

## Genetic Material Upgrading: Misconception Identification Study in High School Biology Teachers

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### Abstract

*This study aims to identify and map patterns of genetic misconceptions in high school biology teachers. This research was conducted in several stages, including the development of diagnostic test instrument with Certainty of Response Index (CRI). The instrument used in measuring misconceptions in this study is a three-tier test diagnostic instrument. There are 20 questions covering Basic Competencies 3.3, 3.5, 3.6, 3.7, and 3.8. The cognitive level of the questions covers C2 to C5 in Bloom Taxonomy. The validator's assessment shows that the instrument is suitable for data collection. The results of data collection indicate that the topics identified as having misconceptions among high school teachers are quite high (above 50%), among others: (1) The relationship between DNA, genes, and chromosomes; (2) Chromosome structure of eukaryotic cells; (3) The process of protein synthesis (transcription, translation, and genetic code); (4) Mendel Law 1; (5) Mendel Law 2; (6) Crossing-Over, Sex-Linkage, and Non-Disjunction; and (7) Causes of Mutations. Apart from misconception data, this study also reveals the experiences of teachers in conducting Biology teaching and learning activities, especially related to Genetics in high school.*

## 1. INTRODUCTION

One important aspect of learning including biology learning is the material aspect or concepts being learned. Genetics is an important material for science in schools. Genetics is seen as the basis for understanding and developing biological sciences or other sciences related to biology (Roini, 2013). One of the problems that arise in learning is the correctness of the concepts being taught.

Research results show that Genetics lessons are difficult, tiring, and tedious (Venville, 2002). The concept of Genetics is abstract, making it difficult for students to construct it completely. Genetic concepts presented in books or during lessons are still difficult to understand. This because genetic material is still viewed as abstract (Corebima, 2009) and esoteric (Tsui and Treagust, 2003) because it includes microscopic objects and their processes are outside of everyday life.

Genetics Learning in schools and colleges should be able to facilitate students to understand the concept of Genetics as a whole. Prior to the formal learning process at school or on campus,

students have brought the initial concept, including the concept of Genetics. The initial concepts that are brought by students sometimes do not match or conflict with the concepts accepted by the experts. These different concepts are often called misconceptions (wrong concepts) or alternative concepts. They get these concepts when studying at a previous level, for example in elementary, middle school, or from their experiences and observations in everyday people's lives (Berg, 2004).

Misconceptions can have a bad impact on students because they can hinder the learning process due to wrong understanding of concepts. The characteristics of misconceptions that have been identified from several studies reveal that misconceptions tend to spread, are stable and resistant to being changed only by traditional learning methods or strategies and tend to persist while in university even into adulthood (Tekkaya, 2012). If this is allowed to continue, the misconceptions experienced by students will continue to affect the learning process of students, because misconceptions in students that are not

immediately addressed, over time will become dogmas in the mind that will continue to be carried to the next level of education.

Misconceptions that occur to students are not only caused by students' failure to construct the concept itself, but also due to misconceptions that occur in the textbooks they study or misconceptions taught by the Subject Teacher. A number of studies, for example by Elisa et al. (2017); Nusantari (2011); Mustika et al. (2014); and Sholihat et al. (2017) have revealed misconceptions in students and college students. Unfortunately, misconceptions studies on Genetics material that have been carried out are mostly on books and students; while the misconceptions among teachers have not been widely revealed. Studies have been conducted on prospective teachers (Primandiri & Santoso, 2015) in Kediri, and on learning patterns and teacher competency tests (Roini, 2012; 2014) on teachers in Ternate. In Magelang, sources about related matters are still missing, thus opening up opportunities for research studies. With the identification data of misconceptions revealed by the Biology teacher in Magelang, it will be possible to upgrade Genetics material for higher quality Biology learning in the future.

The detection of misconceptions can be done in several ways. Mustika et al. (2014) mentions some of them, namely the presentation of concept maps, multiple choice tests with open reasons, making scientific papers, using concept assessments, and the Certainty of Response Index (CRI) with structured interviews. CRI can be used to identify misconceptions, as well as to distinguish between those who do not know the concept (Hasan and Kelley, 1999).

CRI is a measure of the level of confidence or certainty of the respondent in answering the questions given. CRI is usually based on a scale that is given together with the answer to a question. CRI uses a scale of six (0-5). According to Tayubi (2005) the number 0 indicates that you do not know the concept at all (the answer is guessed in total), while the number 5 indicates complete confidence in the truth of knowledge in answering a question (question), there is no element of guesswork at all. If the degree of certainty is low (CRI 0-2) then this suggests that the logging process played a significant role in determining the answer.

Regardless of whether the answer is right or wrong, a low CRI value indicates an element of guesswork which indirectly reflects ignorance of the concept underlying the answer determination. If the CRI is high (CRI 3-5), then the respondent has a high level of confidence in choosing answers. In this situation (CRI 3-5), if the respondent gets the correct answer, it can indicate that a high level of confidence in the correctness of the biological conception has been well tested. However, if the answer obtained is wrong, it indicates a

misconception in the knowledge of a subject matter that is owned and can be an indicator of the occurrence of misconceptions. There are four possible combinations of answers (true or false) and CRI (high or low) for each individual respondent.

Based on the background that has been stated, the objectives of this study include: (1) Identifying genetic misconceptions in high school biology teachers in Magelang based on the Certainty of Response Index (CRI) model; and (2) Mapping the pattern of genetic misconceptions in high school biology teachers in Magelang based on the Certainty of Response Index (CRI) model.

## **2. RESEARCH METHODS**

This research is a one-shot case study (Sugiyono, 2014). In this study, the independent variable was treated, then continued with the observation or measurement of the dependent variable. This research was conducted in several stages, namely: (1) Development of a diagnostic test instrument for misconceptions with the CRI model; (2) Assessment of the validity of the instrument by experts; and (3) instrument testing. The research was located at SMA Kota Magelang from March to September 2020. The population in the study included all Biology Subject Teachers in SMA Kota Magelang. While the sample in the study included 6 teachers who are members of the MGMP Biology in Magelang City. The selection of samples to be research subjects was carried out by purposive sampling.

Content and construct validity tests are carried out using a validation sheet which includes the following criteria.

- Subjects: The suitability of the questions with the indicators, the clarity of the questions/scope being measured, the suitability of the subject being asked with the level of thinking of the subject
- Problem construction: Use of the appropriate question/command word, there are no questions that cause multiple interpretations
- Language: Use of language that is simple and easy to understand, Use of Indonesian is good and correct

After the respondent fills in the instrument, the researcher checks the results of filling in the instrument with the prepared answer key. The results of examining the respondents' answers to the instruments on the first and second level questions were processed by giving a score of 1 if the answer was correct, and a score of 0 if the answer was wrong. Meanwhile, the confidence level of 0-2.4 on the CRI scale is categorized as low, while the confidence level of 2.5-5 on the CRI scale is categorized as high.

In the diagnostic instrument in the form of a three-tier test three levels, the first level is a conventional multiple choice. The second level (two

tier) consists of a set of reasons for answering questions at the first level, where respondents must choose the reasons for the answers, they choose to the first level questions. At the third level (three tier), respondents choose the level of confidence on the answers they choose at the first and second levels (Kaltakci & Didis, 2007). With three levels of multiple choice, there will be eight possible combinations of respondents' answers, which can be classified in the following table.

**Table 1. Three Tier Test Answer Category**

One Tier	Two Tier	Three Tier	Category
Correct	Correct	High Level of Confidence (CRI > 2.5)	Understand the Concept
Correct	Incorrect	High Level of Confidence (CRI > 2.5)	Misconception ( <i>False Positive</i> )
Incorrect	Correct	High Level of Confidence (CRI > 2.5)	Misconception ( <i>False Negative</i> )
Incorrect	Incorrect	High Level of Confidence (CRI > 2.5)	Misconception
Correct	Correct	Low Level of Confidence (CRI < 2.5)	Guessing (not confident)
Correct	Incorrect	Low Level of Confidence (CRI < 2.5)	Don't understand the Concept
Incorrect	Correct	Low Level of Confidence (CRI < 2.5)	Don't understand the Concept
Incorrect	Incorrect	Low Level of Confidence (CRI < 2.5)	Don't understand the Concept

### 3. RESULTS AND DISCUSSION

#### a. Development of Diagnostic Test Instruments for Misconceptions on Genetics

The findings that are sought in this study are the percentage and the results of the analysis of misconceptions that come from within the high school biology subject teachers in the city of Magelang. The misconceptions studied were specifically focused on Genetics in class XII SMA. The instrument used in measuring misconceptions in this study is a three-tier test diagnostic instrument, which combines multiple choice level 1, multiple choice level 2 (reasons for choosing answers in level 1 questions), and the level of confidence in

answering which is stated in the Certainty of Response Index. (CRI).

The development of test instruments was carried out by first analyzing the class XII SMA curriculum on Biology subjects, especially those related to Genetics material. Based on the results of the curriculum analysis, the expected Basic Competencies, indicators, cognitive level of the questions based on the revised Bloom Taxonomy (C1-C6) were determined, and the distribution of question numbers. Each of these points is written in a grid of questions.

#### b. Validation Results of Test Instruments by Expert Validators

##### 1) Results of Validation by a Genetic Expert Validator

Based on the analysis of the items covering aspects of the subject matter, question construction, and language, it was found that all the items were in accordance with the aspects of the assessment. In addition to an assessment based on these indicators, the validator also provided a number of suggestions for the instrument. Based on the validator, in general the test instruments are good and can be used, it's just that for the instrument grid, especially question no. 3 needs to be checked again whether it is included in the cognitive level category C3 or C2 yes. Then the instructions for filling out the test instrument in point 3 are added information that what needs to be answered are questions and reasons. Because not every test instrument includes reasons, so if the instructions are not clear, it could be that only the questions are filled in, the reasons are not filled in. So that giving clearer instructions is better.

##### 2) Results Validation by expert validators in the field of learning evaluation

Based on the item analysis covering the subject matter aspects, question construction, and language, it was also found that all the items were in accordance with the assessment aspects. In addition to an assessment based on these indicators, the validator also provided a number of suggestions for the instrument. According to the validator, the instrument is good and feasible to be tested. The researcher should pay attention to the presentation of the questions and the layout of each question so that the respondent who later answers the questions on the instrument does not experience confusion. This is also related to the characteristics of the instrument as a three-tier test. In addition, the validator also provides input for further questions in addition to the diagnostic test for misconceptions on genetic material, which is related to the teaching and learning experience of teachers in Genetics material. According to the validator, clear questions should be used and can be related to the results of working on the test instrument.

**c. Trial of Misconceptions Diagnostic Test Instruments on Genetics**

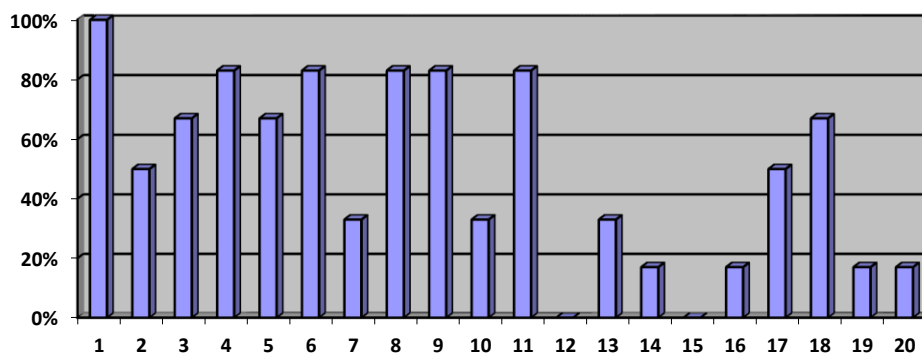
Based on the three-tier test answer category which is also used in the research of Istiyani et al.

(2018), obtained the following interpretation of the results of filling out the diagnostic test.

**Table 2. Interpretation Diagnostic Tests Results for Genetics Misconceptions**

No.	Topics	Persentase			
		Understand the Concept	Don't Understand the Concept	Guessing	Misconception
1	Relationship between DNA, Genes and Chromosomes	0%	0%	0%	100%
2	The parts in the eukaryotic cell structure	17%	17%	0%	50%
3	The parts in the eukaryotic cell structure	33%	0%	0%	67%
4	Protein synthesis processes (transcription, translation, genetic code)	0%	17%	0%	83%
5	Protein synthesis processes (transcription, translation, genetic code)	0%	17%	17%	67%
6	Protein synthesis processes (transcription, translation, genetic code)	17%	0%	0%	83%
7	Protein synthesis processes (transcription, translation, genetic code)	17%	50%	0%	33%
8	Mendel Law 1	17%	0%	0%	83%
9	Mendel Law 2	17%	0%	0%	83%
10	Application of Mendel Law 1 and 2	67%	0%	0%	33%
11	Crossing Over, Sex-Linkage, and Non-disjunction	17%	0%	0%	83%
12	Gene Interactions	100%	0%	0%	0%
13	Patterns of Heredity	67%	0%	0%	33%
14	Basis of Sex Determination	50%	33%	0%	17%
15	ABO Blood Type Trait Heredity	100%	0%	0%	0%
16	Hereditary Disease and Disability in Human	83%	0%	0%	17%
17	Types of Mutation	50%	0%	0%	50%
18	Causes of Mutation	17%	17%	0%	67%
19	The impact of mutation to daily life	83%	0%	0%	17%
20	The utilization of mutation to daily life	83%	0%	0%	17%

If displayed in graphic form, the topics on Genetics material that trigger many misconceptions can be seen in Figure 1.



**Figure 1. Percentage of Topics Identified with Misconceptions**

Based on the results of data analysis, it can be seen that the topics identified as having misconceptions among high school teachers are quite high (above 50%), among others:

1. Relationship between DNA, Genes and Chromosomes
2. The parts in the eukaryotic cell structure
3. Protein synthesis processes (transcription, translation, genetic code)
4. Mendel Law 1
5. Mendel Law 2
6. Crossing Over, Sex-Linkage, and Non-disjunction
7. Causes of Mutation

The topics mentioned above are consistent with the results of research by Primandiri & Santoso (2015). In this study, it was found that the lack of relevance of the teaching materials used could cause misconceptions among prospective teachers regarding: (1) understanding the structure of chromosomes, (2) location of genes on chromosomes, (3) understanding of sex cells and body cells related to the type of chromosome (autosome). and gonosomes), (4) misunderstanding of genetic material replication and expression, and (5) misconceptions about mutation and recombination. Apart from the lack of relevance of teaching materials, other factors that influence the occurrence of misconceptions in this study are the absence of practicum that supports the concept, the absence of support for genomic analysis facilities, and the absence of utilization of the development of a genomic database.

In addition to identifying misconceptions, this study also found findings in the form of teachers' experiences in organizing Biology teaching and learning activities, especially on Genetics in high school. Experiences related to teaching and learning in the topic of Genetics can be described as follows.

1. Aspects of Experience in Higher Education related to Genetics Subjects  
Some materials are difficult to understand, but learning is fun. There were respondents who had experience crossing *D. melanogaster*, but forgot about the results obtained.
2. Aspects of Teacher's Impression / Perception of Genetics Subject  
Genetic material is essential for increasing scientific literacy of Biology. Some material is fun if you can understand it. However, some materials in lectures have also been forgotten and when teaching have to learn again. However, the teacher is motivated to go deeper.
3. Aspect Topics that are easy and difficult to understand  
Teachers find it difficult with materials: genetic substances, protein synthesis and mutations,

and molecular genetics. Teachers find it easy to teach Mendelian Genetics material.

4. Model aspects used in learning Genetics material  
Some of the models used by teachers in learning genetics include: Lectures (66.67%), Discussions (100%), Practicum (50%), Project Learning (16.67%), Multimedia (16.67%), THT and games (16.67%).
5. Aspects of student responses to learning organized by the teacher  
Students' responses to learning genetics varied, some were enthusiastic and satisfied, some were less enthusiastic and less satisfied. Students are motivated and happy with the use of various methods and media. Respondents also stated that there were students who were slow in understanding Genetics material.
6. Aspects of Learning Resources  
There is no specific source because it uses the Biology Package book. However, if necessary, you can use Suryo's Book of Human Genetics (1980), and use videos related to genetics.
7. Suggestions for College Genetics Courses  
Suggestions that teachers can give for courses in Genetics in Higher Education include:
  - The existence of media that can really describe genetic material
  - There is a balance between theory and practice / research, so that literacy levels and scientific mastery increase.
  - More emphasis on human genetics
  - Fun and easy to understand learning
  - More easy, clear, and simple genetics practicums should be expanded
  - Development and effective use of audio-visual media

#### **4. CONCLUSIONS AND SUGGESTIONS**

A diagnostic test instrument for misconceptions on Genetics material has been developed using a three-tier test using the Certainty of Response Index (CRI). Based on the evaluation of the genetic material expert validator and the learning evaluation expert validator, it was found that the instrument was good and suitable for use in data collection. Based on the results of data analysis, it can be seen that the topics identified as having misconceptions among high school teachers are quite high (above 50%), among others: (1) The relationship between DNA, genes, and chromosomes; (2) Chromosome structure of eukaryotic cells; (3) The process of protein synthesis (transcription, translation, and genetic code); (4) Mendel I Law; (5) Mendel II's Law; (6) Crossing Over, Sex Linkage, and Nondisjunction; and (7) Causes of Mutations.

Some suggestions that can be given for further research include the following.

1. Further research can be carried out regarding the identification of misconceptions about Genetics in XII grade high school students in Magelang City and Biology study program students who are taking Genetics courses.
2. Further research can be carried out to follow up the development of teaching materials, namely the Pocket Book of High School Genetic Concepts for Teachers and Students.

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