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THE DEVELOPMENT OF BIOCHEMISTRY TEACHING MATERIALS BASED ON GROUP INVESTIGATION

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Abstract:
Biochemistry is one of the required course in biology education department, Universitas Sulawesi Barat. However, in this course, there is not yet available teaching materials that help students to make scientific skills. Therefore, the authors felt attracted to develop a valid biochemistry teaching materials based on Group Investigation (GI). The type of this study is R&D, adapting 4-D (define, design, develop, and disseminate) model has been developed by Thiagarajan. The developed teaching materials, consisting of the lesson plan, assessment instruments (affective, cognitive, psychomotor), and biochemistry textbook. To view the validity of teaching materials, we used the validation sheets instrument. The teaching materials in this study were validated by the content expert, teaching materials expert, instructional design expert, and biochemistry lecturer. Validation results showed the average percentage of assessment by content expert is 83% (valid); teaching materials expert is 82% (valid); instructional design expert is 80% (valid); and biochemistry lecturer is 84% (valid). Furthermore, the results of testing readability of small groups consisting of 21 students who have different academic ability (high, middle, and low) showed the average percentage of assessment is 83% (valid). The product has good quality and the potential to implement in biochemistry class.

Keywords: teaching material, biochemistry, group investigation, 4-D model

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1. Introduction

The learning based on student needs and potential to become a trend in the field of education in the 21st century (Tan, 2003). The potential and needs of students have to consider so they become creative, self-sustained, democratic and responsible human beings. To empower the potential of students, the teaching material is needed to facilitate them to learned (Chingos and Whitehurst, 2012).

The teaching material is one of the main components of the learning process (Errington and Litic, 2015). The teaching materials are all forms of materials used to assist lecturers in classroom learning activities (Chingos and Whitehurst, 2012; Syamsuri, et al., 2017). The teaching materials could be like written materials and unwritten materials. The teaching materials should be designed and written with the instructional rules because it will be used by the lecturer to help and support the learning process (Paik, 2015). However, some of the existing teaching materials only target low-level of understanding (Stern and Boone, 2002; Donnelly and Ahlgren, 2007) and its contents sometimes unreasonable (Bianchini and Kelly, 2003).

Empirical facts obtained through observations in biology education department, Universitas Sulawesi Barat, obtained data about the situation and conditions of lectures, especially biochemistry course. The results of the document study showed there is not yet biochemistry teaching materials developed based on the characteristics of the students. Biochemistry is one of the required course must be planned by students. The biochemistry course studies molecules and chemical reactions of life, using the principles of biochemistry and chemistry to explain biology at the molecular level (Horton, et al., 2006).

The process of biochemistry lectures is still dominated by the delivery and presentation of material verbally by lecturers, and not many learning activities empower students' self-potential, collaboration in problem-solving, critical thinking, and activities involve students in a scientific approach. The results of the observation also showed in biochemistry lecture is still oriented to the achievement of learning outcomes in the cognitive aspects only. Although the achievement of cognitive aspects alone is not enough to perceive biology (Fausan and Pujiastuti, 2017). In principle, biology consisting of product and process aspects can not separate. Biology product aspects consisting of fact, concept and principle. The biology process aspect is the process skill students need to think and act in their daily life. (Brickman, et al., 2009; Prayitno, et al., 2011).

Lecturers who are product-based tend to used content-based learning strategies, which causes limited learning to memorize concepts. Consequently, the lecturer measures the success of learning of many concepts memorized by students. Content-based learning puts the lecturer as the primary source of information in learning, consequently learning dominated by lecturers. Students rarely practice developing process skills as demands the essence of biology (Prayitno, et al., 2011).

Empirical facts described above, suggests there are gaps between the ideal conditions expected with the real conditions. The ideal conditions are: (1) achieving a

balanced competence between attitudes, skills, and knowledge, (2) teaching materials are arranged and developed by lecturer of biochemistry by looking at the characteristics and potential of students, (3) learning activities are more empowering students' potential and encourage students able to do better in observing, asking, reasoning, and communicating after learning process, (4) lecturer-center learning to student-center learning, and (5) students learn to memorize concepts, to students learn to build concepts.

One of the solution to resolve the above problem is developing biochemistry teaching materials based on Group Investigation (GI), using the 4-D development model (define, design, develop, and disseminate) developed by Thiagarajan (1974). The 4-D development model is a development model for teaching materials are detail and systematically explain the working steps for developing teaching materials (Thiagarajan, et al., 1974). The term teaching materials used in this study is a systematically organized material used by lecturers and students in biochemistry lectures to make learning goals. The teaching materials developed consisting of the lesson plan, assessment instruments and biochemistry textbook based on GI. To could say qualified teaching materials, should have the criteria validity, effectiveness, and practicality (Nieveen, et al., 1999).

GI is considered capable of facilitating students to hold the aspects of biology products and processes because the syntax of GI developed based on the steps of the scientific approach (Asyari, et al., 2017). Scientific attitude refers to the expected behavior of someone who intends to become a successful scientist, consisting of honesty, awareness, responsibility, and critical-thinking (Hamilton, et al., 2007). This scientific method steps could help students to investigate the process as scientists discover science.

GI is a cooperative learning model encourage students to conduct investigations into a group to find problems, analyze, and solve problems (Asyari, et al., 2017). GI has proven able to improve meta-cognitive skills (Listiana, et al., 2016), stimulate critical thinking (Asyari, et al., 2017), improve learning outcomes (Sangadji, 2016), and give a positive response to students (Danial, et al., 2018). (Mitchell, et al., 2008) said various GI advantages, including students: (1) directly involved in obtaining knowledge, (2) not only as the listener, (3) developing interpersonal intelligence, (4) creating knowledge and developing higher-order thinking skills, and (5) learn more information in higher level when they study in groups.

2. Research Method

2.1 Research and Development Model/Procedures

The development research model was adapted from Thiagarajan (1974) development model with four stages of development, consisting of: define, design, develop, and disseminate. In this study, the development stages were limited to develop phase only. The development model in this study is schematically illustrated in Figure 1.

2.1.1 Stage 1: Define

The purpose of this stage is to stipulate and define instructional requirements. This define phase includes five main steps, consisting of front-end analysis, learner analysis, task analysis, concept analysis and specifying instructional objectives.

The front-end analysis aims to raise and decide fundamental problems in learning, so it required the development of teaching material. This analysis would get an overview of facts, expectations and alternative solutions to fundamental problems, which help selection of teaching materials.

Learner analysis aims to review the student characteristics relevant to the design and development of teaching materials are identified. These characteristics consisting of a background of academic abilities, cognitive development, and personal skills related to learning topics.

Task analysis aims to identify the primary skills acquired by researchers and analyzing them into additional sets of skills may be needed. This analysis reviews the task thoroughly in the learning material.

Concept analysis aims to identify the major concepts to be taught. Concept analysis is needed to identify declarative or procedural knowledge in biochemistry material has been developed.

Specifying learning objectives aims to summarize the results of concept and task analysis to determine the behavior of objects. This set of objective provides the basis for test construction and teaching materials design.

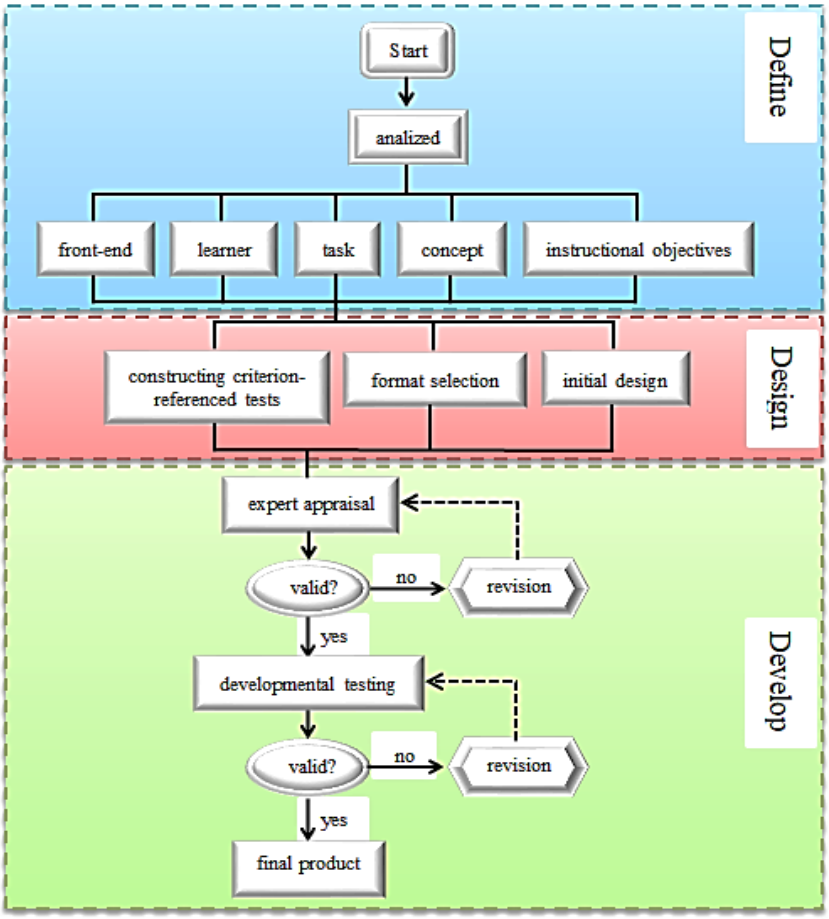

Figure 1: Development procedures of the 4-D model (adapted from Thiagarajan, 1974).

2.1.2 Stage 2: Design

The purpose of this stage is to design prototype teaching materials. Three steps were taken at this stage, consisting of constructing criterion-referenced tests, format selection, initial design.

Constructing criterion-referenced test is the step to bridging between define and design stages. Reference tests are prepared based on learning objectives and students analysis. The test developed based on the level of cognitive abilities of students. Test scoring using an evaluation guide consisting of answer keys and scoring guidelines.

Format selection and initial design, format selection was intended to design learning content, strategy selection, and references. The selected format fulfills the criteria of interest and helps the students in understanding biochemistry. The initial design is the design of all teaching materials done before testing.

2.1.3 Stage 3: Develop

The purpose of this stage is to modify the prototype instructional material which has been produced since the defining stage. There are two steps taken at this stage, consisting of expert appraisal and developmental testing.

The expert appraisal is a technique for obtaining suggestions for the improvement of the materials. Expert appraisal of teaching materials consisting of the suitability of teaching materials with the principles of developing teaching materials, the format of teaching materials, materials coverage, materials accuracy, the novelty of content, discussion of the material, construction, linguistics, and attractiveness of appearance. Based on advice from experts, teaching materials were revised to have better quality.

Developmental testing aims to obtain the appraisal from students. In this study, small group testing was conducted on students who had different academic abilities, consisting of high, middle, and low (Palennari, 2016; Prayitno, et al., 2017).

2.2 Subjects of Testing

The subjects consisting of expert, lecturer, and students. The expert consisting of one teaching materials expert, one learning design expert, one material expert, and one biochemistry lecturer. The small group testing subjects in this study were students who had taken a biochemistry course. Students were chosen 21 peoples based on their academic abilities.

2.3 Instrument

We used the validation sheets has been developed as the data collection instrument. Scoring criteria (Sugiyono, 2013; Johnson and Christensen, 2014) used in the validation of teaching materials and small group testing, consisting of score 1 (unsuitable), score 2 (less suitable), score 3 (suitable), score 4 (very suitable).

2.5 Data Analysis

Data validity of teaching materials is data describes the validity of teaching materials have been developed. Validity data of teaching materials were analyzed using the following formula.

$$P = \frac{\sum(\text{overall score of questionnaire answers})}{\text{n x highest indicator x number of respondents}} \text{ x } 100\%$$

Note: P is the percentage of appraisal; n is the number of questionnaire items.

Determination of the validity of teaching materials have been developed using validity criteria (Sudarma, 2006), are 86 until 100 (very valid); 71 till 85 (valid); 56 till 70 (valid enough); 41 till 55 (less valid); <40 (invalid). Analysis of cognitive test questions consisting of analysis of validity, and reliability. The formula used to analyze the validity of the item is Moment Product (Johnson and Christensen, 2014). Criteria: if $R_{(t)} < R_{(c)}$ it is valid, if $R_{(t)} >$ from $R_{(c)}$ it is invalid. The formula used to analyze the reliability of cognitive test questions is Cronbach Alpha (Johnson and Christensen, 2014). The criteria of the reliability level of the test, consisting of 0.80 till 1.00 (very high criteria); 0.60 till 0.79 (high criteria); 0.40 till 0.59 (high enough criteria); 0.20 till 0.39 (low criteria); 0,00 till 0,19 (very low criteria).

3. Results and Discussion

3.1 Stage 1: Define

The results of observation and study of documents in biology education department, Universitas Sulawesi Barat, especially in biochemistry course showed there are not yet biochemistry teaching materials developed based on students characteristics. Students are still limited to using old biochemistry textbooks, and books are difficult to understand by them. Most of the sampled learning textbooks are only suitable for low-order to mid-order learning (Lau, et al., 2017).

The results of observation are also known there are still few learning activities or experiments in biochemistry course drill students to develop their science process skills. Although scientific process skills were playing an important role in completion experiment activities, the meaning of content and harmonizing with daily life (Cigrik and Ozkan, 2015; Silay and Celik, 2013; Kaya, et al., 2012). Students who actively do experiments directly would give positive developments in their science process skills (Ozdemir and Presley, 2007). The problems described above are the main problems experienced by students in biochemistry lectures. Therefore, the alternative solution used to develop biochemistry teaching materials based on Group Investigation (GI), because GI is considered capable of drill students to work based on the steps of scientific methods to construct their knowledge (Asyari, et al., 2017).

The characteristics of students in the biology education department generally come from various families. The students liked experiment activities and group

discussions, because according to them, by experimenting and discussing they could learn many things. Moreover, biochemistry courses according to them are the most difficult courses, so it needs a teaching material could easily understand by them.

Cognitive development of students has shown a level of formal operational cognitive development. At this level, students can coordinate both simultaneously and sequentially two types of cognitive abilities, consisting of the capacity to used hypotheses and the capacity to used abstract principles (Barrouillet, 2015). So it is expected students at this stage of development have been able to learn with GI learning. Generally, students have individual skills acquired in other courses, e.g., general biology and basic chemistry courses. The concept of biochemistry materials and learning objectives must be understood by students are shown in Table 1. The tasks must be done by each student in the last chapter of a biochemistry textbook.

Table 1: Concept of Material and Learning Objectives of Biochemistry

Materials concept	Learning objectives
Introduction to Biochemistry	After studying this chapter, students are expected to understand: (1) Brief history and biochemistry development; (2) The basic concept of living organ cells reviewed of biochemistry aspects; (3) Energetic in life.
Carbohydrate structure	After studying this chapter, students are expected to understand: (1) Carbohydrates and their role in everyday life; (2) Structure and configuration of carbohydrate molecules; (3) Carbohydrate grouping; (4) Chemical properties of carbohydrates; (5) Carbohydrate derivatives.
Protein structure	After studying this chapter, students are expected to understand: (1) Structure, characteristics, classification, separation, and derivation of amino acids; (2) Structure and characteristics of peptides; (3) Structure, classification, characteristics, role and sequencing of proteins.
Structure of lipids and membranes	After studying this chapter, students are expected to understand: (1) Definition and function of lipids in life; (2) Relationship of the group structure of lipids and their classification; (3) Lipid bilayers and proteins in cell membranes; (4) Transport to cell membranes.
Nucleic acid	After studying this chapter, students are expected to understand: (1) Definition and function of nucleic acids; (2) Structure of nucleic acids; (3) DNA structure; (4) Structure and classification of RNA.
Enzyme	After studying this chapter, students are expected to understand: (1) The basic concept of enzyme catalysis; (2) Function and how the enzyme works; (3) Classification of enzymes; (4) Kinetics of enzymes; (5) Effect of pH on enzyme reaction rates.
Carbohydrate metabolism	After studying this chapter, students are expected to understand: (1) The process of glycolysis; (2) Gluconeogenesis; (3) Citric acid cycle.
Protein metabolism	After studying this chapter, students are expected to understand: (1) Digestion of protein in the body; (2) Amino acid metabolism; (3) urea cycle; (4) Protein Biosynthesis.
Lipid metabolism	After studying this chapter, students are expected to understand: (1) Digestion of lipids in the body; (2) Lipoprotein metabolism; (3) Oxidation of fatty acids; (4) Phospholipid and sphingolipid synthesis; (5) Cholesterol metabolism.

3.2 Stage 2: Design

The parts contained in the textbook of Biochemistry based on GI are a title, preface, table of contents, list of tables, list of images, instructions for using the textbook,

concept mapping, material descriptions, investigation activities, summaries, formative tests, glossaries, bibliography. There are two essential things related book format, consisting of the frequency and consistency in the preparation of the book must be considered, as well as ease of learning. The book has been arranged easy format to learn and systematic, making it easier for students to learn it (Prastowo, 2013). The strategy chosen in teaching biochemistry material is GI, so students have a thorough understanding of the biochemistry concept.

Cognitive tests have been developed based on the test grid, which refers to the learning objectives have been set. The questions compiled form C3 until C6 cognitive levels. The question tested for validity and reliability. Validity is related to accuracy and reliability is related to provision (Johnson and Christensen, 2014). The results of the analysis of cognitive test items are shown in Table 2. Affective and psychomotor learning outcomes were measured using the observation sheets had been developed. Each indicator has clear scoring guidelines.

Table 2: Summary of Data From Analysis of Cognitive Test Items

No	Number of students	Questions validity			Questions reliability				
		R_{xy}	R_{tab}	Decision	Items variant	Number of item variants	Total of variance	Cronbach alpha coefficient	Decision
1	30	0.731	0.361	Valid	0.86	2.35	4.51	0.60	Reliable
2		0.371		Valid	0.24				Reliable
3		0.669		Valid	0.22				Reliable
4		0.716		Valid	0.62				Reliable
5		0.602		Valid	0.42				Reliable

Table 2 shows the cognitive test items have varying levels of validity. The results have shown $R_{xy} > R_{tab}$, so the test items developed to fulfill the valid criteria (R_{tab} is 0.361). Table 2 also shows the coefficient Cronbach alpha on cognitive test questions is 0.60. Based on these results, it could be understood the developed cognitive test items fulfill reliability, with a high category.

The lesson plan was written on A4 paper using Times New Roman, fonts 12 pt, 1.5 spacing, black fonts. Components of lesson plans consisting of course names, credits, learning outcomes of courses, brief descriptions, learning media, prerequisite course, references, expected final abilities, teaching materials, forms of learning (methods/strategies), assessment criteria (criteria and forms).

The assessment instrument was written on A4 paper using Times New Roman, font 12 pt, 1.15 spacing, black fonts. Aspects assessed on the instrument of affective assessment consist of Acceptance; Participation; Determination of attitude; Organization; Formation of lifestyle. Each aspect has an assessment rubric. The psychomotor assessment instrument there are aspects assessed, consisting of the assessment of the implementation experiment through observation, assessment of experiment reports, and class discussion. (1) Assessment of experiment through observation, consisting of perception, readiness, guided movements, adjustment of movement patterns, responsibility. (2) Assessment of experiment reports, consisting of

conformity with the format, experiment title, the problems, hypothesis, the purpose of the experiment, tools & materials, and working procedures, data tabulation, data analysis & discussion, and conclusion. (3) Assessment of class discussion, consisting of readiness to make presentations, the truth of the concept conveyed, Systematic delivery of presentations, the appearance of presentation media, used of language, body language, voice & expression, ability to answer the questions. Cognitive assessment instruments have question instructions, question descriptions, and scoring guidelines.

The textbook was written on A4 paper using Maiandra GD, font 12 pt, 1.3 spacing, black fonts, margins 3 cm for all around. Generally, each chapter contains learning objectives and concept mapping. The material was presented from easy to difficult, according to the level of understanding of students. Each chapter includes relevant images of the material presented. Each chapter also group investigation activities. The last of each chapter is summaries and formative tests. The textbook cover is specifically designed used Corel draw X7 program.

3.3 Stage 3: Develop

After the design stage is finished, then validated by experts. Validation aims to obtain appraisal data, opinions, and suggestions to content accuracy and suitability of teaching materials. Summary results of data analysis by experts are shown in Table 3.

Table 3: Summary of Data Analysis Results by Experts and Students

No	Learning materials are validated	Validator appraisal (%)					Qualification
		Teaching materials expert	Content expert	Biochemistry lecturer	Instructional design expert	Students (small group testing)	
1	Lesson plan	84	81	84	-	-	Valid
2	Biochemistry textbook	81	84	85	80	83	Valid
3	Assessment instruments	80	85	82	-	-	Valid

3.3.1 Validation of Teaching Materials Expert

The indicators assessed by teaching materials experts on the lesson plan consisting of conformity with the principle of developing lesson plans, completeness of the lesson plan components, the feasibility of content, linguistic, and benefits. The indicators assessed in biochemistry textbook consisting of the suitability of the materials with the principles of developing teaching materials, book format, material explanation, the appearance of textbook, and linguistics. The indicators assessed in the assessment instrument consisting of conformity with the principles' assessment of learning outcomes, the materials, construction, and linguistics. Table 3 shows the teaching materials expert giving appraisal for the final product with an average of 81.6%. Generally, components are appropriate and valid.

Teaching materials expert has provided suggestions are including (1) learning objectives in the textbooks should be adjusted to the lesson plan developed, (2) note the writing of foreign words and non-standard words, (3) sentences do not began with

conjunction, (4) the picture in the textbook should be added, and seen the proportion of its size, (5) the number of the text should be included in the description of the textbook material, don't used the word "the image above", "the image below", "the image side ", but just wrote down the picture number, (6) correct ambiguous sentences in all assessment instruments, (7) the language should be communicative for students. Feedback: all suggestions from teaching materials expert have been received, and teaching materials have been revised well.

3.3.2 Validation of Instructional Design Expert

The indicators assessed by instructional design experts on the biochemistry textbook consisting of the suitability of the materials with the principles of developing teaching materials, book format, material explanation, the appearance of textbook, and linguistics. Table 3 shows the instructional design experts giving appraisal for the final product with an average of 80%. Generally, components are appropriate and valid from the instructional design side.

Instructional design expert has provided suggestions are including (1) there are still sentences in affective assessment instrument could be interpreted more than one meaning, (2) there are still statements in affective assessment instrument containing less specific ideas, (3) color composition of textbook's cover is less attractive, (4) note the font size in the material description. Feedback: all suggestions from instructional design expert have been received, and teaching materials have been revised well.

3.3.3 Validation of Content Expert

The indicators assessed by content experts and biochemistry lecturer on the lesson plan consisting of conformity with the principle of developing lesson plans, completeness of the lesson plan components, the feasibility of content, linguistic, and benefits. The indicators assessed in biochemistry textbook consisting of the suitability of the materials with the principles of developing teaching materials, book format (related to the material), material coverage, material accuracy (truth), contemporary, material explanation, the appearance of textbook, and linguistics. The indicators assessed in the assessment instrument consisting of conformity with the principles' assessment of learning outcomes, the materials, construction, and linguistics. Table 3 shows the content experts and biochemistry lecturer giving appraisal for the final product with an average of 83.3% and 83,6%. Generally, components are appropriate and valid.

Content experts and biochemistry lecturer has been provided suggestions are including (1) add the prerequisite courses on lesson plan, (2) add assessment forms to lesson plan, (3) given cognitive levels to instrument of cognitive assessment, see Bloom's taxonomy revised, (4) affective assessment instrument added scoring guidelines, (5) the purpose of the material and concept mapping should specific, (6) add three-dimension structure to carbohydrate, lipid, and protein materials, (7) there are some words difficult to understand, but the word isn't found in the glossary, (8) group investigation activities on textbook isn't specific, please specify, (9) correct several typos in the textbook, (10) add a summary to each chapter. Feedback: all suggestions from

content experts and biochemistry lecturer have been received, and teaching materials have been revised well.

3.3.4 Small Group Testing Results

Readability indicators assessed by students in biochemistry textbook consisting of components in textbook, linguistics, materials review, the appearance of the textbook, and benefits. Table 3 shows the small group testing results. Students gave an average of 83% for biochemistry textbook based on GI. Generally, the level of legibility of the components in the textbook is valid. Therefore, a biochemistry textbook based on GI could be used as learning resources in biochemistry lectures. Learning resources such as textbooks play an essential role in the learning process, to give users a clear framework to follow and help define the boundary of a course (Nie, et al., 2013; Arnold, 2013; Lau, et al., 2018). Biochemistry textbook emphasizes on scientific skills through GI with steps according to Jolliffe (2007) are: identify topics and organize students into groups, planning the task, doing an investigation, preparing the final report, presenting the final report, and evaluation. Students have provided suggestions are including (1) need to add the picture at the beginning of each chapter that represents the material, (2) there is still punctuation marks inappropriate, (3) list of words in the glossary are still less.

4. Conclusions

Teaching materials were developed accordance needs of lecturer and students became one of the essential factors in improving the quality of learning. Biochemistry based on GI has been developed is feasible to use as a learning resource in biochemistry lectures. This is based on the results of the validation from teaching materials expert, instructional design expert, content expert, biochemistry lecturer, and small group testing. They said the teaching material was valid, after several revisions. The teaching material produced in this study will be used in future research to empowering scientific performance skills, and biochemistry concepts of students biology teacher candidates.

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