Using *Certainty of Responses Index* (CRI) for Assessment to Identify Graduate Students' Misconceptions in Genetics

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Abstract: Misconceptions in genetics can be found in various levels of education: students at middle schools, graduate or postgraduate students, and even biology teachers and lecturers. This descriptive exploratory study aimed to identify graduate students' misconceptions in genetics before they were enrolled in a genetics classroom. Research data was analyzed using a CRI instrument. A descriptive analysis was also employed to analyse the data. The use of CRI assessment as an instrument to identify graduate students' misconceptions in genetics was assisted by a diagnostic test and structured interviews. The results of the research suggested that students' misconceptions were found in the entire main concepts of genetics examined that were definitions and scopes of genetics, genetic materials, reproduction of genetic materials, and changes in genetic materials. These misconceptions were successfully identified based on the students' descriptions of the answers and the students' level of confidence in answering questions listed in the CRI instrument. However, no misconceptions could be recognized in genetics sub-concepts because not all respondents provided answers to them. Research findings indicate that a multiple choice test and an essay test should be added to the diagnostic test which is accompanied by the CRI instrument. In addition, a close book and an open book diagnostic test should also be compared to examine students' misconceptions level.

1 INTRODUCTION

Recently, students' misconceptions have become an interesting topic discussed by the educational researchers. There are still many biology concepts misunderstood by learners (Duit, 2007; Kaharu, 2007; Shaw et al., 2008). Misconceptions can occur at every level of education. Misconceptions are the accumulation of learners' inappropriate understandings of correct concepts. Students' misconceptions in genetics have been found at some high schools and colleges (Shaw et al., 2008), and at the graduate schools in the United States (Smith and Knight, 2012). Misconceptions can also be found in biology textbooks (Nusantari, 2011).

Teachers can use a diagnostic test, interviews, and question and answer tasks to identify students' misconceptions. Both common multiple choice test (Treagust, 2006) and essay test are not very effective in distinguishing students who either understand a concept, misunderstand the concept, or do not understand it at all. Misconceptions may result from students' lack of confidence in answering a question. Even though misconceptions are sometimes hard to fix, they can be detected and prevented (Salirawati, 2011). Students' misconceptions can be discovered by integrating CRI (certainty of responses index) technique to a diagnostic test (Hasan et al., 1999). CRI (certainty of responses index) technique is a technique used to measure the level of respondents' certainty or confidence in answering every task.

This study was focused on the use of CRI technique to identify biology students' misconceptions in genetics. The diagnostic evaluation instrument combined CRI technique with an essay test. This instrument would give the participants freedom to provide answers and argue about genetic problems. In general, genetic concepts are difficult to understand because they are abstract and wide-ranging. Therefore, the use of CRI technique to diagnose students' misconceptions in genetics hopefully can result in the improvement of learning in the classroom.

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2 METHOD

This descriptive exploratory research was conducted from October until December 2017. Research samples consisted of 16 graduate students from Khairun University. Before they were registered to a genetic class, they were required to complete a test. Data was collected using a diagnostic test containing genetic concepts and a CRI instrument. The diagnostic test contained 35 items related to genetic concepts. The six scales of CRI instrument which represented the participants' level of certainty are presented in Table 1 below.

Table 1: The Certainty of Responses Index (CRI) Scales (Hasan, et al., 1999).

Index	Explanation
0	*Guessing*
1	*Almost guessing*
2	*Not certain*
3	*Certain*
4	*Less certain*
5	*Completely Certain*

The percentage of the students' misconceptions in genetics was determined based on CRI technique criteria as shown by Table 2 as follows.

Table 2: Criteria of Students' Misconceptions Based on CRI Technique (Nofiana, 2013).

Criteria of Answers	Low CRI (< 2,5)	High CRI (>2,5)
Correct answers	Correct answers; low CRI means unable to understand the concepts.	Correct answers; High CRI means able to understand the concepts.
Incorrect answers	Incorrect answers; low CRI means unable to understand the concepts.	Incorrect answers; High CRI means misconceptions.

3 RESULT AND DISCUSSION

3.1 Students' Level of Certainty in Answering Questions in Genetics

The results of the CRI-based diagnostic test showed that 52% of the students guessed the answers (scale 0). The percentages of the students who almost guessed (scale 1) and was uncertain (scale 2) about the answers were 19% and 11%. Unfortunately, relatively low percentages were found on scale 3 (10%), scale 4 (6%), and scale 5 (2%). These numbers suggested that the lowest percentage of the participants' certainty was observed on the highest scale of CRI and vice versa. It, therefore, indicated that the participants' responses varied inversely with CRI scales. There were only 2 students (12.5%) completely certain about the answers while the rest (14 students) were less certain and /or only guessed the answers (87.5%). The percentage of students' certainty level is shown by Figure 1 below.

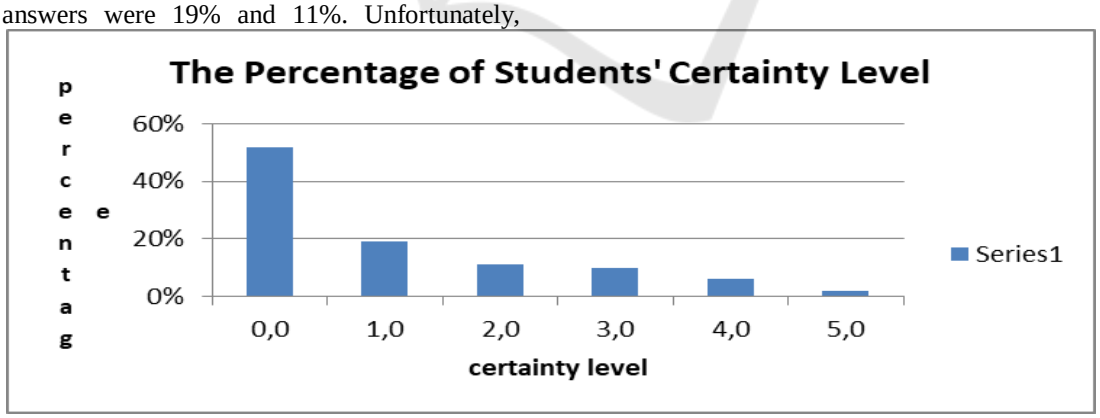


Figure 1: The Percentage of Students' Answers Based on CRI Levels.

Around 87.5% of the students were not ready or not certain about answering the diagnostic test questions. It, thus, indicated that the quality of the answers being true was categorized low. Many students were not certain about the answers because

they misconceived, could not remember, or could not understand the genetic concepts.

3.2 Students' Understanding of Genetics Concepts

There are five concepts of genetics being studied in this research: a) definitions and scopes of genetics; b) genetic materials; c) reproduction of genetic materials, d) genetic materials expression or functions; e) changes in genetic materials. Meanwhile, the concept of genetic materials existence in population would be represented by evolution, and genetic manipulation would be represented by biotechnology. Students' misconceptions in genetics should be identified in order to evaluate their understandings and investigate problems they faced to comprehend the concept. The participants of this research were required to answer 35 questions provided by the CRI-based diagnostic test questions. The distribution of the students' level of certainty in answering the questions is presented in Figure 2.

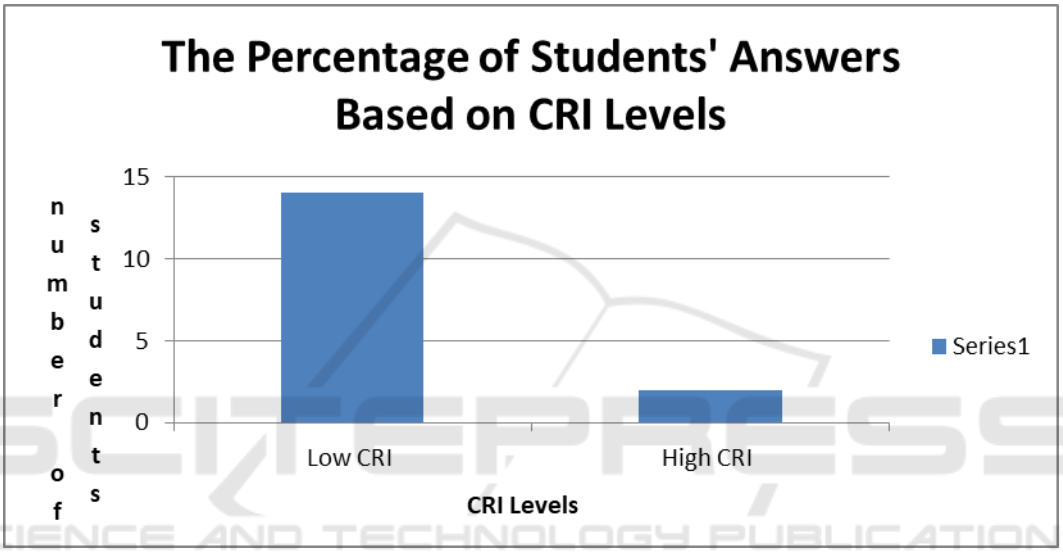
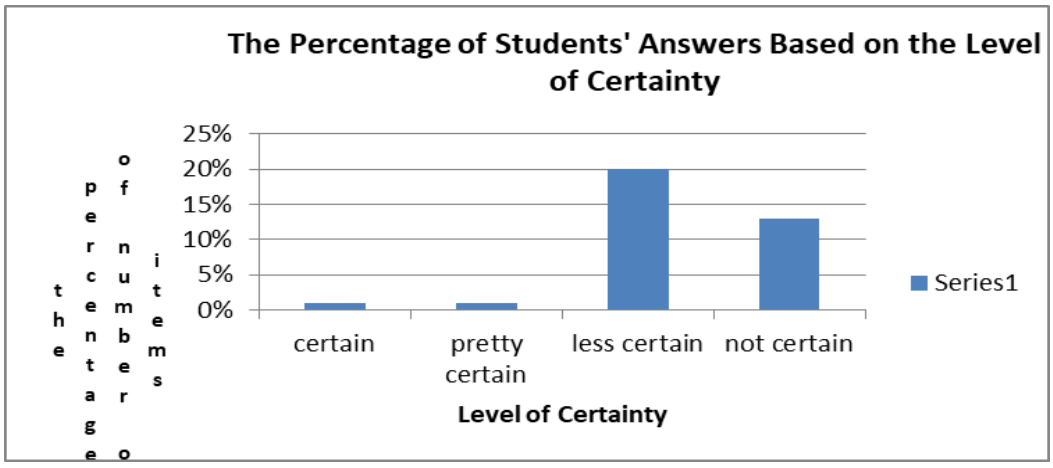


Figure 2: Distribution of Students' Level of Certainty in Answering the Test Questions.

In general, the students answered the test questions with low CRI. In average, the respondents were not completely sure or in other words only guessed the answers (scale 0). This number had a positive correlation with the incorrect answers provided by the students. Out of 35 questions, 13 questions were answered "not certain" and 20 questions were answered "less certain", as shown in Figure 3.



4 DISCUSSION

The current research has successfully identified graduate students' misconceptions in genetics. Furthermore, research findings also suggested that the students did not understand genetic concepts. It was proven by the fact that the number of incorrect answers provided by the students had a positive correlation with the CRI levels. Students' misconceptions may result from: (1) the presentation of genetic concept which was not based on concept-approach; (2) the presentation of genetic concept which did not combine molecular approach and molecular; (3) the use of inappropriate analogy; (4) the use of biased terms; (5) the use of inappropriate language (words and sentences) as the reflection of writer's interpretation; (6) the results of analysis which were not supported by credible references (Roini, 2013; Nusantari, 2012).

The graduate students' misconceptions in genetics can be identified in all sub concepts found in the test. Additionally, some questions related to genetic materials changes, mutation, and genetic manipulation were also misconceived and not answered by the students. The examples of the students' answers which indicated their misconceptions in genetics and the instances of the correct answers to the questions based on some references with high credibility are explained as follows.

4.1 Misconceptions about the Definitions and Scopes of Genetics

When the students were asked about the definition of genetics, they would answer "genetics is the study of heredity (from parents to their offspring)". This definition could be considered as a misconception because heredity is only one among many branches that are studied in genetics that constitutes part of genetic materials reproduction. This sub concept refers to the manifestation of Mendel I and Mendel II laws on crossbreeding or marriage.

Another example of a misconceived concept is about the scopes of genetics. According to the students, genetics covers 1) human and living creatures genetic; 2) biotechnology. This statement can be categorized as a misconception because human genetic and living creatures genetic are actually two different branches of genetics while biotechnology is one of the sub concepts learned in genetic manipulation (Corebima, 2008).

In addition to that, the students also provided a wrong definition of genetics. According to the students, "genetics studies about DNA and RNA in relation to human heredity" while actually DNA and RNA are important sub concepts of genetic materials structure. Corebima (2010b) defines genetics as the study of genetic materials. In details, genetics covers: 1) the structure of genetic materials, including DNA (which can be found in cell nuclei, mitochondria, chloroplasts, viruses, bacteria, plasmids, episodes, and transposable elements), and RNA; 2) reproduction of genetic materials in eukaryotic cells, including: DNA replication, cells reproduction, and *Mendelian inheritance*; 3) genetic materials functions, including: genes transcription, modification after transcription, translation, interaction, and control in eukaryotic cells; 4) changes in genetic materials, including: mutation and recombination; 5) the existence of genetic materials in population and 6) manipulation of genetic materials.

4.2 Misconceptions about the Definition of Genetic Materials Reproduction

Students' answers which showed their misconceptions about the reproduction of genetic materials were: a) reproduction is a process of multiplying genetic materials with transcription, translation, and translocation; b) genetic materials are reproduce in a nucleus where DNA replicates RNA; when dRNA leaves the nucleus, tRNA comes to bring genetic codes (protein synthesis). These reproduction definitions confuse the concept of expression or functions of genetic materials. Transcription, translation, dRNA, tRNA, genetic codes, and protein synthesis should be discussed in the genetic materials expression or functions. Meanwhile, translocation should be understood as part of genetic materials changes related to chromosome structure.

Genetic materials reproduction is actually genetic materials inheritance which includes the inheritance of nucleotide sequence (such as DNA) in general, and the inheritance of genes nucleotide sequence in particular. DNA is reproduced by replicating and RNA is reproduced through reverse transcription. Genetic materials (both DNA and RNA) contain genes. Therefore, children will inherit their parents' characteristics because genetic materials are inherited (Corebima, 2008).

4.3 Misconceptions about the Expression or Functions of Genetic Materials

There were some misconceptions found in the students' answers related to the transcription and translation process. The students made some mistakes in determining nitrogen base pairs between the sense gene chains and the codons, or between the sense gene chains and the tRNA arrangement. The students could only understand that if thymine (T) was found on a sense gene chain, then tRNA would contain adenine (A); if adenine (A) was found on a sense gene chain, then tRNA would contain uracil (U). Meanwhile, the correct concept is if thymine is found on a sense gene chain, then the codon will contain adenine (A) and tRNA will contain uracil (U); if adenine (A) is found on a sense gene chain, then the codon will contain uracil (U) and the tRNA wukk contain adenine (A). It happens because the arrangement of the nitrogen bases on tRNA is actually the arrangement of the anticodons chains (Gardner, et al., 1991).

Some examples that show that the students did not recognize the concepts at all are described as follows:

1) Genetic Materials Changes

According to the students, environment is able to change genetic materials (DNA, RNA, protein, and enzyme). Viewed from the structure, DNA and RNA are categorized into the concept of genetic materials and viewed from the functions, DNA and RNA could be discussed in genetic expression or functions. Therefore, it can be concluded that the answer provided by the students showed that the students did not understand the concept.

The correct answer, on the other hand, is that genetic materials can be changed through induction by humans. Genetic materials are induced for several different purposes, such as for medication, research, plants or animals breeding, and many others. One of the examples of the beneficial genetic materials changes is manipulation through tumor inducing (Ti) plasmid from *Agrobacterium tumefaciens* (Agrobacterium). Small pieces of leaves are cultured in a medium which contains a genetic-modified agrobaterium. The bacterium transfers a small part of its genetic materials (Ti-plasmid) into the host genome during the infection period. The small pieces of leaves are added with hormones to grow their buds and roots. Therefore, the bacterium genes which have been modified will be expressed by the infected plant (Thieman & Palladino, 2004).

2) Mutation Risks

None of the students answered questions related to mutation risks. In fact, the students should be able to understand the advantages of mutation, such as the benefits of mutation in agriculture (the production of golden rice). Rice can undergo genetic engineering procedures to produce a big number of beta-carotene (pro-vitamin) that can be changed into vitamin A. Adding some nutrients to beta-carotene contained in food will be more efficient to combat malnutrition (Thieman & Palladino, 2004).

Somatic mutation will be harmful if the offspring inherits the characteristics of the parents through either sexual or asexual breeding. As stated by Corebima (2010b), somatic mutation of eyes buds of citrus plants will grow into a branch. If the branch produces flowers, the mutation can be inherited through sexual breeding because genital cells can be found inside a flower. If the branch or part of the branch is cut and planted, the new individual will inherit the mutation through vegetative breeding.

3) Random Mutation

No misconceptions can be found in random mutation topic because the students did not provide any answer to it. According to Corebima (2000): 1) mutation occurs accidentally or randomly because it cannot be identified. We cannot predict which individuals can/not mutate. However, it does not mean that there is no regularity in a mutation process; 2) mutation is random or coincidental because it is not intended for adaptation purposes. Mutation, in this case, happens without recognizing whether the generated mutants will be adaptive or not.

The results of the present research indicated that many biology students from graduate school of Khairun Universitay did not understand and misconceived concepts in genetics. It has been proven by the absence of correct answers provided by the students. The use of CRI instrument to detect the students' level of certainty in answering the test questions has been known to be effective in identifying students who guessed and were unsure about their responses.

The impromptu closed-book diagnostic test may be the main cause of the students' low confidence in answering the questions. This was intentionally done to examine basic understanding of genetics of the students who were dominated by teachers who were at that time teaching biology to junior and senior high school students (81.25%). The students'

learning experiences also contributed greatly to their misconceptions in genetics. The results of the interviews conducted to the participants revealed that the students often obtained wrong concepts at schools. These errors were brought by the students to the university. Suparno (2005) states that preconceptions or basic conceptions can trigger misconceptions.

There are some ways that can be used to identify misconceptions, such as concept mapping, open ended multiple choice test, scientific writing, concept assessment, and CRI with structured interviews. CRI can be used to identify misconceptions and distinguish it from "unable to understand the concepts" (Hasan and Kelley, 1999). CRI technique can also be used to measure respondents' confidence/certainty level in answering every question based on six scales (0-5). According to Tayubi (2005), 0 indicates that the respondents do not know the concept at all while 5 shows the respondents' full confidence in answering the question. Low certainty level (CRI 0-2) describes that the respondents use guessing as the main strategy to complete the test. Regardless of the correct or incorrect answer, low CRI indirectly shows that the respondents do not understand concepts underlying the correct answers. On the other hand, high CRI (CRI 3-5) suggests that the respondent have high confidence in selecting answers. In this condition (CRI 3-5), the respondents' correct answers indicate their high confidence because their biology concepts have been tested. However, if the answers are incorrect, it shows that there are misconceptions in the subjects. There are four possible combinations of the answers (correct or incorrect) and CRI (high or low) for each respondent individual. Low CRI (<2.5) with correct or incorrect answer indicates that the respondents are not familiar with the concept. Meanwhile, high CRI (>2.5) with correct answer shows that the respondents are very familiar with the concept and can master it. If the answer is incorrect but the CRI is high (>2.5), the respondents have a misconception.

This study employed CRI assessment tool accompanied by a diagnostic test and structured interviews as an instrument to identify graduate students' misconceptions in genetics. Research findings suggest that the majority of the students misunderstood some concepts in genetics and some others did not understand the concepts at all. It can be identified based on the description of the students' answers and level of certainty in answering the test questions.

5 CONCLUSION

Based on the results of the diagnostic test and CRI analysis, it can be concluded that the majority of the graduate students of biology education program from Khairun University (2017-2018) did not understand concepts in genetics. Some of them even misunderstood the concepts. The CRI instrument has been proven effective in identifying university students' misconceptions based on the level of the students' certainty in answering the diagnostic test questions correctly.

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