Utilization of multiple representations in science learning

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Abstract. This study aims to develop a science teaching model by utilizing multiple representations in each syntax to be implemented by science teachers in order to improve understanding of science concepts, science process skills, and critical thinking skills of students. This study is a research and development (R & D), adapting R & D model of Borg and Gall which consists of 10 developing stages, specifically: 1) research and information collection; 2) planning; 3) develop preliminary form of product; 4) preliminary field testing; 5) main product revision; 6) main field testing; 7) operational product revision; 8) operational field testing; 9) final product revision; 10) disseminaton and implementation. This research was carried out until the main product revision stage (5th stage). Revisions were conducted after the experts’ judgments obtained. The result of this study is the framework of Discovery Learning using Multiple Representations (DLMRs). Based on experts judgments, this model is suitable to be implemented in science learning to improve science process skills, critical thinking skills, and students’ curiosity.

1. Introduction

Characteristics of science learning that requires students to have descriptive, procedural and declarative abilities, then each science teacher should be prepared to bring students to understand each science concept as a whole related to the three characteristics of the science. Learning science does not only understand concepts through descriptive memorization but science concepts that are abstract and must be illustrated before understanding them. This problem should be an obligation for every science teacher to help and to bridge students in understanding science concepts comprehensively. Concepts and problems in science learning require students’ ability to transform verbal knowledge into other forms, such as pictures or diagrams before it solved mathematically. This is a problem for students in understanding the concept of science comprehensively, and on the other hand, is a challenge for every science teacher. One recommendation from the National Science Teachers Association (NSTA) regarding General Skills of is the learning of science concepts should be given to students in various ways. Learning certain concepts should involve different interactions. Some concepts have to be integrated into network concepts that are coherent with others to make the decisions properly. A teacher is obliged to provide learning opportunities to students with multiple interactions on a concept in various contexts, and through various ways [1].

A student has a different interpretation when faced with the concept in science learning because each student has a different ability of the internal interpretation from the others. This internal interpretation skill must be supported by the ability of external representations related to the real world or the
surrounding environment so that students can develop knowledge in the thought process and consider the information they will have. This external interpretation is used to communicate ideas, concepts or scientific phenomena in learning science with the aim of helping students to develop their internal representations appropriately [2]. Students who are able to use more than one form of representation in interpreting a science concept will find it easier to understand the concept. This capability is known as multiple representations. Every student should have this ability to build the cognitive processes, limit the possibility of misinterpretation, and strengthen their understanding of a situation in depth [3].

Some indicators that must be possessed by students at this advanced level are demonstrated basic knowledge and skills related to the inquiry, understand how experimental activities should be conducted, interpret the results of investigations, give reasons, draw conclusions based on descriptions and diagrams, evaluate and support arguments [4]. The results of preliminary studies conducted at SMPN 1 Watopute (secondary high school) is the understanding of science concepts, science process skills, and critical thinking skills of students taught with models and methods commonly used still low. The method commonly used by teachers in schools is lecture and discussion, and the teacher does not provide a variety of learning models in the classroom. The use of multiple representations is also less emphasized by the teacher. This situation has an impact on the lack of students' ability to interpret and understand the concepts they have received. Students can interpret concepts through images but are not able to interpret concepts form of diagrams or graphs before they are solved by mathematical equations.

Active involvement of students in the process of discovering concepts in the science learning with various representational abilities in interpreting the concept has the opportunity to improve understanding of science concepts and sharpen scientific skills and thinking skills of students. In addition, several studies using multiple representations strategies can improve students’ conceptual understanding. Research by [5] shows that knowledge can be organized using multiple representations so that understanding can be achieved comprehensively. [6] conducted research in the field of physics, where the results showed that students better understood the concept by using multiple representations. The use of discovery learning models and multiple representations in science learning is the right choice in order to create a learning climate that involves active students in the discovery process by using scientific and thinking skills. Based on various studies of the problems described, the researcher is interested in conducting a study by developing a new science teaching model, which modifies the discovery learning model, and places multiple representations on each syntax. This model is then called Discovery Learning using Multiple Representations (DLMRs).

2. Methods

2.1. The Developing Procedure Model
The developing model used in this study is the Research and Development (R & D) adapted from Borg and Gall. The implementation of the R & D model proposed by [7] consists of 10 steps, but for this research was only carried out until the stage of preliminary field testing. The explanation of each product developing step used in this study is as follows.

2.2. Research and Information Collection
This stage aims to find and to identify the clarity of information from the object of research. The literature study is carried out by examining some of the results of research relating to students' science process skills and critical thinking skills, and the importance of sharpening and enhancing these two skills in learning science. Literature studies are also conducted to understand effective science learning models used to develop science process skills, critical thinking skills, and can facilitate the implementation of science learning that is descriptive, procedural, and declarative.

2.3. Planning
The planning phase is intended to develop guidelines for developing the DLMRs model. This guide aims as a benchmark for designing DLMRs models.
2.4. Develop a preliminary form of product
The stage of developing a preliminary form of product aims to construct a raw product design that is compiled based on the guidelines for developing the DLMRs.

2.5. Preliminary Field Testing
This stage aims to assess the initial product developed. The DLMRs model has been developed, then it will be assessed by experts whether this model is suitable for implementing in science learning to improve students' science process skills and critical thinking skills. Analysis of the data obtained through the DLMRs model assessment sheet, then the following steps are carried out: a) tabulate all data obtained from each product validation sheet and assessment instrument; b) calculate the average score of each aspect of the assessment given by the validator; and c) change the average score into the category scale. The quality of the product results developed will be known by changing the data that was originally a quantitative score into qualitative data (intervals) with a scale of five.

3. Results and Discussion

3.1. Teaching Model
The teaching model can attract students into certain types of content (knowledge, values, and skills) and improve their competencies to grow on an individual, social, and academic level [8]. The teaching model has four special characteristics that are not possessed by learning strategies, approaches, methods or procedures. The four characteristics consist of 1) logical theoretical rationales compiled by the inventor or developers; 2) the rationale for what and how students learn (learning objectives); 3) teaching behavior needed so that the model can be implemented successfully (learning syntax); and 4) the learning environment needed to achieve learning goals [10]. According to [9] that there are 5 main characteristics that must be fulfilled by the teaching models, specifically as follows: 1) compiled based on educational theories and theories of learning that have been proposed by certain experts; 2) have a certain educational goals and learning objectives; 3) can be used as a guide for improving teaching and learning activities in the classroom; 4) have parts such as learning steps, principles- reactions, social systems, and supporting facilities; and 5) have an impact (instructional and companion impacts).

All teaching models have a theoretical base because the inventors present reasons that explain why we must use these models to achieve the goals that have been designed. The instructional objectives of some models are constructivist, which are almost purely related to academic content. This learning model that adheres to a constructivist foundation is designed so that students are able to construct categories, test them, and from these categories produce inferences and hypotheses that lead to the investigation [8]. [9] also states that in addition to the theoretical foundation, there are several elements that must be possessed by the teaching model: 1) theoretical constructs; 2) syntax; 3) social system; 4) the principle-reaction; 5) supporting systems; and 6) the impact or effect (instructional and companion/parenting impact).

3.2. Multiple Representations
In general, representations can be divided into two forms, specifically internal representations and external representations. Internal representations are interpreted as mental models built by students from a learning material. Internal representations of each individual are difficult to observe directly because it is a mental activity in his mind. External representations are representations that can be observed or seen such as text, graphics, and images. The term external representations are also often referred to as visual representations [11]. Furthermore, external representations are specifically calcified into five types of representations namely verbal, numerical, graphical, symbolic and geometric representations [2]. The interaction between internal and external representations is fundamental in the teaching and learning process. External representations can be used by the teacher to communicate ideas for helping students develop appropriate internal representations [12].
[13] state that science learning requires the practice of multi-representation instruction, including thought processes, thinking habits, rationalization of the implementation of these learning practices. According to [14] various formats of representation include: 1) verbal representation, giving an explanation of a concept qualitatively 2) diagrams or drawings, helping when visualizing abstract concepts become easier to understand; 3) graph representation, giving an explanation of a concept can be represented by a graph; and 4) mathematical representation, needed when solving quantitative problems using equations that are in accordance with the information obtained. The ability of multiple representations is needed by every student in understanding the concepts given in the classroom. Multiple representations can also help students learn concepts and overcome problems, use them to solve problems, and address problems. A conceptual analysis of multiple representations according to Haili et al [15] that multiple representations have three main functions in learning: 1) giving presentations that contain complementary information or help complete cognitive processes; 2) limiting the possibility of errors in interpreting; and 3) helping students to build an understanding of the phenomena in depth.

Teaching through multiple representations can train students' ability to understand and explain verbal concepts, graphs, diagrams, and mathematical equations to solve problems comprehensively. Multiple representations provide opportunities to understand and communicate concepts, and how they work with systems and processes [16]. Previous study states that multiple representations are very related and needed in learning to construct and develop understanding concepts of the scientific phenomena and scientific methods in depth. [14] shows that students' ability to complete tests is better when students learn through giving more representation formats. According to [15] that before conducting multi-representation teaching, the facilitator introduces the instructional objectives. Before stepping on the use of multiple interpretations, it should be stated the phenomena that will be taught. Then students convey their representations with the cognitive skills they have. [13] revealed that the step to explore is by demonstrating several phenomena. The purpose of this activity is to find out the understanding of students' initial concepts regarding the phenomena given. According to [17], teaching using the multiple representations strategy consists of four phases: a) orientation; b) exploration; c) internalization; and d) evaluation.

3.3. Developing of the DLMRs Model

3.3.1. Theoretical Constructs of the DLMRs Model

Discovery learning is a model of teaching developed based on constructivism [9]. Discovery learning is a teaching model that allows students to ask questions and draw conclusions based on their experience. [18] also states that discovery learning is part of modern learning constructivism, where students construct their own knowledge. There are some experts who support this constructivism learning theory, specifically Piaget, Vygotsky, and Bruner.

Piaget's cognitive development theory is one of the theories underlying the developing of the teaching model in this study because students will construct their knowledge through organizing (assimilation and accommodation) the concepts given in the process of learning with experimental methods, so that students are expected to feel confident and finally equilibrium in their cognitive structure will be achieved [19]. DLMRs models will help assimilate or accommodate student knowledge. Assimilation is expected to occur when the phenomenon is given by the teacher at the beginning of the teaching process, then practiced conducting experiments and finally matched the experience they had been through. Students who feel that they are not compatible with what is obtained in the experiment with previous knowledge, are expected to be accommodated through the use of multiple representations. The characteristics of learning activities according to Vygotsky's theory are the foundation in the developing of the DLMRs model because it demands social interaction and students who are more active in learning. DLMRs model in science learning creates a dominant social interaction between students in the classroom so that in the DLMRs model divides students into groups when conducting experiments. The purpose of this is expected to create a learning environment of mutual cooperation between students
in each group to understand the concept or material based on what they get from the experimental activities. Bruner with his theory that free discovery learning states that the learning process will run well and creatively if the teacher provides an opportunity for students to find a concept, theory, rule, or understanding through the examples found in their lives. According to Bruner, a person's cognitive development occurs through three stages (enactive, iconic, and symbolic). This Bruner's theory is one of the theoretical foundations used in developing the DLMRs model in this study. This DLMRs model provides an opportunity for students to find out their own science concepts with minimal help from the teacher.

3.3.2. Syntax
The syntax is a picture of the structure of a teaching model that includes the elements or stages that are important and how they are applied [9]. Model DLMRs in science learning have characteristics based on the discovery of concepts through experiments by testing hypotheses based on some treatment manipulations provided by the teacher. The syntax of the DLMRs model is a modification of the discovery learning syntax and learning steps that must be taken when using multiple representations [6] and [17]. The syntax of DLMRs model presented in Table 1.

| Discovery Learning Model | Descriptive Description (Ainsworth & Sprianus) | DLMRs model |
|--------------------------|-----------------------------------------------|--------------|
| Planning                 | Orientation                                   | Planning     |
| Stimulation              | Stimulation_MRep                              | Stimulation_MRep |
| Problem Statement        | Exploration                                   | Statement_MRep |
| Data Collection / Finding| Internalization                               | Internalization_MRep |
| Data Processing          | Evaluation                                    | Verification_MRep |
| Verification             |                                               | Generalization_MRep |
| Generalization           |                                               | Evaluation_MRep |

3.3.3. Social System
[9] the social system describes student and teacher roles and relationships and the kind of that is encouraged. Organizing class in the DLMRs model is designed by dividing students into several groups, and each group consists of 4 to 5 students. Interaction at the stage of stimulation_MRep and problem_statement_MRep is dominated by the teacher. Interactions at the stage of internalization_MRep (data collection, data processing), and verification_MRep in the class are dominated by students in their respective groups, both in conducting experiments or when completing tasks in the student worksheet, while the teacher's role at this stage is very minimal, just going around to each group to ascertain whether there are groups who have difficulty when conducting experiments. At the generalization_MRep stage, teacher takes a more role in summarizing the learning outcomes.

3.3.4. The Principle-Reaction
The principle-reaction can be interpreted as a pattern of activities of educators in seeing and treating students [9]. The principles-reactions of the DLMRs model in science learning are as follows: a) educators provide phenomena in everyday life related to science subject matter; b) educators use communicative language to students when providing information; c) educators provide opportunities for students to convey questions about the phenomena that have been given; d) educators provide flexibility to students to be independent in thinking and issuing opinions; e) educators need to be supportive of student hypotheses and create dialogue where students test each other's hypotheses; f) educators provide minimal assistance to students when conducting experiments and completing tasks; g) educators provide a comfortable learning atmosphere; h) educators help students discuss and evaluate their strategies of thinking; and i) educators have to control the conditions in the classroom.
3.3.5. Supporting Systems

The supporting system is the entire means, materials, and tools needed to implement the teaching model [9]. Supporting systems in the DLMRs model are including: a) problems or phenomena related to the science learning, in order to encourage each student's curiosity and enthusiasm; b) teaching material; c) lesson/instruction plan; d) student worksheet; e) experiment tools and materials; and f) science process skills assessment instruments in the form of observation sheets; g) critical thinking skills assessment instruments in the form of an essay test; and h) instruments to assess students' curiosity in the form of observation sheets.

3.3.6. Instructional and Companion Impacts

Instructional impacts are learning outcomes that are achieved directly by accompanying students to the learning objectives [9]. The instructional impact that can be achieved by students through the application of the DLMRs model is expected to increase science process skills and critical thinking skills. Companion impacts are learning outcomes attained by students in learning as a result of a conducive learning atmosphere experienced by students [9]. The companion impact expected through the application of the DLMRs model is the increasing students’ curiosity.

3.4. Results of the DLMRs Model Feasibility Assessment

The assessment of DLMRs Model given by experts presented in the Table 2.

| No. | Aspect                        | Empirical Score (X) | Score Interval | Category     |
|-----|-------------------------------|---------------------|----------------|--------------|
| 1   | Theoretical Constructs        | 9                   | X ≥ 7.2        | Very high    |
| 2   | Syntax                        | 8                   | X ≥ 6.4        | Very high    |
| 3   | Social System                 | 3                   | X ≥ 2.4        | Very high    |
| 4   | The Principle-Reaction        | 6                   | X ≥ 4.8        | Very high    |
| 5   | Supporting System             | 5                   | X ≥ 5.6        | Very high    |
| 6   | Instructional and Companion Impacts | 2               | X ≥ 1.6        | Very high    |

4. Conclusion

DLMRs model is a conceptual framework that can guide educators in designing learning activities in the classroom, as well as having characteristics, namely as follows: a) developed based on constructivism; b) syntax; c) the design of the social system; d) the principle-reactions; e) has the supporting systems; and f) has an instructional impact (science process skills and critical thinking skills), and the companion impact is a students’ curiosity. This DLMRs model is feasible to use in science learning for improving science process skills, critical thinking skills, and students' curiosity.

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