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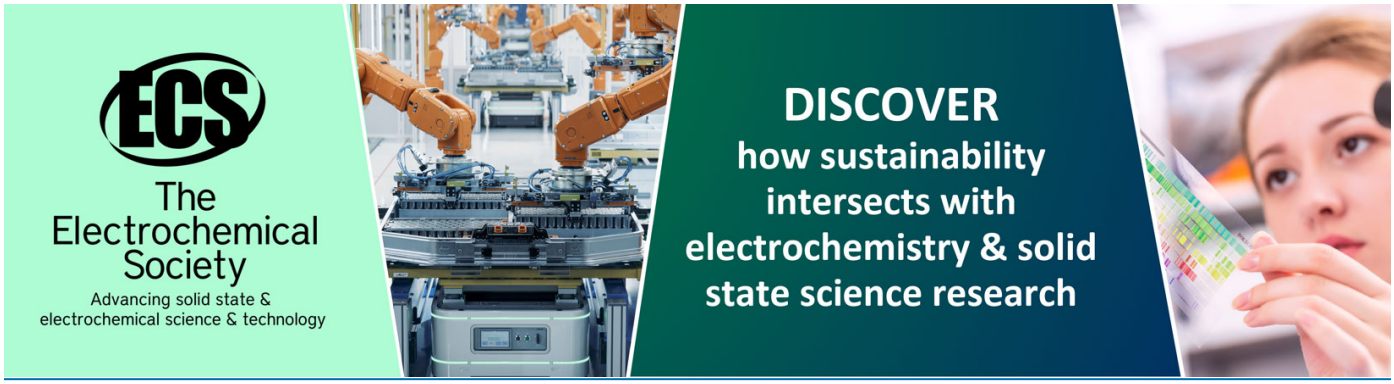

Development of mathematics teaching-learning material with metaphors approach

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Abstract. The research proposed to develop teaching-learning material with metaphor phase in mathematics for students at High School. The teaching-learning materials developed in this study consist of three kinds of metaphors: grounding metaphors, linking metaphors, and redefinitional metaphors. The selection subject matter in modules is composition and inverse function. Hopefully, it would help students learn mathematics independently and students are expected to be able to understand abstract material concepts with more concrete and meaningful concepts. The method research is R&D with 3D models (Define, Design and Develop). Using the questionnaire, the teaching-learning material was validated by three lecturers at mathematics education and five mathematics teachers who teach at high school. Some notes from the validator provide improvement. And finally, teaching-learning material was tested on 27 students at State High School 1 Jawilan-Serang City class XII. The result shows that the teaching-learning material in review by validator is very feasible criteria (89%) and review from students shows suitable criteria for use in teaching-learning mathematics (86%), so the conclusion is the teaching-learning material is feasible to use in teaching and learning mathematics especially in subject composition and inverse function.

1. Introduction

Education cannot be separated from learning and learning activities. Learning is defined as a process of change that occurs in students as a result of obtaining information, changes in students can be shown by changes in cognitive, affective or psychomotor aspects; while learning is defined as the process of transferring knowledge from teachers to students. Teaching and learning are activities that are closely related.

The teaching and learning process is generally influenced by three main factors, namely teachers, students, and the learning process. From the three learning factors, various problems can arise. Problems that come from students, problems that come from teachers, or problems that occur in the learning process. In learning mathematics, problems that come from students are usually indicated by low learning motivation [14] cause feelings of laziness, fear, boredom, tiredness, do not understand, lack of confidence in learning mathematics [15], they can't memorize formulas, they get dizzy when they read mathematics problems [4], abilities that have not been optimal, the lack of development of students' higher order thinking skills [14], etc. Problems that come from the teacher for example the attitude or personality of the teacher who is less liked by students, the lecture method that dominates learning activities, [14] the teacher's attitude is firm, the teacher's attitude is fierce, the teacher's attitude is humorous, the teacher's preparation in teaching is less than optimal, for example not

preparing the lesson plan properly [19]. While the problems that occur from the learning process, such as the availability of facilities and infrastructure, such as available books, worksheets, the two do not complement each other, even surprisingly, the use of technology, the unavailability of learning media, or the available media. Will be available in schools, but teachers and students cannot make the most of it [1,5,6,8].

Learning mathematics is not only able to solve mathematical problems using formulas, but students can communicate or represent mathematical ideas in concrete and abstract forms and are able to deal with mathematical ideas that exist in every problem solving [4,20]. One of the learning strategies that can help students understand mathematics is to use metaphor or analogies [2,13]. Metaphors in learning mathematics aim to give meaning to the concepts being taught. In addition, parables can also be interpreted as an analogous context from one material to another [3] so that students not only memorize formulas but also understand the concepts because they are taught meaningfully [4,20].

The research problem in this article is about the availability of mathematics teaching-learning materials to help the learning process. As we know, during the COVID-19 pandemic, teaching-learning materials have become learning aids for students in understanding mathematical concepts. Learning activities during the COVID-19 pandemic are very limited, lacking physical interaction between teachers and students because learning is done online. Although learning is not problematic, another problem that arises is the limitations of the internet or an internet network that is less stable. So in this case, the existence of teaching-learning materials can be used by teachers or students to improve the quality of learning. Teachers are expected to be able to develop innovative teaching-learning materials. During the COVID-19 pandemic, teaching-learning materials can be a representation or representative of the teacher's explanation.

Teaching-learning materials are devices that support the learning process, especially during the pandemic, where the learning process is carried out online. Students must be able to learn independently to understand the material taught by the teacher, so that learning activities become more efficient [7]. For this reason, teaching-learning materials must be arranged systematically, displaying complete content in accordance with the lesson plan [8,14].

In educational institutions, the development of teaching-learning materials is considered as one of the main aspects that will encourage student learning and help achieve academic goals and objectives [7]. Educators need to focus on bringing developments in teaching-learning materials [8,17]. Teaching-learning materials provide a variety of experiences for students. When they are used in an adequate manner, then they are used to motivate learners towards educational gain.

The main purpose of using teaching-learning materials is that they can be used in classroom learning activities or in this case online classes. These teaching-learning materials must support the teacher's presentation in order to transfer knowledge to students [7] in accordance with the achievement of the learning objectives that have been set. The material developed in teaching-learning materials must be understood by students because it will be studied by students independently after the learning process is carried out. Teaching-learning materials are very important in the learning process. there are five benefits that can be obtained if these teaching-learning materials are used, namely motivating students, developing creativity, generating initial knowledge, encouraging the process of interpreting, understanding, organizing and combining educational content, logical thinking, reasoning, and communication and contributing to the development of skills, values, and different attitudes among students, and enables them to gain an efficient understanding of academic concepts. Teaching-learning materials are defined as instruments for the presentation and transmission of certain educational materials [18].

Teaching-learning materials made by teachers generally contain material and practice questions for students to work on. In this article, the teaching-learning materials developed that use the metaphorical thinking approach. In learning with metaphors students will discuss questions related to the context that is raised so that students can understand mathematical concepts through phenomena that exist in everyday life [20]. This teaching-learning consists of concepts that are analogous to the concepts to be taught. The goal is to equip students with real prior knowledge, so that students understand the meaning of applying the concepts to be studied in everyday life. In addition, the teaching-learning materials developed include learning stages which are generally carried out if we study face-to-face.

First students are given a real context, then students are given questions related to the context raised. The aim is to find out the extent to which students understand the given context. Students are considered to have a substantial understanding of a mathematical problem if they can put forward statements that begin with questions based on data, guarantees, ideas, and even claims in the problem correctly [12,13].

Quoting from research conducted by Kapur [17], there are 10 benefits that can be obtained from learning using teaching-learning materials, such as:

1. Motivating Students – Teachers who use teaching-learning materials in learning activities must be able to ensure students can make maximum use of them, teachers ensure students can feel happy and motivated to learn. Therefore, the teaching-learning materials made by the teacher are able to encourage students to be more enthusiastic and motivated in learning.
2. Developing Teacher Knowledge and Skills – Through the application of effective teaching and learning methods, teachers are able to develop their knowledge and skills. They are able to raise awareness about how to use this knowledge in carrying out their job duties properly. They need to utilize these skills and knowledge in achieving educational goals.
3. Assistance in Longer Retention of Information – teaching-learning materials when applied, it must be ensured that they assist in the longer retention of information. When students can work on each step of learning that we are blind to, then students can not only gain an effective understanding of concepts, but can also increase information retention for a longer time.
4. Facilitating Holistic Learning – Through the use of teaching-learning materials, students can not only gain an efficient understanding of academic concepts, but teachers also help and support them in enhancing their psychomotor, cognitive and intellectual development. Because the development of these aspects is considered important to encourage the process of problem solving and rational thinking.
5. Teaching Implementation Assistance in Classroom – Teachers are able to increase awareness in implementing learning plans and concepts. Teachers are able to apply learning strategies that are integrated with the concepts in teaching-learning materials, so that the prepared teaching-learning materials are able to carry out the learning process. It's not just about practice. When they use teaching-learning methods in the right way, they can plan and organize teaching methods in the classroom as well. In this case, teachers are able to improve their pedagogic competence as well as their professional competence.
6. Promoting Effective Communication – The use of adequate teaching-learning methods helps in promoting an effective communication process between teachers and students and among students themselves, even though the learning process is designed in the form of teaching-learning materials. The process of communication between students and teachers must be visible even though it is written.
7. Facilitating Attitude Change – Teachers and students are able to bring about changes in attitudes and behavior through the use of teaching-learning methods. Especially during the COVID-19 pandemic, where the learning process is transferred online, teachers must be good at integrating innovative learning methods so that students don't feel bored, and they feel motivated to learn and are also able to bring about a change in attitude.
8. Practical Application – Teaching-learning materials should be able to promote the application of theoretical knowledge into practical application. The theoretical knowledge conveyed by the teacher is explained in concrete form through teaching-learning materials so that teaching is more effective. The application of theoretical knowledge into practical application enables students to achieve academic results effectively.
9. Make Learning Fun – Teaching-learning materials developed by teachers should make learning fun and easy to understand. Students feel happy in gaining understanding of new concepts because they are delivered in an easy-to-understand context. This teaching-learning material also needs to be ensured that it invites students to understand concepts based on their previous experiences. So that the concept will be easier to digest, especially for high school students where the mathematical concepts presented have include abstract concepts

10. Building Concepts – teaching-learning materials should facilitate the formation and achievement of concepts among students. Certain mathematical concepts are difficult to learn and understand. Therefore, it is very important for students to ensure that they can gain efficient understanding. The teaching-learning materials that are arranged must also be able to improve understanding of mathematics in accordance with the desired learning objectives.

Based on the explanation of the 10 benefits of developing the material above. This teaching-learning material is integrated between the mathematical concept of "composition and inverse function" with the learning strategy, namely using a metaphorical approach, the objectives of this research are 1) to develop mathematics teaching-learning materials on composition and inverse functions by using stages in the metaphorical approach; and 2) researchers also want to know the feasibility of the prepared materials.

2. Methods

This study uses the Research and Development method [1,8,9], where researchers develop teaching-learning materials based on metaphors on the subject matter composition of functions and the inverse of functions. The development model used in this study is a 3D model, which consists of 3 stages: define, design, and develop. While the Dissemination stage could not be carried out due to the implementation of research during the COVID-19 pandemic where schools were closed to carry out face-to-face learning processes. In the Define stage, the researcher observed the documentation of the 2018/2019 high school national exam results. Analyzing the characteristics of students, through interviews with mathematics teachers at SMA Negeri 1 Jawilan Serang Banten, identifying mathematics material to be developed through SK KD, studying the application of metaphors in learning mathematics. At the Design stage, the researcher begins to design mathematics teaching-learning materials with the composition of functions and inverse functions using a developing metaphor approach that covers various contexts of everyday life as a metaphor for the material to be developed, the stages of learning designed for teaching-learning materials and questions. Which supports the metaphorical approach. The last stage is the development stage, researchers carry out a process of validating teaching-learning materials that have been developed by several mathematics education experts to get input for the improvement and development of teaching-learning materials that have been made. The validation stage was carried out by three mathematics education lecturers at UIN Jakarta and five high school mathematics teachers. After the teaching-learning materials were validated, a limited trial was conducted on 27 high school students.

The instrument used to determine the feasibility of teaching-learning materials, researchers used a questionnaire given to mathematics education experts and mathematics teachers. The questionnaire uses a Likert scale with 5 choices consisting of eight aspects, namely: the relevance of the material, the suitability of the chosen metaphor, the organization of the material, the organization of questions, language, editorial, aesthetics and usability. In addition, researchers also used a questionnaire given to students with a Likert scale with 5 choices consisting of four aspects, namely material organization, problem organization, appearance and interest in teaching-learning materials. The data obtained will be analyzed quantitatively to show the level of feasibility of the instrument. In addition, descriptive analysis is also used to provide an explanation of the revisions or suggestions given by the panellists.

3. Results and Discussion

The teaching-learning materials developed in this research are composition and inverse functions. Based on the results of the preliminary analysis, information was obtained that most of the students were still many high school students who did not understand the structure of the function concept. According to Sintema, some preservice teachers still have difficulty understanding the concept of composition of function [10]. This is indicated by the acquisition of students' passing scores on the material, mostly below the minimum passing grade threshold, most students have difficulty understanding basic concepts, have difficulty understanding basic concepts, and some students still have difficulty performing the calculation process [5,6,20].

This teaching-learning refers to competency standards and basic competencies that are guided by the Regulation of the Minister of Education and the State of the Republic of Indonesia. The indicator was developed into 8 formulations:

1. Determine the result of the composition operation from two functions.
2. Determine the result of the composition operation from three functions.
3. Create a mathematical model that involves the operation of a composition function.
4. Solve problems related to operations composition function.
5. Determine the inverse function.
6. Calculate the value of the inverse function.
7. Determine one of the functions if the composition of functions is known.
8. Solve daily life problems, which are related to inverse functions.

The term function in everyday life is different from the meaning in mathematics. In mathematics, the function is defined as a special relationship between two sets. Namely Seta A and Set B. The function can be related for each of element on Set A (domain) with exactly one element of Set B (codomain). The extension of the concept of function is widely used by branches of mathematics, so the meaning of this function must be fully understood by students to learn other mathematical concepts.

One extension of the concept of function in mathematics is the composition of functions. Function composition is defined as the operation of more than one function. The composition of a function in mathematics is denoted by little circle ($\circ$). Suppose we know that there are two functions, namely f and g than composition of f and g denoted by $(f \circ g)$, if f and g qualify $R_g \cap D_f \neq \emptyset$, then there is function h from subset of D_g (domain of function g) to subset of R_f (range of function f) which is denoted by $h = f \circ g$ with the rule: $H(x) = (f \circ g)(x) = f(g(x))$ as domain $D_{f \circ g} = \{x \in D_g | \, g(x) \in D_f\}$. And vice versa, for example, the composition function g and f denoted by $(g \circ f)$, if f and g qualify $R_f \cap D_g \neq \emptyset$, then there is function h from subset of D_f to subset of R_g which is denoted by $h = g \circ f$ with the rule: $H(x) = (g \circ f)(x) = g(f(x))$ domain $D_{g \circ f} = \{x \in D_f | \, g(x) \in D_g$.

To understand the notation of mathematics above, consider Figure 1. It can be seen the relationship between the functions f and g. Where is the function g is operation from x to $g(x)$ and the function f is operation $g(x)$ to $f(g(x))$, this formula can says as composition f and g or $(f \circ g)$.

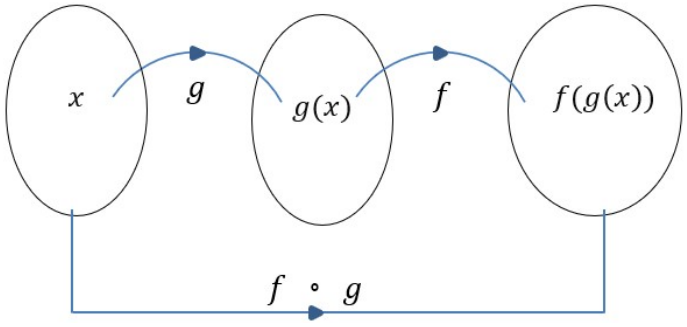

Figure 1. The flow of composition of function.

In the teaching-learning materials developed, we provide an explanation of the material using a metaphorical approach. It is hoped that this analogy will help students understand the concept of composition of function. Metaphor is defined as the process of associating ideas with other ideas by using analogies [2], make connections between new material that is not yet known with material that students already know [11] or the process of linkage between mathematical concept and existing materials [3] therefore the material becomes more meaningful. See the Diagram 1.

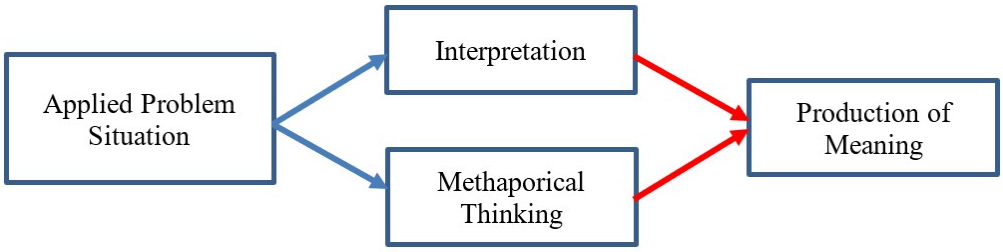

Diagram 1. Relation between real situation and metaphor thinking.

Interpretation of diagram 1, there is a different relationship between applied mathematics problems and the act of interpretation in the expression of metaphorical thinking. But the other hand, interpretation and metaphor are in a convergent relationship where both are processes to produce meaning [15]. Metaphor is defined as the correspondence between two concept domains. Metaphors consist of mechanisms that allow us to understand one domain with another, and usually use our everyday experiences. Focusing on the mechanisms involved in metaphorical thinking, a first assumption must be made: the possibility of identifying two distinguishable topics, the primary topic (target) and the subsidiary topic (origin). Each topic works as a conceptual system rather than just a number of disconnected elements. Metaphors must have a strong cognitive function. Metaphors not only make connections between concepts and the real world but must create realistic contexts.

Metaphor does not only mean figuratively, but rather means an important mechanism of students' thinking processes related to everyday life, not only in language but also in thought and action [16] Reasoning with metaphors is considered a basic method of human thought and communication, for example in the use of abstract mathematical concepts in everyday life, such as time and change. Metaphor is a type of mapping between the target and source domains. Metaphors also introduce new elements into the target domain. [16] The metaphor used by the teacher in the learning process is expected to help students become aware of the questions, assumptions, and values raised in the problem or learning context; promote a reflective approach; exert a strong influence on the analysis and planning process of mathematical problem solving; and shows the relationship between students, the real world and mathematics.

Conceptually, there are three kinds of metaphors, namely:

a. Grounding Metaphors, is the basis for understanding mathematical ideas experienced directly by students through daily life activity. Metaphor grounding, its means using a metaphor as an illustration of the concept to be taught
b. Connecting Metaphors, making connection between two things, namely choosing, affirming, giving freedom, and organizing the characteristics of the main topic which are supported by additional topics in the metaphorical statement. Connecting Metaphors, it means using metaphors as concept development.
c. Redefining metaphor, using metaphor to provide a more detailed explanation about the concept or context being taught. For this component, we must choose the most suitable for the topic to be taught so that students do not get confused. Metaphor Redefinition means using metaphor as a deepening of the concept.

Based on the study of the subject matter in mathematics and the learning approach used, the teaching-learning materials developed consist of two sub-chapters, composition of functions and inverse functions. Each sub-chapter is divided into four parts, 1) learning objectives, 2) material explanations by metaphor approach, 3) summaries, and 4) tests. Each sub-chapter is broken down into several learning activities based on metaphor approach (see Diagram 2).

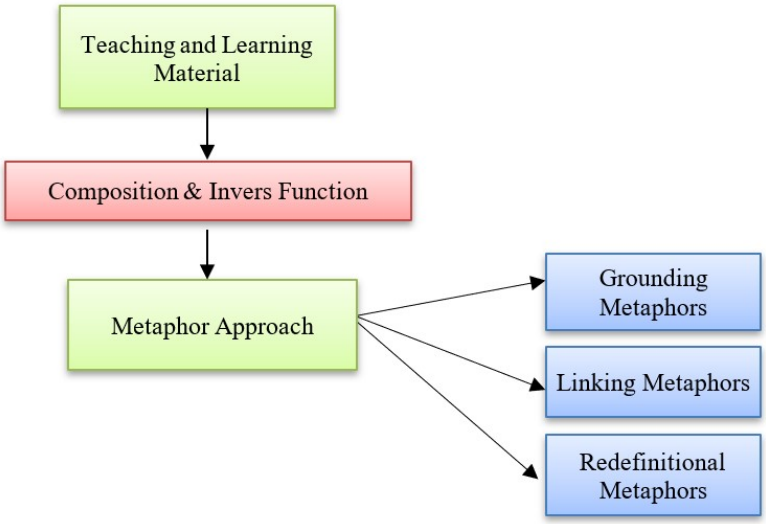

Diagram 2. Theoretical framework of teaching-learning material with metaphor.

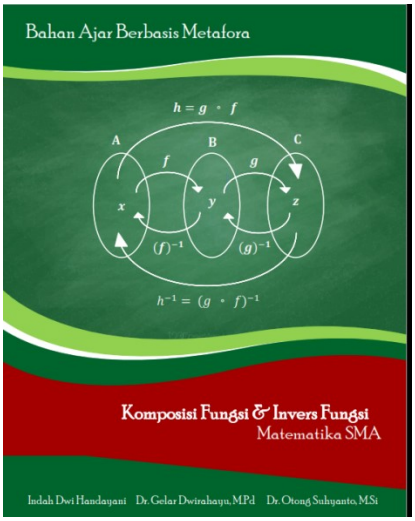

Figure 2. Cover of teaching-learning material.

Figure 2 shows our research product. Figure 2 is the cover of teaching materials compiled by researchers. Teaching materials consist of 2 sub chapters (composition function and inverse function) 61 pages.

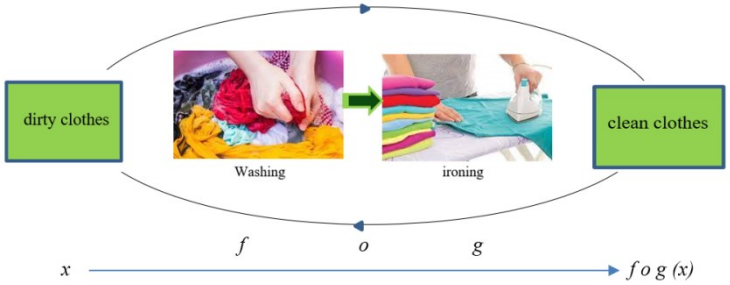

Figure 3. Process of tidying up clothes.

Figure 3 is an example of a metaphor used to explain the concept of composition of function. $f(g(x))$ is the activity which is start form $f(x)$ process then continues with the $g(x)$. If $g(x)$ is

assumed to be washing and $f(x)$ is ironing. Then the illustration of the composition of the function $f(g(x))$ is: dirty clothes will be washed first until they become clean or $g(x)$. Then the clean clothes will be reprocessed into the next activity, which is ironing until they become neat or $f(x)$. In this activity, when the $f \circ g$ has been carried out, the clothes are clean, tidy and ready to be reused.

Another example of a metaphor is the process of making salt. Kitchen salt is very important for cooking, without salt, the taste will bland. But have you ever seen the process of making salt? Salt is made from seawater that has evaporated, when the evaporation process occurs in a container, it will remove air from seawater and leave solid lumps, then called salt. For more details, the process of making salt is shown in Figure 4.

Do you still remember the concept of evaporation and dissolution in chemistry?

If the salt comes from the evaporation of seawater, then brine can be made from the process of dissolving salt. If the evaporation process is assume as $f(x)$, aiseawater is x and salt as y, then $y = f(x)$ garsalt comes from brine that has been evaporated. To find the value of *x*, it is necessary to reverse the action of evaporation, that is dissolution (f^{-1}). So the process of dissolving salt can be symbolized by $f^{-1}(y) = x$. Likewise if $f^{-1}(y) = x$ we do inverse again, than we get $f^{-1}(y) = x$.

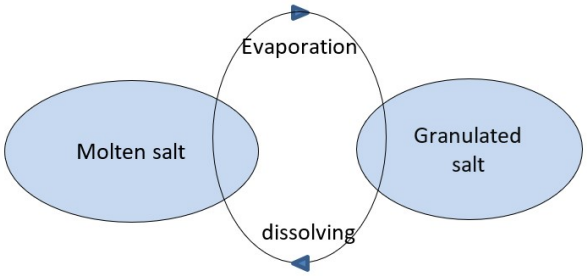

Figure 4. Process of production of salt.

After completing the teaching-learning materials, then validation was carried out by 3 lecturers and 5 high school mathematics teachers as experts (see Figure 5).

In the process of validating teaching-learning materials by experts, we use 8 assessment criteria: 1) Relevance of material: the suitability of the material with competency standards, basic competencies and learning objective in the curriculum for education year 2013; 2) Metaphor: choosing of context used in interesting material. The analogy context help students understand of concept; 3) Organizing Materials: The systematic presentation of material in teaching-learning materials is well organized. The pictures presented in the teaching-learning materials are in accordance with the concept of the material. Learning objectives in teaching-learning materials are clearly defined; 4) Problem Organizing: the suitability of the questions with the material, showing a proportional level of difficulty, the quality of the questions, the questions have represent all the material; 5) Language: The Bahasa or sentence is easy to understand and does not cause misunderstanding or ambiguity; 6) Editorial, it means that the display of letters, images, layouts on teaching-learning materials has been proportional; 7) Aesthetics: The appearance of the presentation of teaching-learning materials is well regulated. The combination of color choices is presented in matching teaching-learning materials; and 8) Usefulness: Teaching-learning materials provide the information students need. Teaching-learning materials are able to motivate students to learn independently.

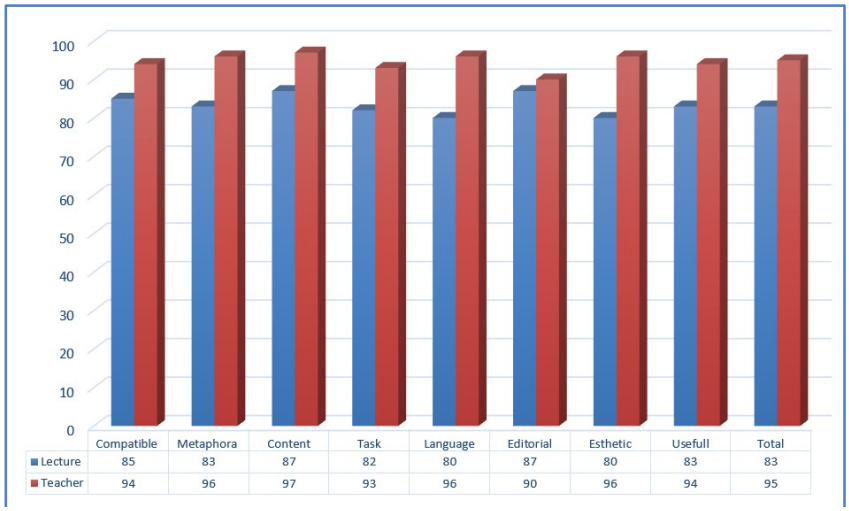

Figure 5. Score the feasibility of teaching-learning material according to judgment expert.

After the instrument was validated by experts, the last step was the test of teaching-learning materials to 27 students. It is to find out students' responses regarding the teaching-learning materials. The instrument for students consists of four criteria, 1) Organizing Materials: The systematic presentation of material in teaching-learning materials is well organized and easy to understand, and also for metaphor concepts easy to understand. 2) Problem Organizing. The examples and the task are easy to understand and the number of tests is sufficient to study; 3) Layout and Display. The context and concept is well organized, interesting and it is not confused; and 4) Interest in teaching-learning material. After studying it, students do not feel bored and they feel comfortable. Students enjoy learning using metaphor-based teaching-learning materials with a metaphor approach.

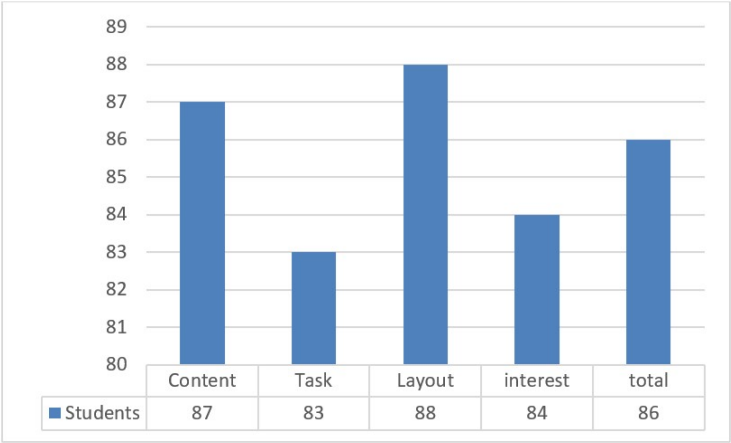

Figure 6. Score the feasibility of teaching-learning material according to Student.

4. Conclusion

The conclusion of this study is that the teaching-learning materials for subject matter composition and inverse function show a feasible criteria. The criteria shows:

a. Validation by lectures to criteria: relevance of the material, metaphor, material organization, task organization, language, editorial, aesthetic, and usefulness shows the score 83.49%. It is mean that the teaching-learning material is good criteria

b. Validation by math teachers to criteria: relevance of the material, metaphor, material organization, task organization, language, editorial, aesthetic, and usefulness shows the score 94.47%. It is mean that the teaching-learning material is good criteria
c. Assessment by the students based on criteria organizing material, organizing task, display and layout, and interest show score 86.19%. It is mean that the teaching-learning material is very good criteria
d. If face-to-face learning has been carried out, the teaching learning materials made can be implemented in the classroom, so that the effectiveness of teaching learning materials with metaphors approach to improve students' conceptual understanding on function can be known.

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