ISSN No:-2456-2165

The Development of Introductory Physics Teaching Materials in a Biological Context Based on Scientific Creativity

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Abstract:- Introductory Physics learning for biology students of UIN Walisongo has not used teaching materials that accommodate students' needs in a biological context, so the students are skeptical of the relevance of this course to biology. In addition, the teaching materials have not accommodated to develop students' scientific creativity. This study is aimed at developing a model of Introductory Physics teaching materials in a biological context based on scientific creativity and finding out the students' response to the use of it. The data was obtained from assessment experts and students using questionnaires. The results showed that the characteristics of IP teaching materials can be seen from two things, namely the application of physics in biology and scientific creativity activities. The quality of IP teaching materials is good. The feasibility score of IP teaching materials is 3.71 or Very Eligible. While student responses to the use of IP teaching materials are good, with an average score of 3.16.

Keywords:- *Teaching Materials, Physics, Biological Context, Scientific Creativity.*

I. INTRODUCTION

Many people think that creativity is only related to art and not to science. However, this has been refuted by various studies. Meador (2003) states that science learning has a very close connection with creativity, so that there is an opportunity to encourage creativity in science learning. The National Education Commission (1964-1966), known as the Kothari Commission, recommended the need to develop creative thinking as one of the objectives of science education (Mukhopadhyay & Sen, 2013). In addition to being oriented towards the development of scientific creativity, science learning is also directed towards cross-disciplinary science learning. The National Academy (2009), National Research Council (2003) and AAMC-HHMI (2009) recommend that science learning be implemented across disciplines (Watkins et al., 2012). This is intended to raise students' awareness that the fields of knowledge in science are interrelated and require each other. Based on this thought, many colleges have applied interdisciplinary science learning, one of them through The Introductory Physics for Life Science (IPLS) for science students. IPLS is different from the Introductory Physics course for physics and engineering students that emphasizes Calculus-based Introductory Physics (Crouch & Heller, 2014; Mochrie, 2016). IPLS and other physics courses rarely show physics ideas for biology. Even if it is related to biology, it is usually only done with examples or questions for homework (Watkins et al., 2012). Physics concepts such as energy and entropy are usually taught with a limited focus so that they are not relevant to biology. Finally, important topics for biology students, such as static and dynamic fluids, diffusion, and the effect of dielectrics on electrical interactions are taught superficially. Research on learning shows that placing physics in a biological context is very important for biology students to understand physics well.

The Introductory Physics (IP) is a basic course for students at the faculty of Science and Technology UIN Walisongo and serves as a foundation for the development of engineering, design, planning, and technology. However, during this time, IP learning has become very difficult for non-physics students due to the use of the same standards and demands as physics students. The main problem of IP learning among biology students is no common understanding among lecturers about the learning model, teaching media, and teaching materials. The IP learning approach emphasizes calculus rather than a biological context. In addition, the teaching materials used have not adopted the needs of biology students, so they feel skeptical about the relevance of IP to their academic needs (Mochrie, 2016). Therefore, it is necessary to develop teaching materials for IP in a biological context based on scientific creativity for biology students at UIN Walisongo Semarang. Accordance to the problems, this research aims to find a model of IP teaching material in a biological context based on scientific creativity and find out the students' response to the use of the teaching materials.

II. LITERATURE REVIEW

Research on interdisciplinary science courses, teaching materials, and scientific creativity has been widely carried out. One of them is research on the application of Introductory Physics for Life Science (Meredith & Bolker, 2012). Student responses to IPLS were very positive. As many as 90% of students were satisfied with the implementation of IPLS and more than 90% of students demonstrated their ability to see physics in the context of biology. Meredith and Bolker also recommend IPLS implementation strategies, namely rearranging IPLS topics, collaborating with biologists, realizing limitations or obstacles in implementing IPLS, using science learning research results, and mapping work plans for integration between physics and biology to be better.

Science learning success is not only determined by the learning method, but also by other learning components, one of which is teaching materials. Various studies on the use of teaching materials have proved to be influential on the success of learning, including research conducted by Crouch and Heller (2014). This research succeeded in restructuring IPLS with a biological context in order to bring up the concept of physics in biological science explicitly. Restructuring is done to the learning design and the equipment or teaching materials used. It also successfully demonstrated the role of biological context in IPLS learning and identified problems in learning. Park et al. (2010) have developed around 30 teaching materials to foster scientific creativity by using the AGA model, which is a teaching materials development model that consists of three stages, namely activity spontaneously, guides for creative thinking, and activity again. Students are given tasks or problems that must be solved at the first stage. For example, they modify the electroscope, suggesting new scientific hypotheses to explain observed phenomena, or suggesting new and interesting situations that show unusual phenomena. Students complete tasks independently and there are no instructions or guides to get involved in problem-solving activities. At the second stage, students are given current guides that can encourage their creative activities to help suggest new and unusual situations. Students are guided to change the usual structure or assumed conditions to think upside down. Finally, students are asked to apply the guidelines to other new situations, situations they have never found or thought about before.

The content of teaching materials cannot be separated from the context of physics learning, so it is necessary to understand the learning design that will be applied, including creativity in physics. Creativity in physics is explained as a multidimensional and very complex intellectual process related to knowing, understanding and applying different concepts, laws, principles, theories, formulas, and symbols in physics. Creativity is also related to efforts to help learners recognize the causes of problems, formulate problems, identify variables, find relationships between variables (build equations or use semantic relationships), find alternative solutions using analytical thinking, anticipatory imagination, and experimental verification if needed. These will help develop the learner's perspective in planning, find new relationships between conventional objects and similarities between seemingly different concepts, elaborate concepts, find various word associations with different scientific terms, use correct language in physics, connect various concepts and improve the quality of scientific products, encouraging different thinking in general and convergent thinking in particular.

Scientific creativity refers to the efforts of science teachers to encourage learning to think creatively or to produce something differently by thinking creatively (Hadzigeorgiou et al., 2012). Creativity in the context of science education must reflect as many scientific creative ideas as possible, scientific research that is authentic, meaningful and in accordance with the needs and abilities of students (Kind & Kind, 2007). This is also what is expected to happen in physics learning (Alrubaie & Daniel, 2014). However, the reality shows that science learning at the elementary, junior high, and high school levels has the same problem, namely not training students to engage in exploration activities (Nasri et al., 2010), problem solving, decision making, and thinking comprehensively. and creative (Amran et al., 2019; Daud et al., 2012)

The research above shows the importance of interdisciplinary science learning in colleges as an effort to develop students' scientific creativity comprehensively, especially in physics and biology. Therefore, the IP teaching materials at UIN Walisongo need to be organized in a biological context and based on scientific creativity.

III. METHOD

This research uses the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model to develop Introductory Physics (IP) teaching materials in a biological context based on scientific creativity. Data was obtained from expert assessments and students of IP courses at UIN Walisongo Semarang. The questionnaire is used to examine the feasibility of IP teaching materials and determine student responses to the use of IP teaching materials. The feasibility of IP teaching materials is assessed in four aspects, namely content feasibility, layout feasibility, language feasibility, and scientific creativity, which are described in 14 indicators and 28 questions. While the response questionnaires consist of three aspects and 18 statements and use a Likert scale ranging from 1 to 4 (Disagree, Disagree, Agree, and Strongly Agree). The assessment experts consist of three creative thinking experts in science learning from three teaching universities.

The results of the expert assessment of IP teaching materials and student questionnaires were analyzed from the average score and then converted into qualitative data based on the feasibility level of teaching materials as shown in Table 1.

ISSN No:-2456-2165

Table 1: Feasibility Level of Teaching Materials

Score	Level of Feasibility
$3.4 < \bar{x} < 4.0$	Very feasible, can be used without revision
$2.8 < \bar{x} < 3.4$	Feasible, can be used with minor revision
$2.2 < \bar{x} < 2.8$	Less feasible, can be used with major revision
$1.6 < \bar{x} < 2.2$	Not Feasible, need major revision
$1.0 < \bar{x} < 1.6$	Very inappropriate, can't be used

Source: Riduwan (2003)

IV. RESULTS AND DISCUSSION

A. The Characteristics and Feasibility of the Introductory Physics Teaching Materials in a Biological Context Based on Scientific Creativity

The characteristics of Introductory Physics (IP) teaching materials in a biological context based on scientific creativity can be seen from at least two things. First, examples of the application of physics in biology in each chapter. For example, the static fluid chapter describes the process of hydrostatic contraction in the worm's body so that the worm can move even though it doesn't have legs, insects walk on water due to surface tension, pressure on the infusion flow, and the movement of fish when swimming in water.

Second, section of "Scientific Creativity Activities". This section contains stages of activities that focus on developing four aspects of scientific creativity, namely fluency, flexibility, originality, and elaboration (Figure 1). For example, the activity in point a encourages students to produce valid answers or responses in a fast time (fluency). Therefore, the time limit for answering this order is an important factor that must be obeyed by lecturers and students. Points b and c contain questions that encourage the development of flexibility. Both questions require students to provide a number of answers that vary from different points of view, look for many alternative solutions, and use various approaches or ways of thinking about solving problems. Originality is developed through points d and e, while point f is directed at developing the elaboration aspect. Students are asked to predict the water level when the ice melts (which contains iron) and devise ideas so that plasticine can float on the surface of the water is quite a challenging activity because it is unique and requires students to think outside the norm. Original answers and ideas can only be generated if students are able to get out of the frame of mind of people in general. While at point f, students are invited to think in detail about the condition of canned drinks when put into water based on the data presented. Students are invited to analyze the relationship between physical quantities in the case and predict the probability that this could occur by revealing the reasons why it could happen.

G. *SCIENTIFIC CREATIVITY ACTIVITIES*

1. Objective
   a. to improve students' understanding of physics concepts in static fluids
   b. to train students' scientific creativity
2. Steps
   Lectures divide students into many groups, which is a group that consists of 3-4 students. Then the lecturer asked each group to do the following activity.
   a. Write as many static fluid phenomena in daily life (maximum time is 3 minutes)
   b. There are three types of fluids: oil, glycerin, and spirits. Write down two ways to find out which liquid has the greater density than the other.
   c. Figure 1 is an image of the connected vessel with A_1 is smaller than A_2. If you want $F_2 = 50F_1$, what can you do about the hydraulic tube? Give some possible solutions.
   d. An image of ice filled with iron is floating in a container filled with water (Figure 2). Predict the water level when the ice melts.

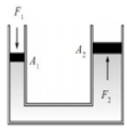

Figure 1

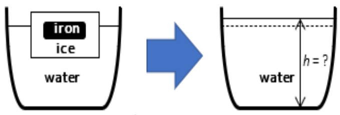

Figure 2

   e. Take a piece of plasticine and put it in the water. Observe what happens. Come up with an idea how to make plasticine float on the surface of the water.
   f. The data on sugar content in 330 ml soft drinks are presented as follows.

Soft drinks	Sugar content
W	10.6 g
X	8.2 g
Y	6.3 g
Z	9.5 g

   If the mass of the can and soft drink is the same, what is the condition of the soft drink when it is put into water? Which can is under more pressure and why is this happening?

Fig 1. Part of Scientific Creativity Activities

The feasibility score of IP teaching materials in a biological context based on scientific creativity can be seen in Table 2.

Table 2: Feasibility of Introductory Physics Teaching Materials

Aspects of Assessment	Score			Average Score	Level of Feasibility
	Expert 1	Expert 2	Expert 3		
Content feasibility	3.67	3.89	3.67	3.74	Very feasible
Layout feasibility	3.56	3.89	3.78	3.74	Very feasible
Language feasibility	3.17	4.00	3.67	3.61	Very feasible
Scientific creativity	3.20	4.00	4.00	3.73	Very feasible
Average Score				3.71	

Based on Table 2, the average score of the expert's assessment was 3.71 or very feasible with details, as many as 82.76% of the questions are very valid and 17.24% are fairly valid. Meanwhile, based on the assessment of each aspect, it is known that the language aspect gets the lowest score of 3.61, which is contributed by two indicators, namely "sentence effectiveness" and "motivational ability". This means that the sentences in the teaching materials have not been fully effective and have not motivated the reader to master the material in them. Other indicators that get low scores are the up-to-date facts and data (3.00), up-to-date examples and cases (3.33), and accuracy of examples and cases (3.33).

ISSN No:-2456-2165

The content feasibility and layout feasibility have the same score, which includes the suitability of the material with the learning achievement of the subject and the accuracy of the material. This means that the IP teaching materials have met the completeness, breadth, and depth of good material. In addition, it has presented the material accurately and clearly both concepts, definitions, facts, data, pictures, diagrams, illustrations, notations, and symbols, and the credibility of the library used. The language aspect has reached the lowest score, but it is still feasible, so it is necessary to revise the language aspect, which includes the suitability of writing, communicative, dialogic, and interactive sentences.

The assessment experts gave their opinion by answering supporting questions in the assessment instrument. They expressed their appreciation for the discussion approach in teaching materials that use the subject of living beings and contextual. This approach is rarely found in other physics teaching materials. In addition, it was stated that creative activities and problems that support the training of creative thinking skills have been presented well. They also stated that the advantage of this teaching material lies in the relevance of the physics learning context for biology students, so that the examples and concepts presented are relevant to the students' needs. In addition, this teaching material has accommodated critical and creative thinking skills. The statements of the experts show that this IP teaching material has advantages over other physics teaching materials. The advantage lies in the interdisciplinary integration of the biological context into the concept of physics and accommodating the development of students' scientific creativity.

Even though it has advantages, IP teaching materials still have shortcomings, namely the lack of supporting illustrations to connect one concept to another and the content of biological material in the form of scientific expression and quantity, so that information and data are needed and real in the field of biology. Therefore, it is necessary to make efforts so that the information and data presented are closer to the field of biology, but the nature of physics still looks real. The latest technological developments in the fields of biology and medicine can be used as a reference to foster student curiosity. The keyword for creative thinking is being able to solve problems in new situations or different contexts that still need to be improved. Creativity in most of the new teaching materials is reflected in the "Scientific Creativity Activities" section, while in other parts it is still not visible, so training creative thinking skills more intensively can be done by presenting problems in new contexts or situations for students. Similar issues have been discussed. Meanwhile, subject matter experts II found that the lack of teaching materials in the context of biology that had been developed had not been subtly related to the concept of physics, so that the concepts and context of physics in biology seemed less integrated with physics content before learning. context is explained. Furthermore, this material expert suggested that researchers develop biological contexts from the bottom and, hierarchically, the concepts in physics were derived to obtain a subtle formulation of the biological context so as not to impress biological concepts and contexts apart from physical concepts. A rough shift or separation of the concept of physics from biology will affect the reader's impression of the content of the material. As a result, readers will feel less comfortable with teaching materials.

According to the expert assessments, the IP teaching materials in a biological context based on scientific creativity can be used with minor revisions. The following is a part of the minor revision;

- The sentence "Physics divides fluids into two types" can cause a misconception because it is not physics that divides fluids, but the properties of fluids that form the basis of fluid categorization in physics. Therefore, experts suggest that the sentence be changed to "Fluids can be categorized into two types based on their properties". In addition, there was a lack of information and sentence structure errors that could potentially cause misinterpretation. The sentence reads, "Both fluids have the ability to …"
- It is necessary to have an introduction to any material that will be discussed in the next part so that students will know at a glance what they will learn. In addition, there needs to be a connecting idea between the type and nature of the fluid with the concept of force and pressure so that the inter-sentences do not come loose and feel harsh. It is also necessary to explain the reason why static fluids are discussed first and the suggestion to change the subtitle to "Force and Pressure in Static Fluids". This material expert's notes reflect the need for explicit connections between sentences so that students can understand the content of teaching materials more easily. The sentence structure that jumps will actually confuse students.
- The writing of symbols and equations is not consistent, especially vector quantities, such as force and pressure. The frasa "force vector" in figure 4.1. (in IP teaching materials) is accompanied by the symbol F so that the meaning is not clear.
- Some tables and figures are not provided with accurate sources. The inclusion of citation sources is intended to maintain the credibility of this teaching material and avoid plagiarism. For example, in "Table 4.1. Surface tension of some substances", whether the data is the result of an experiment by whom or from what book/journal.
- Some images are not accompanied by clear information so that it can lead to incomplete understanding and confusion in understanding the meaning of the image.

B. Student Responses to the IP Teaching Materials in a Biological Context Based on Scientific Creativity

Data on student responses were obtained from participants in the Introduction to Physics course at two universities in Semarang. They are first year students of the Biology and Biology Education study program for the 2018/2019 academic year. Respondents gave an assessment of three aspects, namely the layout of the teaching materials, the content, and the language of the teaching materials used, which consisted of 18 statements. The data on student responses can be seen in Table 3.

ISSN No:-2456-2165

Table 3. Student responses to IP teaching material in a biological context based on scientific creativity

Aspects	Score	Criteria
Layout	3.13	Good
Content	3.24	Good
Language	3.20	Good
Average score	3.19	

Based on Table 3, the average score of student response is 3.19 or good, with the highest score on the content aspect is 3.24 and the lowest average score on the layout aspect is 3.13. It shows the IP teaching materials are interesting, clear and complete, the layout is logical and systematic, it has made it easier for students to understand physics concepts, helped them understand biology from a physics perspective, encouraged the development of scientific creativity. While in the layout aspect, some things need attention to be improved, among them the variation of images, diagrams, and tables as well as the combination of the three, both in the proportion of arrangement and color.

V. CONCLUSION

Characteristics of Introductory Physics teaching materials in a biological context based on scientific creativity can be seen from two things, namely the application of physics in biology and scientific creativity activities. Both appear specifically and explicitly in each chapter of teaching materials. The IP teaching materials developed are included in the good category so that they are feasible to be applied in Introductory Physics learning for biology students. Meanwhile, students' responses to the use of IP teaching materials in the context of biology based on scientific creativity are also included in the good category so that IP teaching materials are interesting, clear and complete, logical and systematic layout, making it easier for students to understand physics concepts, helping them understand biology from a physics perspective, encouraging the development of scientific creativity.

The development of IP teaching materials needs to be extended to students from other science groups, so that IP teaching materials will be produced in other science contexts. Likewise, if this course is taught in another study program, such as an engineering study program. In addition, the development of scientific creativity of biology students will be difficult to realize if the learning model and teaching materials applied are still using the old pattern, which is based on calculus. Therefore, the development of teaching materials needs to be directed at developing content and various activities that encourage students' scientific creativity. Materials and activities in teaching materials can be arranged jointly between physics and biology lecturers so that the spirit of biology cannot be separated from the concept of physics.

ACKNOWLEDGMENT

We would like to thank Universitas Islam Negeri Walisongo Semarang dan Univeristas PGRI Semarang for the opportunity and facilitation of students in conducting research. Special thanks to the expert assessors from Universitas Sebelas Maret, Universitas Negeri Yogyakarta, and Universitas Pendidikan Indonesia who have contributed to the validation of developed teaching materials.

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