

## Nature of models in biology learning

Fenny Roshayanti <sup>(1)</sup>, Rizqi Ramayanti <sup>(2)</sup> \*, Muhammad Syaipul Hayat <sup>(1)</sup>, Reni Rakhmawati <sup>(2)</sup>

<sup>(1)</sup> Department of Science Education, Postgraduate School, PGRI Semarang University, Semarang, Central Java, Indonesia

<sup>(2)</sup> Study Program of Biology Education, Faculty of Mathematics, Science and Technology Education, PGRI Semarang University, Semarang, Central Java, Indonesia

\*Corresponding Author Email: [rizqiramayanti678@gmail.com](mailto:rizqiramayanti678@gmail.com)

| Article Information                                                                                                                                                                                                                                                                        | Abstract                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
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| <p><b>Keyword:</b><br/>Nature of models; Type of model; Characteristics of model; Biology learning</p> <p><b>Kata Kunci:</b><br/>Hakikat model; Tipe model; Karakteristik model; Pembelajaran biologi</p> <hr/> <p><b>History:</b><br/>Received : 14/01/2022<br/>Accepted : 06/06/2022</p> | <p>A model is a key element in the daily practice of biologists, students, and teachers in learning biology. The existence of models, both physical and non-physical models, is crucial in learning implementation. Therefore, this article aims to explain the importance of the nature of model (NoM) in learning biology. This study used the literature review method. The literature review contains reviews, summaries, and the author's thoughts on several library sources. Thus, this study provides a description, summary, and information about the nature of models, especially in biology learning. Based on the literature study results, the study of the nature of models in the biology class is on the implementation of learning, teaching materials, and assessments. Models can be divided into types and characteristics that become alternative solutions to represent an object since biology studies a lot about living objects.</p> <p><b>Abstrak</b></p> <p>Model merupakan elemen kunci dalam praktik sehari-hari bagi para ahli biologi, siswa guru dalam pembelajaran biologi. Keberadaan model baik itu model fisik maupun nonfisik sangat penting dalam pelaksanaan pembelajaran. Oleh karena itu, tujuan dari penyusunan artikel ini adalah untuk menjelaskan pentingnya hakikat model dalam pembelajaran biologi. Kajian ini menggunakan metode studi kepustakaan (<i>literature review</i>). Studi kepustakaan berisi ulasan, rangkuman dan pemikiran penulis tentang beberapa sumber pustaka. Dengan demikian, kajian ini memberikan deskripsi, ringkasan dan informasi mengenai <i>Nature of Models</i> khususnya dalam pembelajaran biologi. Berdasarkan hasil studi literatur, kajian <i>Nature of Models</i> dalam kelas biologi terdapat pada pelaksanaan pembelajaran, bahan ajar, dan asesmen. Model dapat dibagi ke dalam tipe dan karakteristik yang menjadi solusi alternatif untuk merepresentasikan suatu objek, karena ilmu biologi banyak mempelajari tentang objek-objek kehidupan.</p> |

## A. Introduction

21st-century skills and education are strongly linked with technology development. The use of technology develops along with the times so that students are required to compete and adjust to become quality human resources (HR) in the field of education. According to Ningrum (2016), education requires competent human resources because it can be used as an asset in the development and progress of a country. Thus, human resources have become a country's most important part of education. In the aspect of education, scientific literacy is needed since Indonesia ranked the lowest in the Program for International Student Assessment (PISA) out of 69 countries. Also, Indonesian students from 69 countries' science, reading, and mathematics achievements were still ranked 62, 61 and 63. Meanwhile, scientific literacy in the 2013 Curriculum is the ability to identify, understand, and interpret science-related issues that a person needs to decide on based on scientific evidence (Kemdikbud, 2017). Further, scientific literacy is a goal to be achieved by subjects based on science, one of which is the subject of biology.

Biology is a part of science. The word biology comes from the Greek, meaning "science of life" (bios = life and logos = knowledge) (Burlingame et al., 2011). Moreover, biology is the science that studies living organisms and how they interact with each other and their environment. In a broad sense, biology studies living things (Mcinerney 1991). Biology studies all living things, natural phenomena, and their interactions, all that students can learn through learning biology in class.

In learning biology, much empirical data is obtained from researchers, which is presented as a theory. It is done so that students can study the empirical data findings. For the theory presented to be easy to understand, it requires pictures, illustrations, concepts, and infographics related to living things and events in nature. These things are called models.

Models are an integral part of thinking and working scientifically, and it can be said that the relationship between science and models is inseparable (Louca & Zacharia, 2012; Gilbert & Justi, 2016; The model is also a product of science, primarily as a teaching and learning method and tool (Harrison & Treagust, 2000). Models act as memory aids, explanatory tools, and learning tools that are easy to remember and understand. Concerning students' understanding of modeling described in the research by Chittleborough & Treagust (2009) "Why Models are Advantageous to Learning Science" it is evident that most students

(>70%) perceived that 1) models can represent ideas or ways of working; 2) the model can explain the idea; 3) models are used to explain scientific phenomena; 4) the model can be accepted by students when the teacher explains well to show the results; 5) a model based on facts support theory; 6) models may change in previous years. In addition, Gogolin and Kruger's (2017) research showed that students saw the model as an ideal representation of the original form and aimed to describe it.

Moreover, using models can improve learning so that better quality learning outcomes are achieved, especially in terms of understanding concepts, operations, procedural skills, and reasoning (Louca & Zacharia, 2012). Models can also be key in explaining science (Gilbert et al., 1998). In addition, modeling also provides a way to reconstruct an established scientific model and become a route for developing mental skills, a core component, and validation of science and technology (Gilbert & Justi, 2016).

Bamberger & Davis (2013) research revealed that students experienced increased knowledge of learning content on model-assisted evaporation materials. Students also could reconstruct the theory into a model. This increase proves that model-based instruction could help students gain an understanding of new concepts

Given the importance of using it in the science learning process, it is necessary to review articles related to the study on the nature of the model (NoM). Hence, this study aims to describe the nature of models in science learning. This review can be used as study material and information for researchers, especially those related to model-based science learning.

## B. Material and Method

This research method used a systematic literature review (SLR) perspective or method Kitchenham (2004) explained that SLR is a research method to identify, evaluate, and interpret relevant research results related to a particular study, topic, or phenomenon. A systematic literature review is also useful for synthesizing relevant research results to make the presented facts more comprehensive (Siswanto, 2010). According to Perry & Hammond (2002), the stages in conducting a systematic literature review are described below.

### 1) Identify research questions

At this stage, the problem must be transformed into a research question (Perry & Hammond, 2002).

- 2) Develop research rules for systematic literature review  
The next stage is to develop research rules to guide a systematic literature review (Perry & Hammond, 2002).
- 3) Establish the research results database  
A research database is created and defined to define the boundaries of the search area (Perry & Hammond, 2002).
- 4) Select relevant research results  
Relevant research results are selected to be collected and structured (Perry & Hammond, 2002). In this study, the research articles on the nature of models were selected and limited from 2002 to 2021.
- 5) Choose quality research results  
The next step is to choose a linear and quality research result. It excludes and includes research in a systematic literature review (Perry & Hammond, 2002). Therefore, articles were taken from journals with qualifications, such as national journals, international journals, and reputable international journals.
- 6) Extracting research data  
Quality research results take the points or important findings (Perry & Hammond, 2002).
- 7) Synthesize research results  
Two techniques can be used, namely meta-analysis or meta-synthesis techniques. Meta-analysis is a literature review method with a quantitative approach to obtain statistical power in identifying causal relationships between risk factors or treatment of an effect. Meanwhile, meta-synthesis is a literature review method with a qualitative descriptive approach to get new theories and concepts that are more in-depth and comprehensive (Perry & Hammond, 2002). In this article, the data synthesis stages employed meta-synthesis.
- 8) Presenting results  
The findings are written in a systematic literature review report document (Perry & Hammond, 2002).

### C. Results and Discussion

The literature review conducted in this research was to collect various journal articles related to the nature of models (NoM) in biology learning. The model's scope in learning biology was seen from two parts: the model type and characteristics. The distribution of model types according to Harrison & Treagust (2000) is presented in Table 1.

According to Harrison & Treagust (2000) the types of models are divided into eight types. These models are used in the classroom as cognitive tools. First, the scale model describes a form of an object

so that students can describe it. This model is widely used in science classes that contain many objects. Its use includes transferring information from teachers to students. The teacher uses the model to describe an easily observed object accessed by students. Meanwhile, the pedagogical-analogical model can build students' conceptual knowledge (Harrison & Treagust, 2000). Third, the iconic-symbolic model is the interpretation of an abstract thing through a special sign. Iconic-symbolic models are widely used in science classes, especially in describing chemical formulas and equations (Harrison & Treagust, 2000). Teachers and students understand a fact of the formation of a chemical compound because it is explained by a model that illustrates a clear and communicative equation. Formulas and equations are so embedded in chemistry's language. For example, CO<sub>2</sub> is a symbol representing carbon dioxide, which can be transformed into OCO, O=C=O, and others. With this symbol, teachers, students, and researchers can distinguish carbon dioxide compounds' character, nature, and workings from other compounds.

Then, mathematical models are the most abstract, accurate, and predictive models (Harrison & Treagust, 2000). This model is widely found in mathematics, physics, and chemistry. Mathematical models are presented as mathematical equations and graphs that relate concepts, such as Boyle's Law, exponential equations, Newton's Laws, and others. Mathematical models can be used for various reasons since they can develop an understanding of science, test the effects of changes in systems, and aid decision-making (Voit, 2020). Fifth, a theoretical model can build the construction of one's mind from abstract ideas. An example of a theoretical model is the kinetic theory of gases' volume, temperature, and pressure. The process of oversimplification of the kinetic theory particle as a perfectly elastic space-filling sphere also qualifies as a scale model (Harrison & Treagust, 2000).

Other models that describe many concepts and/or processes are map, diagram, table, concept-process, and simulation models. Using the model of maps, diagrams, and tables, students can easily visualize. Examples are periodic tables, phylogenetic trees, weather maps, circuit diagrams, metabolic pathways, blood circulation, genealogies, food chains, and food webs. Students can also interpret a model through different colors; for example, the sea color on a map is blue (Harrison & Treagust, 2000). Meanwhile, the concept-process model represents an abstract process of natural events (Harrison & Treagust, 2000). The concept-

process model also helps students not memorize but understand the concept through a model.

On the other hand, the simulation model is unique. Simulations allow students to develop skills without sacrificing lives and property. The

application of a complex process of model simulation is the stages of global warming and population fluctuations. This simulation can encourage students to visualize reality (Harrison & Treagust, 2000).

**Table 1 Distribution of Model Types**

| Type                          | Description                                                                                                                                                                     |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Scale models                  | Scale models depict external colors and proportions but rarely show internal details, function, and use, nor are they made of the same material as the target.                  |
| Pedagogical analogical models | They are called 'analogical' because the model shares information with the target and 'pedagogical'. After all, they are teacher-crafted explanations that make non-observable. |
| Iconic and symbolic models    | Iconic, symbolic models represent an object in the form of icons and symbols that need to be interpreted.                                                                       |
| Mathematic models             | Mathematic models depict mathematical equations and graphs that elegantly show conceptual relationships.                                                                        |
| Theoretical models            | Theoretical models depict many concepts and/or processes that consist of abstract ideas.                                                                                        |
| Maps, diagrams, and tables    | These models help students visualize objects, patterns, pathways, and relationships that cannot be observed directly.                                                           |
| Concept-process models        | This model is a representation of an abstract process.                                                                                                                          |
| Simulation                    | Simulations enable novices and researchers to develop and hone skills without risking life and property and may include "virtual reality" experiences.                          |

(Source: Harrison & Treagust, 2000)

**Table 2 Model Characteristics**

| Category                     | Sub category                    | Description                                                                                                                           |
|------------------------------|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Illustration                 | Structural model                | Structural models illustrate anatomical and morphological aspects.                                                                    |
|                              | Functional model                | The focus is placed on the structure and structural aspects of the object.                                                            |
|                              | Structural and functional model | Functional models illustrate process and relations. The focus is placed on processes, functions, and causal relations.                |
| Complexity                   | Fact                            | The model displays only real data or facts.                                                                                           |
|                              | Relation                        | The model provides a relationship of facts with one another.                                                                          |
|                              | Concept                         | The model embeds concepts, relates various relationships, and can be generalized to new situations.                                   |
| Abstraction                  | Low                             | The model resembles real objects.                                                                                                     |
|                              | Medium                          | The model resembles a real object only in certain elements.                                                                           |
|                              | High                            | The model contains only certain elements that are important to the content. The model has no or little similarity to the real object. |
| Fitting to the learning goal | Fitting to the learning goal    | The complexity and the level of abstraction of the used model fit the lesson's learning goal.                                         |
|                              | No fitting to the learning goal | The model's complexity and abstraction do not fit the lesson's learning goal.                                                         |

(Source: Werner et al., 2019)

Each type of model has an explanation and characteristics. Judging from the explanation, the models' types are related but still have differences. The difference can be in the characteristics. According to Werner et al. (2019) the characteristics of the model in learning can be described in Table 2.

The characteristics of the model in the illustration category make a difference in visualizing a model. According to White et al. (2014) the model is divided into three subcategories: structural, functional, and combination. The petrified structural model illustrates the anatomy and morphology of real objects. For example, the composition of the cell structure. In contrast to the functional model

focusing on processes, functions, and causal relationships, the combination model combines structural and functional elements.

Then, the complexity category describes the model's contents in a complex manner. According to Wadouh et al. (2014), the category is classified into three subcategories: facts, relations, and concepts. The low-complexity model allows students to learn anatomical structures without connecting the three subcategories. Meanwhile, the high complexity model can show students scientific concepts as a whole.

Meanwhile, abstraction categories can be found in several frameworks and describe the degree of similarity of the model to the real object. The abstraction level is considered low if the model

is a duplicate of the real object. Conversely, the abstraction level is considered high when the model has little or no resemblance to the real

object. Then, the last category is compatibility with learning objectives, namely whether or not the model used is appropriate for learning objectives.

**Table 3 Results of the Review of the Nature of the Model in Biology Learning**

| Literature source           | Research Title                                                                                                                           | Research result                                                                                                                                                                      |
|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (Susanti, 2019)             | Analysis of the Application of Nature of Models (NoM) in Biology Learning at SMA Negeri 15 Semarang.                                     | Application of the nature of models in learning biology for the types, characteristics, and levels of understanding was used by both teachers to adapt to students' learning styles. |
| (Roshayanti et al., 2021)   | Understanding the Aspects of Testing Models and Purpose of Models for Mathematics and Natural Sciences Students at all Brebes Regencies. | Students' understanding of the nature of the model was lower because the use was less varied, and the teacher's learning model did not develop student skills.                       |
| (Bryce et al., 2016)        | Exploring Models in the Biology Classroom                                                                                                | In fact, the practice of modeling in biological research is very important. Incorporating modeling into the science curriculum can help achieve student learning outcomes.           |
| (Van Driel & Verloop, 2002) | Experienced teachers' knowledge of teaching and learning of models and modeling in science education                                     | Teachers need to understand how important models and modeling are in learning.                                                                                                       |
| (Weber 2014)                | Experimental modeling in biology: In vivo representation and stand-ins as modeling strategies                                            | In evolutionary material, the model represents the evolutionary stage using the microorganism <i>Saccharomyces cerevisiae</i> .                                                      |

**Table 4 Results of the Review of the Nature of the Model in Teaching Materials**

| Literature source            | Research Title                                                                                   | Research Result                                                                                                                                                                                                                                                   |
|------------------------------|--------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (Sholihah et al., 2019)      | Multiple Representations of Nature of Models (NoM) Types at Biology Textbook Class XI Semester 1 | The dominant type of scale model was used in class XI biology textbooks.                                                                                                                                                                                          |
| (Susanti, 2021)              | Analysis of Nature of Models (NoM) in Class X Biology Student Books                              | The type of scale model was most widely used in the textbooks of class X students. The results of the analysis of the nature of models (NoM) pattern in the books of class X Biology students were in accordance with the characteristics of biological sciences. |
| (Kusumaningrum et al., 2021) | Patterns of Model Types in High School Biology MGMP Student Worksheets                           | The type of scale model was most widely used in the eleventh-grade biology worksheets.                                                                                                                                                                            |

**Table 5 Results of Reviewing the Nature of the Model in Learning Assessment**

| Literature source       | Research Title                                                                                                       | Research result                                                                                                      |
|-------------------------|----------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| (Jansen et al., 2019)   | Assessing students' understanding of models of biological processes: a revised framework                             | Four additional points assessed students' understanding of the process concept model.                                |
| (Grünkorn et al., 2014) | Assessing Students' Understandings of Biological Models and Their Use in Science to Evaluate a Theoretical Framework | The model can be used as a copy of the real object and represents students' subjective conception in the assessment. |

Furthermore, models are widely used in biology learning activities. Its application can be seen in the learning process, textbooks, assessments, and learning content. The model review results in the biology learning process can be seen in Table 3.

Based on Table 3, it is known that the nature of model (NoM) in biology learning revealed four findings. In addition, using models in the biology

learning implementation adapts to the characteristics of students' learning styles visually, auditory, and kinesthetically. According to Susanti (2019) in learning biology at SMA 15 Semarang, many dominant types of models were found, namely theoretical and process concept models. Meanwhile, the dominant model characteristics were functional, facts, and concepts with a low level of abstraction, and the overall model used in

biology learning at SMA Negeri 15 Semarang was in accordance with the learning objectives. Although the model used was suitable, the student understanding level was not optimal. It was conveyed by Roshayanti et al. (2021) that the student's understanding level of the model was lower because the model used was less varied.

In fact, applying the nature of models in biology learning is crucial to improving student learning outcomes (Bryce et al., 2016). For example, in evolutionary material, a simple model to describe the process of natural selection is to use the yeast microorganism *Saccharomyces cerevisiae*. According to Ratcliff et al. (2012) yeast cells rapidly evolved to form aggregates with a snowflake-like appearance. Therefore, it should be underlined that teachers must understand the use and importance of models in science classrooms (Van Driel & Verloop 2002) to improve student learning outcomes.

Applying the nature of the model (NoM) is not only used when learning biology. There is also the use of the nature of models incorporated into biology materials through teaching materials. The research results found can be seen in Table 4.

Based on Table 4, using models in teaching materials could be in the form of textbooks and student worksheets. Overall, the models in the teaching materials had characteristics in accordance with the learning objectives. The dominant type of model used was the scale model. It is in accordance with the characteristics of the biological sciences, covering material in the form of abstracts of various sizes, including microscopic and macroscopic. As for the characteristics, the models in the teaching materials are in accordance with the learning objectives since students and teachers are helped to achieve goals in learning activities (Susanti, 2021).

There is also the use of the nature of models incorporated into biology materials through learning assessment. The research results found can be seen in Table 5.

The results of research findings on the nature of models (NoM) in biology learning assessments uncovered that process concept models were very useful for students studying biological sciences. In addition, the process concept model was the most complex type of model. Also, students' understanding of the process concept model can be measured using the Grünkorn framework. As a result, not all students answered the questions with a description of the explanation of the material in Grünkorn's theoretical framework. Therefore, Jansen et al. (2019) added a framework to make it more perfect. Based on their

research, there are four descriptions, including 1) nature of the model, level 1: showing the processes and related components; 2) purpose of models, level 1: models to display something; 3) testing model, level 1: schoolbooks as a source of information that has absolute truth; 4) changing the model, level 3: changing the model from concept to process. Aside from these findings, the nature of the model in learning assessment was also found in the research of Grünkorn et al. (2014). According to Grünkorn et al. (2014), models can be used as copies of real objects and represent students' subjective conceptions in solving problems. A model can also assist the problem-solving process as a comparison, and prior knowledge or personal experience can play an important role when assessing the model.

## D. Conclusion

There are eight models: scale models, pedagogical-analogical models, iconic-symbolic models, mathematical models, theoretical models, diagrams, maps and tables, concept-process models, and simulation models. Meanwhile, the model characteristics are divided into four categories: illustration, complexity, abstraction, and suitability with learning objectives. The model application in the biology class was found in the learning process, teaching materials, and assessments.

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