibility for improving the understanding of pre-service teachers about scientific inquiry as well as the ability to design and implement reform-based instruction are on the shoulders of educators/lecturers [12].

The scope of the course of General Biology contains knowledge of basic concepts of biology, organizational life, physiology of the body of living beings, as well as education on the environment and the natural surroundings. Learning objectives should adopt the formation of attitudes, skills and knowledge. Selection of technology-based media and appropriate learning models / methods is required to implement the various materials. In relation to achieving learning objectives, the assistance of multimedia has contributed in explaining abstract things and showing hidden things, obscure or complex teaching materials [13]. Multimedia itself refers to the use of computers to present text, graphics, video, animation, and sound in an integrated learning process [14]. Krishnamoorthy and Perumal reported that multimedia is one of the effective learning media that stimulates the interest of learners and motivates them to acquire knowledge and skills [14]. A better learning can be achieved when using audio-visual materials that are close to reality, where in Biology class, there are many abstract concepts. In General Biology learning, there are some abstract concepts that are not easy to learn directly and taken into the classroom during the learning [15], which further require the help of multimedia to explain the complex materials and natural phenomena[16].

Learning tools and instruments developed in the research are student worksheet, assessment rubric, lecturer and student observation sheet, instructional multimedia, attitudinal observation sheet and student response questionnaire. These learning tools are tested for validity. Inquiry learning involves a variety of student activities and skills, of which the focus is the search for knowledge or active understanding and satisfying curiosity [17]. Scientific inquiry in addition to building skills and understanding of investigative-based concepts also builds scientific attitudes that may affect student performances, such as conveying opinions, reflecting on their work, being more diligent, cooperation, prediction based on data, submitting investigative results, and being sceptical. The development of scientific attitudes is just as important as the cognitive aspects of science education [18]. Scientific attitude encourages questioning and the spirit of inquiry. Without that attitude, then science learning is only acceptance [18,19]. Such capability is required to produce qualified and required graduates in a globalized workplace [17], while high scientific attitudes positively correlated to student learning outcomes [20,21].

Multimedia learning can also be designed on General Biology materials. The draft, if applied, is expected to attract students' interest, generate passion and motivation of students, so as to develop conceptual understanding, scientific work ability/skills, and develop scientific attitude.
2. Methods
The objectives of the research are: 1) to analyze students' difficulties in learning General Biology course; 2) to design a General Biology course learning program based on multimedia-assisted inquiry skill multimedia; 3) to validate the program design. Research method used Research and Design.

2.1. The subject
The subjects are 27 pre-service teachers of SD/MI (elementary level) who enrolled in the subject of General Biology and Science

2.2. Data analysis
The program design workflow includes: 1) analysis of students’ learning difficulties obtained from the questionnaire; 2) the proportion of scientifically inquiry-based learning program, including a) program flow, b) implementation of learning in the classroom, c) multimedia characteristics, d) worksheet characteristics; and, 3) instrument validation by expert judgement. All instruments were designed based on scientific inquiry indicators, namely: 1) collecting data; 2) formulating the problem(s); 3) determining the tools (variable), 4) formulating the hypothesis; 5) predicting, 6) calculating; 7) graphs/data/drawings, 8) conclusion; and, 9) communication [5,22]. The observed scientific attitudes are: 1) curiosity, 2) expressing opinions, 3) cooperation, 4) responsibility, 5) creativity, and 6) care for the environment [20,21,23,24]. The scientific attitude developed and observed during the learning (indirect teaching) were evaluated by using the Likert scale ranging from 1-4. The validation of the instrument was conducted by two experts’ judgment with Likert scale ranging from 1-5.

3. Results and discussion
3.1. Identification of learning problems
The result of questionnaire analysis toward students who had taken the General Biology course shows that there are several difficulties identified during the process of learning in General Biology course. The results of the questionnaire analysis of biological learning problems are shown in Table 1. Assessment for numbers 1-5 using a score of 1-4, with categories: 1 = very easy; 2 = easy; 3 = quite difficult; 4 = difficult and many. However, the scoring for number 5-7 use a score of 1-4, with the categories: 1 = bad; 2 = less; 3 = enough; 4 = good.

| No. | Aspects of the problem       | Score | Information   |
|-----|-----------------------------|-------|---------------|
| 1   | Course material             | 3.58  | Very difficult|
| 2   | Amount of material          | 3.55  | Very difficult|
| 3   | Tasks                       | 2.97  | Quite difficult|
| 4   | Submission of material      | 2.89  | Quite difficult|
| 5   | Learning method             | 2.75  | Quite difficult|
| 6   | Instructional media         | 2.30  | Insufficient  |
| 7   | Library facilities          | 2.25  | Insufficient  |

The lecture material is considered especially difficult because it is related to the abstract concepts. The difficulty is also present in the high amount of materials that use many Latin words. The tasks assigned to students are also considered to be difficult enough to be done or understood by the students, which is reflected in the score of 2.97. In terms of material delivery by lecturers, the value of 2.89 indicated that it is also considered quite difficult to understand as it may be related to the limitations of learning media used that hinder the process of learning that materials. Students’ learning method is also found to score enough difficulty in 2.75, which indicated that in the first semester, the freshman students must adapt to the new style of their lecturers in new places (universities) in addition to using most general students’ learning style in the form of repeated memorizing[25]. They assume
the abstract biological knowledge to be unrelated to their everyday life [26]. Additionally, there is another problem caused by the inadequate usage of references in their Biology textbooks[27]. However, as Prokov, Prokov, and Tunnicliffe[28] convey, in general, female students possess more positive attitude towards Biology compared to the male students. In order to make Biology learning more effective, it is suggested that the teachers teach biology through the use of visual materials, conducting practical experiments, and connecting topics of everyday life [26]. Prokov, Prokov, and Tunnicliffe also suggested that the experiment can be conducted through group work or other inquiry activities. The implementation of inquiry and scientific investigation activities may increase students' confidence and interest in scientific investigation, hone their critical thinking skills and understand concepts better [8].

3.2. Design of biology learning program

The design of the General Biology-based learning program inquiry and multimedia-assisted is designed in four chapters: Cell Reproduction, Basic Ecology, Natural Resources and Conservation, and Climate Change. The flow of program design is as follows.

![Diagram](image)

**Figure 1. General Biology Based Learning Program in Multimedia-Assisted Sciences**

In the figure, the flow of program includes: 1) selection of topics to be asked, 2) determining scientific inquiry indicators on inquiry learning and designing the instrument, 3) designing/selecting multimedia to explain the topic of learning area, and 4) multimedia is used as a source to explore the information of the problem. The design integrates cognitive aspects, scientific inquiry skills and attitude development.

The characteristics of multimedia itself are as follows: 1) selection of material/sub-section in accordance with the learning model; 2) multimedia content contains observed indicators; 3) multimedia content takes no more than 5-7 minutes; and, 4) multimedia provides information to answer the problem.

Meanwhile, the characteristics of the worksheet are: 1) multimedia-aided scientific inquiry skill worksheet; 2) worksheet refers to nine indicators of scientific inquiry; and, 3) multimedia displays become sources of information/data to answer and discuss worksheets.

Here is an example of a climate change worksheet based on scientific inquiry indicators

*Worksheet Student Climate Change*

1. Assignments before using multimedia:
   1. Check the multimedia/movie to be watched!
2. Record the information/data that you think to be important related to the questions on the worksheet.

II. Assignment After Multimedia / Movie Views;
   1. Discuss the problem(s) stated in the worksheet in a group of 2-3 people
   2. Create an individual report and submit it at the end of the session.

III. Problems
   1. Arrange the information and data you get from multimedia neatly and clearly!
   2. Define some of the problems found on the movie show!
   3. Make a hypothesis of the problem formulation you made!
   4. Formulate independent and dependent variables from the hypothesis you have created!
   5. Draw a graph of the relationship of the concentration of CO$_2$ to the temperature change!
   6. In relation to question 5, what will happen to CO$_2$ gas and the temperature of the earth if the tree planting is done continuously?
   7. If there is 5 kg of waste containing methane, calculate how much CO$_2$ is produced from the waste!
   8. Define the causes of global warming that you know!
   9. Formulate some conclusions about climate change!

   Observed scientific attitude indicators: (1) curiosity, (2) expressing opinions, (3) cooperation, (4) responsibility, (5) creativity, and (6) care for the environment [20,21,23,24]. The scientific attitude was obtained from the attitudinal observation during the learning session by using Likert scale from 1-4. Meanwhile, the observations were conducted in accordance to the student groups.

3.3. Instrument validation
Instrument validation is obtained from two validators. Questionnaire validation contains 28 statements consisting of worksheet sheet, assessment rubric, observation sheet, attitude observation sheet, multimedia content and student response sheet. The scales range from one to five.

| Type of learning tool / Instrument                  | Validator score I | Validator score II | Average score | Score | Info |
|---------------------------------------------------|-------------------|--------------------|---------------|-------|------|
| Student worksheet (4 items)                       | 16                | 16                 | 16            | 80    | Valid|
| Assessment rubric (5 items)                       | 18                | 20                 | 19            | 76    | Valid|
| Observation Sheet (5 items)                       | 21                | 22                 | 21.5          | 86    | Valid|
| Attitude Lookout Sheet (4 items)                  | 15                | 16                 | 15.5          | 77.5  | Valid|
| Learning Multimedia (6 items)                     | 24                | 23                 | 23.5          | 78.3  | Valid|
| Student Response Sheet (4 items)                  | 15                | 16                 | 15.5          | 77.5  | Valid|
| Average Value                                     | 15                | 16                 | 15.5          | 77.5  | Valid|

The criterion of the percentage of the validity from quantitative to qualitative: (A) 86% -100%, very valid; (B) 70% -85%, valid; (C) 60% -69%, less valid; (D) 0% -50% invalid [29]. The result of instrument validity is 79.2%, indicating that the instrument can be used with minor revision. The assessment rubric has been slightly revised and associated with each scientific inquiry indicator. Students and lecturer observation sheets were observed based on indicators of scientific inquiry attainment. Scientific observation sheets are observed directly using the Likert scale based on the demonstrable attitudes during the session. The duration of multimedia has been shortened from an average of 10 minutes to 3-6 minutes. Shortening the duration of multimedia is expected to contribute additional time for students to discuss.
4. Conclusion

There are several conclusions that can be inferred. There are some problems identified in learning General Biology, including too much materials containing many Latin words, the difficult tasks that are not supported by the availability of adequate literature, and inadequate motivation promoted by learning media. Interventions have been made to overcome the problems by designing multimedia-based inquiry learning program, where the multimedia is used as a tool to promote information inquiry. Aspects observed/assessed in the program are scientific inquiry skills, cognitive ability, and scientific attitude. Objective indicators include 1) using data, 2) formulating problems, 3) formulating hypotheses, 4) determining variables, 5) using mathematics/counting, 6) making tables/graphs, 7) predicting, 8) making conclusions, and 9) communication. The scientific attitudes observed include 1) curiosity, 2) expressing opinions, 3) cooperation, 4) responsibility, 5) creativity, and 6) care for the environment. The result of validation of the instrument shows that the instrument was valid with minor revision.

This study concludes that there are some improvements made on the development of learning materials, including syllabus, teaching materials of scientific based basic biology, lesson plan, multimedia learning, students’ worksheet, evaluation rubrics, scientific work test, observation sheets over students and lecturer’s activities, and evaluation sheets on students’ attitude, and students’ responses sheets. The materials covered three chapters about awareness of environmental issues and one chapter about reproductions. The multimedia teaching aids were developed in reference to students’ needs to search for information and data for their inquiry. The indicators of scientific inquiry this study developed include the ability to collect data, formulate problem, formulate hypothesis, define variables, make predictions, counting, develop graphics, communicate findings, and draw conclusions. Validation test indicates that the learning materials are valid, reliable, practical, and effective. The study also found that time management, audio equipment, and computer were some of the factors that inhibit the process of the material development.

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