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MENTAL REPRESENTATION LEVEL OF JUNIOR HIGH SCHOOL STUDENTS IN CELL BIOLOGY CONCEPT BASED ON GENDER

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ABSTRACT

This study aims to determine the level of mental representation of seventh-grade junior high school students in cell concepts. The research method used was the explanatory sequential mix method with 60 research subjects. The instruments used in this research were the Mental Diagnostic Test (MDT), which consists of a reasoned true and false test, a symbolic test, and an imaging test. Based on the results obtained from the answers to the MDT instrument, it can be seen that the levels of mental representations are categorized into Initial mental representation, Intermediate mental representation 1, Intermediate mental representation 2, Consensus representation, and Target representation. The results show that on the MDT instrument, the average student is included in the intuition and experience mental model. The level of the mental representations of male students is higher than that of female students. The mental representation of the initial level, intermediate 1, and the target in male and female students have the same level; the difference occurs at the intermediate level 2 and consensus. Male students (30%) have higher intermediate level 2 than female students (20%). Furthermore, there are 10% male students and no female students at the consensus level. This research concludes that the information level profile of mental representation is identified as having the type of intuition and experience.

Keywords: mental representation; Mental Diagnostic test (MDT)

INTRODUCTION

Cells are the basic material for Biology because of the concepts that underlie students' understanding of further biological concepts, such as anatomy, histology, genetics, physiology, and biotechnology (Campbell, 2017; Nicholson, 2019; Yoshida, 2021). The concept of cells begins to be taught at the Junior High School level, grade VII, and if there is student interest in Biology, the cell concept will be studied further at the High School and College levels. Elfada et al. (2015) and Herrmann et al. (2016) emphasize that the cell concept is basic but complex and requires a high level of reasoning to understand. Previous studies show that as many as 95% of students state that cell biology is a complex material, and 80% state that cell biology is a difficult material (Juanengsih, 2015).

Research regarding students' understanding of cell material has been carried out by Hasanti and Zulyusri (2022), showing that the cell is the smallest unit of life, 62.7% of students state they do not know the concept, 28.57% have misconceptions, and 21.43% understand the concept. In line with the research of Ifatrizah (2022), students experience learning difficulties in cell reproduction material with a percentage of 69.10%. The results of Juanengsih et al. (2021) research state that as many as 23% of students need to be corrected in determining the correct information element, provide a logical reason,

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and cannot show the relationship between the selected information elements in the cell concept.

Students need mental representation to understand complex and difficult material easily (Anderson et al., 2013; Hegarty et al., 2013; Yakmaci & Adadan, 2013; Cheng & Gilbert, 2015; Quilin & Thomas, 2015; Fatiha et al., 2017; Ramadhan et al., 2017). Mental representation is the ability to depict an object obtained through the activity of the cognitive system formed based on information processing resulting from interactions with visual and verbal objects. Cheng and Gilbert (2015) present that expressing mental representations is the depiction of cognitive schemas through representations or interpretations in other forms, both orally and in writing, of the knowledge that constructs these cognitive schemas. Gentner and Stevens (2014) also reveal that mental representation is understanding and explaining a phenomenon. The cognitive schema contains interrelated information and depends on working memory, which plays a role in receiving and processing information. In receiving information, each individual has their unique character. Individuals in learning have various ways; some learn in an auditory way, some learn visually, and others learn in a kinesthetic way (Frank et al., 2016). This will affect each individual in receiving and processing information. Different presentation formats (e.g., verbal, picture) or modalities (auditory, visual, haptic) affect the ability to receive and process information.

Kaliampos and Ravanis (2019) emphasize that during the planning stage, educators must identify the concepts or materials to be taught and the forms and functions of representations they will use so that students are actively involved. Based on research conducted by Rahmat and Nuraeni (2017), visualization in learning can be used to reduce students' cognitive load. Thus, using visual media can significantly reduce cognitive load, which impacts increasing working memory (Kayluga, 2013).

Furthermore, Kaliampos and Ravanis (2019) explain that students should be invited to utilize all their senses to work well in the teaching and learning process. Learning by using many senses provides many opportunities for students to absorb learning material, so students need to have an ability called mental representation. Multiple representations allow students to visualize relationships between different concepts and enhance their ability to develop a deeper understanding of scientific phenomena. Kalyuga (2013) also explains that using representation can present information more compactly and efficiently. According to research conducted by Loksa et al. (2016), using representations can improve learning outcomes. However, it has yet to reveal students' learning strategies to increase their understanding.

Mental representation research can be applied in biology learning because mental representations can inform how a person understands a concept, such as the concept of evolution (Begrow & Nehm, 2012), microorganisms, cell biology (Agustina et al., 2020), genetics (Jalmo & Suwandi, 2018), and cell reproduction in a diagram of mitosis (Hansen & Richland, 2020), Virus (Hamdiyati, 2022b). The three studies reveal the mental representation of students. However, studies revealing the mental representation of junior high school students regarding the concept of cells by gender have not been reported.

Based on the problems mentioned above, the researchers conducted research on the ability of mental representation of cell biology concepts through the Mental Diagnostic Test (MDT) instrument in the form of a test to diagnose students' weaknesses in answering questions presented in the form of verbal, symbolic and visual representations. A person's mental representation can be investigated by interpreting the models they express and verbal explanations. Common instruments used in mental model research include multiple choice questions, open-ended questions (with pictures and descriptions), interviews with probing questions (often with pictures and descriptions of the interviewee), interviews with real models or pictures to obtain their model of choice, interviews with the problems presented, and classroom observations (Kayluga, 2010).

In addition to identifying mental representations, mental representation level categorization is also carried out. The levels of mental representation include: 1) Initial mental models that have not been formed in the form of mental models that a person has carried since birth, or mental models formed due to information from the wrong environment, or concepts and structural images made that are not at all scientifically acceptable, or students have no concept at all; 2) Intermediate mental model 1 is a mental model that has begun to form or the concepts and explanations given are close to scientific truth and structural drawings are made unacceptable or vice versa; 3) Intermediate mental model 2 is a student mental model characterized by the concepts students have and structural drawings made close to scientific truth; 4) Consensus mental mo-

del, which is marked by the explanation/concept owned by the scientifically acceptable student and the structural drawing made close to the truth, or vice versa, the explanation/concept that is owned has not been scientifically accepted, but the structural drawing made is correct; 5) The target mental model is characterized by concepts/explanations and structural drawings made by students scientifically.

The purpose of this research: 1) How is the mental representation of grade VII junior high school students in Sukabumi Regency on the concept of cell biology based on MDT? 2) How is the mental representation of male and female students in grade VII Junior High School in the Sukabumi Regency on the concept of cell biology?

This research is vital because mental representation will become important data for analyzing students' difficulties in understanding microscopic, macroscopic, and abstract. The results obtained are expected to provide an overview of the mental representation and mental representation of male and female students as input and reflection for Biology teachers in training students' mental representation to increase students' understanding of biology material, especially the concept of cells.

METHODS

The research method was an explanatory sequential mix method (Creswell & Clark, 2017). This research was conducted in the odd semester of the 2021 academic year at one of the junior high schools in Sukabumi. The sample of this research was the students of class VII, as many as 60 people.

The instrument used was the Mental Diagnostic Test (MDT) (adapted from Hamid, 2016) with the interview sheet. Previously, the instrument had been validated by expert judgment in the evaluation and cell biology material. MDT is a reasoned true and false test with six questions, a symbolic test with three questions, and a picture test with two questions. This research was implemented in three steps: 1) We gave the MDT instrument to students; 2) We defined the level of mental representation from their answers; 3) We identified the level of mental representation with interviews. In this instrument, the students' mental representations were seen from their ability to build causal relationships between causal networks in visual media. The following table provides the indicator of true-false-reasoned MDT Instruments (Table 1).

Table 1. Indicators of True False Reasoned Test

Indicator	Number of Questions	No. Question	Question Indicator
Analyze the chemical components that make up cells	2	1,2	C4/K3
Analyze part of cell function	2	3,4	C4/K3
Compare prokaryotic cells and eukaryotic cells	2	5,6	C5/K3

In Table 1, it can be seen that the questions are right or wrong with reasons which are derived from learning indicators. This part of the test emphasizes analyzing the cell's chemical components, analyzing the part cell's function, and comparing prokaryotic and eukaryotic cells. Furthermore, in Table 2, the indicators of symbolic questions are shown.

Table 2. Indicators of Symbolic Test

Indicator	Number of Questions	No. Question	Question Indicator
Analyze the similarities and differences between animal and plant cells	2	7.8	C4/K3
Make a Venn diagram of similarities and differences between animal cells and plant cells	1	9	C6/K4
Make a diagram of the differences and similarities in the function of cell organelles	2	10	C6/K3

In Table 2, it can be seen that the questions of the symbolic test, in part of the test, emphasize analyzing similarities and differences between animal and plant cells, making a Venn diagram, and making a diagram of differences and similarities in the function of cell organelles. Table 3 presents the indicators of the picture test.

Table 3. Indicators of Picture Test

Indicator	Number of Questions	No. Question	Question Indicator
Draw a picture of the organelles of animal cells and plant cells	2	11.12	C6/K4

In Table 3, students are asked to draw a picture to describe animal and plant cells to diagnose the weaknesses of students' abilities. Then, the data is accumulated for each question, and the proportion of mental representation categories of each type of test is calculated and analyzed descriptively using percentages. The results of these answers are categorized according to the type of mental model (Table 4).

Table 4. Types of Mental Models with the Indicator of Each Type of Mental Diagnostic Test

MDT Test	Types of Mental Models	Score
Right Wrong Reasoning	Type I (Intuition) = T1	7 – 15
	Type II (Experience) = T2	25 – 16
	Type III (Scientific) = T3	35 – 26
Symbolic	Type I (Intuition) = S1	15 – 65
	Type II (Experience) = S2	66 – 100
	Type III (Scientific) S3	110 – 150
Picture	Type I (Intuition) = G1	20 – 80
	Type II (Experience) = G2	86 – 155
	Type III (Scientific) = G3	155 – 200

Adapted from Hamid (2016)

The results of the students' answers based on MDT are categorized at the level of mental representation. That is the initial representation, the intermediate representation 1, the intermediate representation 2, the consensus representation, and the target representation, as presented in Table 5. Then, the data is presented in the form of a bar chart. Furthermore, the data is categorized by gender.

Table 5. Levels of Mental Representations

MR Levels	Indicator
Initial representation	An unformed model is a mental model that a person has carried since birth or a mental model formed due to information from the wrong environment or concepts and images of structures created completely unacceptable scientifically, or learners have absolutely no concept.
Intermediate representation 1	The mental models have begun to form concepts and explanations given approaching scientific truth and drawing structures made unacceptably or otherwise.
Intermediate representation 2	The mental model of learners is characterized by the concept that students have and drawing structures made close to scientific truth.
Representation of Consensus	The mental model that can be categorized as a mental model of consensus is characterized by explanations/concepts that students have that can be accepted scientifically and structural drawings made close to the truth, or otherwise, the explanation/concept that has not been well received scientifically, but the picture of the structure is made appropriately.
Representation of Target	The mental model is characterized by concepts/explanations and drawings of structures made by students with scientifically appropriate.

(Park, 2016)

The result of the data collection obtained answered research problems. Data processing was done in several steps, such as tabulation, counting, and interpreting data.

Data selection means that after all data is collected, the author performs a settlement, whether the collected data can be processed or not to separate which data can be used and which data cannot be used. Data tabulation means the author performs three steps: 1) creating or providing the necessary table lanes according to the needs, 2) entering each alternative answer of each question item and each respondent, and 3) calculating the frequency of alternative answers from each item and alternative answers. Calculating alternative answers means the authors established a percentage calculation technique to obtain research conclusions. This indicates that each alternative answer on each item is calculated in frequency and processed by comparing the number of respondents' answer frequencies on each item with the number of respondents multiplied by one hundred per cent. The formula used to calculate data is from Arikunto (2020):

$$P = \frac{FX}{N} 100\%$$

Description: P = percentage F = frequency (respondent's answer) N = Number of cases (number of respondents)

RESULTS AND DISCUSSION

The results of the data analysis show that seventh-grade junior high school students are dominated at the initial and intermediate levels. The mental representation possessed by students is formed due to the assimilation of the students' internal representations with the external representations they get from the environment. The results of teacher interviews show that the learning approach to students is only conceptual in terms of presenting material, dominated by verbal presentation, and only a little in visual form or symbolic. The concept of material explained verbally is seen in the superior student learning outcomes. However, only some students understand the concept. This means that students only memorize without meaning and cannot relate one concept to another.

This section results from mental representation using MDT with true-false questions, symbols, and pictures (Table 6).

Table 6. Students' Mental Representation Using MTD

Level	True False Question	Symbolic	Picture
Intuition	25%	35%	70%
Experience	65%	50%	25%
Scientific	10%	15%	5%

Based on Table 6, in the true-false questions, the dominance of students' mental representation is the experience level (65%), and in symbolic questions is the experience level (50%). For the picture questions, the dominance of students' mental representation is the level of intuition (70%). According to Hamdiyati et al. (2018), this type of intuition is choosing answers accompanied by ideas written down without a strong conceptual basis and not a product of experience. The type of experience is choosing answers accompanied by ideas written based on interpretations that refer to the basis of experience.

The levels of mental representation formed can be seen after knowing the results of the students' Mental Diagnostic Test (MTD). The emergence of students' mental representation levels is reflected in the ability to interpret the three sub-variables of mental representation abilities, namely verbal, symbolic, and visual, which can be seen from students' answers from MDT. This study's results show that students' average mental representation has been formed only at the initial representation following the percentage level representation (Figure 1).

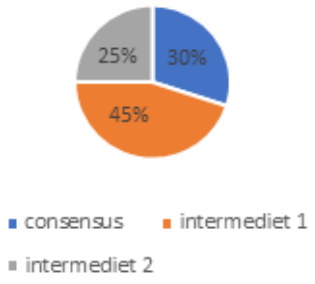

Figure 1. Percentage of Students' Mental Representation Level

Based on Figure 1, the percentage of mental representation levels in class VII obtained the results of 30% (6 students) at the initial mental representation level. There are 40% (8 students)

at the intermediate mental representation level 1. There are 25% (5 students) at the intermediate mental representation level 2. 5% (1 student) are at the consensus mental representation level. Students should be included in the target's mental representation level.

The data analysis results in gender differences can be seen in Figure 2, which shows the level of mental representation of class VII students based on gender.

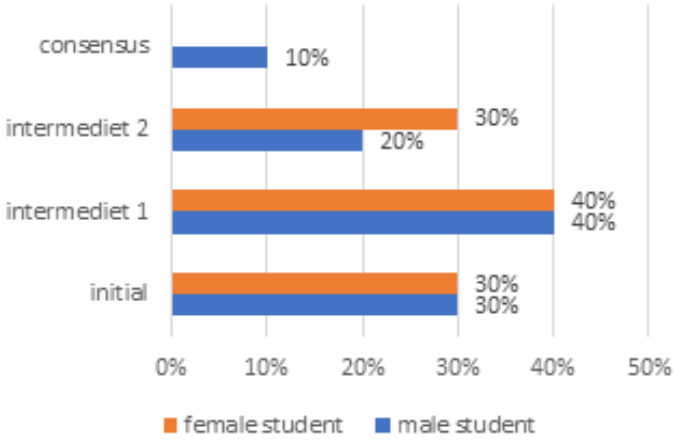

Figure 2. Level of Mental Representation by Gender

The data analysis shows junior high school students are dominated at initial and intermediate levels. The results of this study align with Hamdiyati (2022a) and Hamdiyati (2017), which is not surprising if the level of mental models is in a low category. This is strengthened by the results of interviews that students are accustomed to answering questions in the form of writing rather than pictures. Mental representation is the ability of students to find information and communicate it in verbal and non-verbal forms (Johnson-Laird, 2013). Mental representations are always dynamic, adapting to one's cognitive processes; mental representations are abstract descriptions of memory; individuals can be formed in their own/complex way, can identify misconceptions and preconceptions so that they can be straightened out or corrected, and function as a driver or as a barrier to successful understanding formation scientific.

This study used the Mental Diagnostic Test (MDT) as the instrument. As stated by the mental model, it is used as a reference for mental representations because it can predict and explain phenomena and concepts and play an important role in developing learner thinking (Lucas & Mai, 2022; Li et al., 2023). Mental models simultaneously provide a cognitive framework for spatial information and reasoning (Alfred, 2020). Based on the results of research analysis using the MDT instrument, on average, seventh-grade junior high school students are identified as having the type of intuition and experience as seen from the students' understanding of expressing ideas based on analogies with the basis of their daily experiences and intuition.

Differences in students' prior knowledge cause differences in the formed causal network. This impacts the emergence of different patterns of mental representation of students. Cheng (2018) assert that one can only represent information in an image by knowing and understanding the elements of information contained in it. This aligns with the findings of Kalyuga (2013) that a person's ability to represent information in pictures is related to the amount of knowledge or cognitive schemas in long-term memory.

In addition to the above, differences in students' mental representation patterns found in the same picture can occur due to variations in working memory performance. This working memory performance differs from individual to individual (Jackson, 2016). Thus, the difference in students' knowledge of an image and the difference in students' working memory performance allows for differences in understanding when students read the picture.

The effect of the combined modes of representation means that each mode multiplies the complexity of the meaning achieved; each mode interacts with and contributes to the meaning of the concepts learned from the other modes. The

interaction of these modes can take the form of different meanings. Sometimes, different modes can carry the same meaning, have different meanings, and sometimes even be contradictory (Saptono et al., 2017). An example of conflicting information provided by different modes is the representation of cell size. A diagrammatic representation cannot justify the exact size of a cell compared to a cell as a whole. All the diagrams in school textbooks exaggerate the size of the cells. However, numerical data (symbolic mode) or verbal analogy (verbal mode, such as the analogy between the relative sizes of a tennis ball and a football field compared to cells) can more accurately describe cell sizes. When looking at the size of microscopic cells, the image is asked to understand macroscopically (Billir & Karaçam, 2021). It should be noted that although the information expressed in the visual mode is inconsistent with the other modes, it is important that students understand the nature of multimodal representation and be able to relate between the various modes of representation to arrive at a meaningful understanding of scientific concepts (Cheng, 2018).

Regarding the context of representation, verbal and visual forms of representation are important in learning to construct students' mental representations. According to information processing theory, information received through the five senses is then encoded according to the individual's natural thinking. This code is then stored in memory. Codes (coding) can make it easy for students to remember (long-term memory). When the individual needs that information to remember, he or she must recall the code and perform the re-encoding process. Meaningful learning involves both verbal and visual integration, which was developed based on the cognitive theory mentioned above as well as the latest approaches to understanding text and graphics with the assumption that understanding external representations is the human mind, the interaction between words and pictures and between verbal and visual mental representations and insights contribution of visual representation to the teaching, learning, and assessment of scientific topics (Anagnostopoulou et al., 2015).

When both text and pictures are needed for comprehension and learning, students must integrate verbal and pictorial information into one coherent, task-appropriate mental representation, a process known as text–picture integration (Zhao & Wagner, 2020). Drawing and writing techniques provide detailed information about students' cognitive structure and can also be used to reveal misconceptions (Kiliç, 2019). The picture can serve a scaffolding function for constructing mental representation even after being presented for just a few seconds, which is impossible with text (Eitel & Scheiter, 2015). Mental representations are codes of information that must be remembered. Stains and Sevian (2015) express that mental representation can be formed when students face a particular problem.

In biology, combining verbal, symbolic, and visual representations to build skills to represent macroscopically, (sub) microscopic, and symbolic modes is very important. This supports the idea of Solso et al. (2010), which states that humans have a special ability to categorize (meaning mentally represent) objects in the physical world (such as animals and plants) through mental imagery and visually represent them. With this ability, humans can predict the dynamics of the object at hand to successfully adapt to the object.

Based on Figure 3, the mental representation of the initial level, intermediate 1, and the target of the male students have the same level; the difference occurs at the intermediate level 2 and consensus. Male students (30%) have higher intermediate level 2 than female students (20%). Furthermore, 10% of male and no female students are at the consensus level. In their research, Madsen et al. (2013) find that male students tend to have higher knowledge than girls in observing physical phenomena. Both male and female students can solve problems with the help of pictures. Apparently, male students can better describe problem-solving than female students. This proves that the imagination of males is higher. According to research by Fitriani (2015), male students can solve problems using pictures and describe the solutions. The interview results also show that the learning approach to students is only contextual. The presentation of material is dominated by verbal presentation, only a little in visual form or symbolic. This is indicated by the learning outcomes of students who master the concept of material that is explained verbally. However, very few students understand the concept. This is in line with Dale Cone's (Cone of experience) theory that the more concrete the teaching materials, the more experience they get. If only rely on verbal language, then the more little experience to be gained. This means that students only memorize without meaning and cannot relate one concept to another.

The study's results indicate that using mental representation skills in learning will assist

students in forming mental models as an approach to external reality. Mental representation is essential for teachers to know the students' level of understanding, difficulty, and misconception (Amalia et al., 2018). In addition, learning with mental representation can build procedural and conceptual knowledge if, in learning, interesting visualizations are carried out for concepts at the microscopic (sub) level, and there are procedures for transforming from macroscopic to symbolic and to (sub) levels. This result is important for biology teachers to pay attention to providing visual media that is by the knowledge and performance of students working memory to reduce cognitive load and improve student learning outcomes.

CONCLUSION

This study concludes that the mental representations of grade VII junior high school students on the concept of cell biology based on MDT are identified as having the type of intuition and experience. The novelty of this study is the information obtained that male students have a higher level of mental representation but only at the level of intuition and experience. Through this research, it can be obtained an overview of how effective learning will facilitate cognitive combinations if visual text recognition is used in learning for male and female students according to their mental representation model.

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