



IDENTIFICATION OF STUDENTS' MISCONCEPTIONS USING THE CERTAINTY OF RESPONSE INDEX (CRI) METHOD ON MONOHYBRID CROSSING MATERIAL

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ARTICLE INFO

Article history

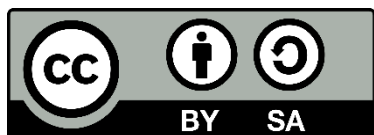
Submission 2026-07-11
Revision 2026-09-28
Accepted 2026-10-06

Keywords:

CRI
Genetics Misconceptions
Monohybrid crosses Virtual learning media

ABSTRACT

This study aims to identify students' conceptual understanding and analyze indications of misconceptions in monohybrid cross material using the Certainty of Response Index (CRI) method. The study was conducted at SMP Negeri 2 Singorojo with 30 ninth-grade students as research subjects. Data were collected using a diagnostic test accompanied by a Certainty of Response Index (CRI) scale to identify students' confidence in their answers. The data were analyzed by classifying students' responses into four categories: Conceptual Understanding (PK), Conceptual Understanding with Less Confidence (PKKY), Misconceptions (M), and Conceptual Uncertainty/Do Not Know the Concept (TTK). The results showed that 40% of the analyzed responses were classified as Conceptual Understanding, 17% as Conceptual Understanding with Less Confidence, 37% as Misconceptions, and 6% as Conceptual Uncertainty/Do Not Know the Concept. The highest proportions of suspected misconceptions were identified in the sub-concepts of basic genetics, particularly genotype and phenotype, gamete formation and segregation, and determining cross results using Punnett squares. These findings indicate that students experienced substantial conceptual difficulties in connecting genetic representations, allele segregation, and the probability of offspring inheritance. This provides an empirical basis for designing subsequent instructional interventions that emphasize conceptual visualization, genetic processes, and contextual learning to strengthen students' understanding of monohybrid crosses.



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INTRODUCTION

Genetics is a fundamental pillar of biology that studies how traits are inherited from parents to offspring through genetic material. A solid understanding of the basic concepts of classical genetics, established by Gregor Johann Mendel through Mendel's Laws of Inheritance, is crucial for students. One fundamental topic in classical genetics is the monohybrid cross, a mating between two individuals focused on a single differential trait controlled by a pair of alleles. Understanding this material provides a crucial foundation before students delve into more complex genetic mechanisms, such as dihybrid crosses, apparent deviations from Mendel's law, and modern genetics (Ojo, 2024).

However, although the concept of a monohybrid cross seems mathematically simple, with a phenotype ratio of 3:1 or a genotype ratio of 1:2:1, this topic is consistently reported as one of the most difficult to grasp in middle school biology (Irani *et al.*, 2021; Kusniawati *et al.*, 2025). Students' primary difficulties stem from the material's abstract nature, which involves sub-microscopic processes such as meiosis and random fertilization of alleles that cannot be directly observed with the naked eye. As a result, many students fail to clearly differentiate between fundamental terms such as gene, allele, genotype, and phenotype. This leads to persistent misconceptions, where students tend to memorize ratios without understanding the essence of probability and the underlying law of segregation (Ibrahim, 2012; Suparno, 2013).

This misconception should not be ignored because biological knowledge is continuous and interconnected. If students experience misconceptions at a basic level, such as monohybrid crosses, they will face significant obstacles in constructing an understanding of more advanced IPA material (Alfionitaria *et al.*, 2019; Rodhiyah *et al.*, 2024). Students' misconceptions are often persistent and difficult to change if not identified early. Therefore, a systematic diagnostic effort is needed to map the location and factors causing students' misconceptions about monohybrid crosses so teachers can design appropriate remediation strategies.

Previous studies have shown that genetics misconceptions occur across various sub-concepts and educational levels. For example, Gusmalini *et al.* (2020) used the CRI method to identify misconceptions among senior high school students on genetics concepts. They found that 42.1% of students held misconceptions, 37.8% understood the concepts, and 22.4% did not understand the concepts. The study also indicated that the

abstract nature of genetics and the large number of difficult scientific terms contributed to students' misconceptions. Similarly, research using CRI among biology education students found misconceptions in several genetic sub-concepts, with Mendelian inheritance among those showing a relatively high level of misconception (Mustika *et al.*, 2014). More recent research has also demonstrated that CRI can effectively reveal misconceptions in biology learning, including at the junior high school level (Marzuki & Diknasari, 2022; Gua *et al.*, 2024). These findings indicate that CRI helps distinguish students who understand a concept from those who answer correctly by guessing or hold misconceptions.

Nevertheless, previous CRI studies have several limitations. First, most studies have examined genetics broadly or focused on genetic substance, chromosomes, DNA, protein synthesis, and other advanced genetic concepts rather than specifically examining the conceptual structure of monohybrid crosses at the junior high school level. Second, several studies have focused on senior high school or university students, so their findings cannot be directly generalized to Grade IX junior high school students, who encounter Mendelian inheritance concepts at an earlier stage of formal science learning. Third, although previous studies have identified the percentage of misconceptions, fewer studies have specifically mapped misconceptions according to fundamental monohybrid-cross sub-concepts, such as basic genetic terminology, gamete formation, and the use and interpretation of Punnett squares. Therefore, a more focused investigation is still needed to provide a detailed profile of students' misconceptions about monohybrid crosses at the junior high school level.

To accurately map misconceptions, teachers need a test tool that measures both answer accuracy and students' confidence in their answers. One proven effective technique is the Certainty of Response Index (CRI). This method measures how confident students are in their chosen answers for each question (Hasan *et al.*, 1999). By combining answer correctness with the CRI score, teachers or researchers can distinguish whether a student has a misconception, does not know the concept (guesses), or understands the concept (Darwis & Hardiansyah, 2022; Mustaqim, 2014; Saputri *et al.*, 2024). CRI is particularly relevant for genetics because students may get correct answers through memorization while still lacking accurate conceptual understanding. Thus, measuring

confidence alongside answer accuracy can provide more detailed information about students' conceptual understanding.

The need for such identification is also evident in the local context of SMP Negeri 2 Singorojo, Kendal. Preliminary observations and interviews conducted at the school indicated that genetics learning still faced conceptual and instructional challenges. The preliminary study involved 30 Grade IX students and an IPA teacher. The results showed that 40% of students understood the concept, 17% understood the concept but were less confident, 37% experienced misconceptions, and 6% did not understand the concept. The misconception profile was particularly evident in several basic genetics sub-concepts, including genetic terminology, gamete formation, and the use of Punnett squares. Teacher interviews also indicated that students had difficulty connecting genetic symbols and ratios with the biological processes underlying inheritance. These preliminary findings provide an empirical basis for conducting a more systematic investigation of misconceptions among Grade IX students at SMP Negeri 2 Singorojo.

Based on previous studies and the preliminary conditions at the research site, research is needed to identify junior high school students' misconception profile of monohybrid crosses using the CRI method. Therefore, this study aims to identify and analyze Grade IX students' misconceptions about monohybrid crosses using the Certainty of Response Index. This study's novelty lies in its focus on the misconception profile of junior high school students on monohybrid-cross concepts and its analysis across fundamental sub-concepts, namely basic genetics, gamete formation, and Punnett-square application. The findings are expected to provide an empirical basis for teachers and researchers in designing more targeted learning strategies and instructional media to address misconceptions in Mendelian inheritance.

MATERIALS AND METHODS

This study uses descriptive research with a quantitative approach. Descriptive research aims to systematically depict or describe the conditions occurring in the research object based on data obtained without providing any specific treatment (Sugiyono, 2023). This study used a quantitative approach to describe students' understanding of concepts and misconceptions in monohybrid cross material, based on

diagnostic test results analyzed using the Certainty of Response Index (CRI) method (Arikunto, 2021).

This study was conducted at SMP Negeri 2 Singorojo and involved 30 ninth-grade students (Grade IX) as research subjects. The participants were selected using purposive sampling based on the consideration that Grade IX learners were relevant to the genetics learning context and participated in the diagnostic assessment. The selection also considered participants' availability and willingness to participate in the study.

Data were collected using a 10-item multiple-choice diagnostic test equipped with a CRI confidence scale ranging from 0 (total guess) to 5 (completely confident). The instrument was developed to identify students' conceptual understanding and misconceptions related to monohybrid crosses. The items covered three main aspects: basic genetics and dominance, monohybrid-cross ratios and probabilities, and analysis of cross patterns or parental genotypes. The distribution consisted of one item for basic genetics and dominance (item 9), five items for ratios and probabilities of monohybrid crosses (items 1, 2, 3, 6, and 8), and four items for analyzing cross patterns and determining parental genotype combinations (items 4, 5, 7, and 10). The items included questions requiring students to interpret Punnett squares, calculate genotype and phenotype ratios, determine probabilities, and identify possible parental genotypes based on offspring data.

The researchers validated the diagnostic instrument before administering it to the research participants. The validation sheet assessed four aspects: alignment with learning objectives, substance/conceptual correctness, suitability for measuring students' misconceptions, and language and writing. Each aspect was rated on a five-point scale from 1 (poor) to 5 (very good). The researchers used expert suggestions and comments to revise the items before using them in the study. The validation procedure aimed to ensure the diagnostic items were conceptually accurate, relevant to the learning objectives, and appropriate for identifying students' misconceptions.

Based on the combination of answer correctness and CRI scores (Hasan *et al.*, 1999), students' conceptual understanding was classified into four categories: Conceptual Understanding (PK), represented by a correct answer and high CRI; Conceptual Understanding with Less Confidence (PKKY), represented by a correct answer and low CRI; Misconceptions (M), represented by an incorrect answer and high

CRI; and Conceptual Uncertainty (TTK), represented by an incorrect answer and low CRI.

A CRI score of 0–2 was categorized as low certainty, while 3–5 was categorized as high certainty. We then used the combination of answer correctness and CRI level to determine the conceptual category for each response. The percentage of students in each category was calculated using the following formula:

$$Percentage = \frac{f}{N} \times 100\%$$

Where f represents the number of students in a particular category, and N represents the total number of students participating in the diagnostic test.

The criteria used to calculate the overall percentages in Table 1. The data were analyzed descriptively by calculating the percentage of students in each conceptual category for the overall diagnostic test and for each aspect of the monohybrid-cross material. The analysis also examined each item to identify the concepts where misconceptions were most frequently observed. The results were then interpreted to describe the misconception profile of Grade IX students at SMP Negeri 2 Singorojo

Table 1. Assessment Criteria Category

Category	Percentage (%)
Conceptual Understanding (PK)	75% - 100%
Conceptual Understanding with Less Confidence (PKKY)	50% - 75%
Misconceptions (M)	25% - 50%
Conceptual Uncertainty (TTK)	0% - 25%

RESULTS AND DISCUSSION

Profile of Students' Conceptual Understanding

Based on the diagnostic test analysis using the Certainty of Response Index (CRI) method, students' responses to the monohybrid cross material were classified into four categories: Conceptual Understanding (PK), Conceptual Understanding with Less Confidence (PKKY), Misconception (M), and Conceptual Uncertainty/Do Not Know the Concept (TTK). The analysis involved 30 ninth-grade students of SMP Negeri 2 Singorojo. The percentages in Table 2 represent the proportion of analyzed responses across the diagnostic-test items, not the proportion of students. Therefore, do not interpret the percentages as indicating an exact number of students in each category.

Table 2. Percentage Distribution of Students' Responses Based on CRI Categories

Class	Subjek (N)	Category Percentage (%)			
		PK	PKKY	M	TTK
Grade IX	30	40%	17%	37%	6%

Note: PK = Conceptual Understanding; PKKY = Conceptual Understanding with Less Confidence; M = Misconceptions; TTK = Conceptual Uncertainty / Do Not Know Concept. Percentages represent the distribution of analyzed responses across the diagnostic-test items.

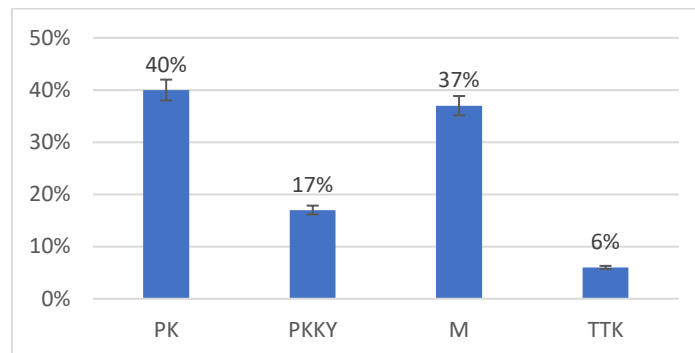


Figure 1. Distribution of Students' Conceptual Understanding Categories on Monohybrid Cross Material Based on the Certainty of Response Index (CRI)

The analysis shows that 40% of the analyzed responses were classified as Conceptual Understanding (PK), indicating that students selected correct answers and expressed high confidence in their responses. A further 17% of responses were classified as Conceptual Understanding with Less Confidence (PKKY), indicating that students selected correct answers but expressed relatively low confidence. This category suggests that although the selected answers were correct, the conceptual understanding may not yet have been sufficiently stable.

Meanwhile, 37% of the analyzed responses were classified as Misconception (M), characterized by incorrect answers accompanied by high CRI scores. This finding indicates that a substantial proportion of students' responses reflected incorrect conceptual understanding held with confidence. However, because the present study used multiple-choice diagnostic responses combined with CRI, this result should be interpreted as evidence of suspected or indicated misconceptions, rather than conclusive evidence of students' underlying cognitive structures. Additional interviews or multi-tier diagnostic instruments would be required to establish students' reasoning more conclusively. The remaining 6% of responses were categorized as Conceptual Uncertainty/Do Not Know

the Concept (TTK), characterized by incorrect answers accompanied by low confidence, suggesting uncertainty or limited understanding of the concepts tested.

The distribution indicates that misconceptions constitute a substantial proportion of the analyzed responses, with the M category accounting for 37%, compared with 40% for PK. The presence of 17% of responses in the PKKY category also suggests that correct responses were not always accompanied by strong conceptual confidence. These findings align with previous studies reporting that genetics is challenging for secondary students because many concepts involve abstract relationships among observable traits, alleles, chromosomes, and cellular processes (Hala et al., 2018; Rahayu & Suratsih, 2018). Therefore, the CRI results provide an important basis for identifying conceptual areas that require further instructional attention.

Analysis of Student Misconceptions on Specific Sub-Concepts

Item-by-item analysis revealed different levels of suspected misconceptions across the sub-concepts of monohybrid crosses. The highest proportions were identified in Question Item No. 1 (23.3%), Question Item No. 5 (16.7%), and Question Items No. 3 and 9 (13.3% each). These results indicate that students had particular difficulty connecting genetic concepts, gamete formation, and interpreting monohybrid-cross results.

Basic Genetics Concepts: Distinguishing Genotype and Phenotype

One identified difficulty involved distinguishing genotype from phenotype. Some students' responses indicated a tendency to associate an observable phenotype directly with a single homozygous genotype. This pattern suggests difficulty in understanding that the same dominant phenotype may result from either a homozygous dominant genotype or a heterozygous genotype because the dominant allele can mask the expression of the recessive allele. Similar difficulties have been reported in studies showing that students may struggle to connect macroscopic characteristics with the underlying genetic composition at the microscopic or sub-microscopic level (Ojo, 2024; Irani et al., 2021).

Gamete Formation and Segregation Mechanisms

Another difficulty concerned gamete formation and allele segregation. Some responses indicated that students had difficulty understanding that allele pairs separate during gamete formation. Some students also indicated that they interpreted dominant alleles as being preferentially inherited over recessive alleles. These responses suggest

that students may recognize genetic terminology but struggle to connect gamete formation to chromosome and allele segregation. Kusniawati et al. (2025) similarly reported that students may rely on memorized gamete ratios without fully understanding the biological processes underlying their formation.

Determining Cross Results Using Punnett Squares

The third major difficulty involved determining the results of monohybrid crosses using Punnett squares. Students' responses indicated a tendency to apply familiar ratios, particularly the 3:1 phenotypic ratio, without first examining the parental genotypes specified in the problem. This pattern suggests a procedural use of the Punnett square rather than an integrated understanding of the relationship between parental genotype, gamete formation, fertilization, and offspring probability. Previous studies have similarly noted that reliance on memorized procedures or ratios can interfere with students' development of conceptual understanding in genetics (Ibrahim, 2012; Muntiani, 2015).

Taken together, the findings across these three sub-concepts indicate that students had difficulty linking different levels of genetic representation. At the macroscopic level, students may have difficulty relating observable phenotypes to possible genotypes. At the sub-microscopic level, they may struggle to visualize allele segregation during gamete formation. At the representational and mathematical level, they may apply Punnett-square procedures or familiar ratios without adequately interpreting the genetic information provided in the problem.

These findings provide an important instructional implication. Learning materials for monohybrid crosses should not only present genetic rules and numerical ratios. They should also include visual representations that connect genotype, phenotype, gamete formation, allele segregation, and offspring probability. Interactive simulations can let students observe these relationships dynamically and examine how changes in parental genotypes affect possible offspring combinations.

Remediation and Educational Implications

The substantial proportion of responses classified as misconceptions (37%) indicates that conceptual difficulties in monohybrid crosses require targeted instructional attention. Because the M category is defined by an incorrect answer accompanied by high confidence, students may need learning experiences that let them compare their initial ideas with scientifically accepted explanations. However, the present CRI data alone do

not establish the persistence or cognitive structure of these misconceptions; therefore, the findings are more appropriately interpreted as an indication of conceptual difficulties requiring further investigation and remediation.

Instructional remediation should emphasize visualization, conceptual explanation, and opportunities for students to examine relationships among genetic representations. In particular, students need to visualize allele segregation, gamete formation, random fertilization, and the resulting genotype and phenotype probabilities rather than relying solely on memorized genetic ratios. Virtual simulations may support this process by allowing students to observe and manipulate genetic crosses at the sub-microscopic level.

In addition, integrating Education for Sustainable Development (ESD) contexts can connect monohybrid-cross concepts with authentic applications, including selective breeding, food security, biodiversity conservation, and the use of local genetic resources (Patonah et al., 2023a; Patonah et al., 2023b). Such contextualization can provide meaningful situations in which students apply genetic concepts to real-world problems. Accordingly, the CRI findings support the need for instructional media that combine conceptual visualization, interactive simulation, numerical reasoning, and contextual ESD problems to address the conceptual difficulties identified in this study.

CONCLUSION

The study concludes that student responses across diagnostic test items are distributed across four conceptual categories: Conceptual Understanding (PK) at 40%, Conceptual Understanding with Less Confidence (PKKY) at 17%, Misconceptions (M) at 37%, and Conceptual Uncertainty (TTK) at 6%. A substantial proportion of responses (37%) reflect misconceptions, primarily clustered around distinguishing genotypes from phenotypes, understanding meiotic allele segregation, and correctly interpreting Punnett square probabilities. Educators should prioritize instructional approaches that focus on conceptual change strategies and visual representations of sub-microscopic genetic processes to help students reconcile erroneous ideas. Future research should expand diagnostic tools to multi-tier formats combined with qualitative interviews and explore the effectiveness of contextual learning media in remediating identified genetic misconceptions.

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