# Five-Tier Instrument to Identify Students' Misconceptions and Representation: A Systematic Literature Review

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Initial knowledge and conception are one of the factors that have a major influence on learning activities. This is the basis for building students' knowledge of a material concept. However, not all students have the same ability, there are students who have low ability to build concepts. As a result, students who have low ability to build concepts may experience misconceptions that have an impact on their learning outcomes. Therefore, it is necessary to have an appropriate test instrument to identify misconceptions and multiple representation profiles especially in chemistry learning materials, one of which is the topic of reaction rate. This article aims to provide an overview of the application of the five-tier diagnostic instrument in identifying misconceptions and profiles of students' misconceptions about reaction rates. The method used is the SLR (Systematic Literature Review) from literature studies from 2011 to 2021 which are available in the ERIC, SINTA, and Google Scholar databases. The findings of the research results show that the five-tier test instrument can identify students' misconceptions about learning material. Information obtained from the use of the instrument can be used to determine the development of students' ability to understand chemistry using representations.

Graphical abstract
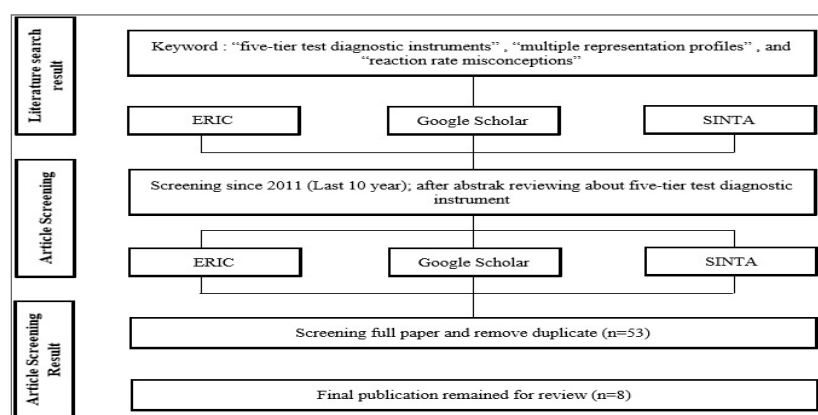
1. Introduction

Initial knowledge is one of the influential factors in learning because it acts as a basis for building new knowledge for students in subsequent material. Students who get the concept of a learning material and can construct it well, these students will have the right understanding [1, 2]. However, each student has different thinking abilities, so not all students can construct towards correct understanding. Students who are unable to build a complete understanding of

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the concept correctly can experience misconceptions.

Misconceptions occur when there is a misunderstanding of the correct concept in scientific studies. An understanding that is inconsistent with or erroneous with scientific concepts, but is believed to be true by students is an indication of misconceptions among students [3-7]. If this situation is ignored, it can have an impact on understanding the wrong concept. Students who experience misconceptions will have an impact on hindering their learning process, because they tend to reject concepts scientifically and defend their own conceptions [8]. Another impact of misconceptions is that students get low learning outcomes and do not even meet the minimum graduation criteria [9]. Akmali [10] explains that if a large number of students have misconceptions, it will result in the disintegration of science and technology development. Another study belonging to Rokhim et al. states that most causes of misconceptions in students are due to the incompatibility of students' preconceptions with teachers, which can be classified as internal factors [11].

Misconceptions in general are influenced by several factors including students, educators, teaching media, materials, and material contexts. Rosita et al., [12] also explained that misconceptions originating from students can occur as a result of each student's initial knowledge, thinking skills, friend factors, etc. The inability of educators to master material concepts, lack of mastery of teaching material content, inappropriate selection of instructional media, and inappropriate teaching patterns can affect the process of transferring knowledge to students. According to research [1] the misconceptions that occur in an educator are the same as the misconceptions that occur in their students. These misconceptions arise in the process of planning and implementing learning, so that misconceptions in students are even stronger because they are not corrected with scientific facts [1]. Misconceptions can also arise due to the weakening of students' understanding in understanding a learning material that has conceptual and unobservable characteristics [13].

Chemistry is a learning material that has complex material concepts and unobserved phenomena [2]. Students tend to find it difficult to understand or believe a concept without seeing it. Based on the characteristics of chemistry, it will be easier to understand if chemistry learning materials are presented together with multiple representations [2]. Multiple representation includes three levels including macroscopic, submicroscopic, and symbolic. But in fact, so far learning chemistry in schools has only been limited to the level of macroscopic and symbolic representation, while submicroscopically it is rarely presented. The imbalance in students' knowledge of the relationship between chemical concepts and their representations results in students experiencing difficulties in understanding the material and applying it in everyday life [2]. Multirepresentation is an essential component in learning chemistry. A deeper understanding is needed in studying chemistry because chemistry is a very abstract science [14]. Given that misconceptions can have an impact on student learning outcomes, misconceptions must be identified immediately. In line with research from Rokhim & Septiani, which implemented a virtual lab based on triplet representation to maximize student chemistry learning, especially in chemical equilibrium material, which can be accessed via a laptop [15].

The process of identifying students' misconceptions can use diagnostic test instruments. Diagnostic test instruments have been developed by researchers including concept maps, interviews, open questionnaires, pictures, word associations, multiple choice tests, as well as multilevel multiple choice tests ranging from ¬ two-tier to four-tier [3, 4, 16]. The newly developed multilevel multiple-choice diagnostic test instrument is a four-tier diagnostic test instrument which is the result of the development of a three-tier diagnostic test instrument with the addition of a confidence rating for each answer to the main question and reasons. However, the four-tier diagnostic test instrument has drawbacks, namely that it can only be used to identify misconceptions in students, but cannot reveal the causes of misconceptions and students' understanding at the multiple representation level, especially in the matter of reaction rates.

Based on the explanation above, this article aims to provide an overview of the application of the five tier diagnostic instrument in identifying misconceptions and profiles of students' misconceptions about reaction rates. The problems that the author gets include:

1. What are the techniques used by researchers in identifying misconceptions and profiles of multiple student representations in the reaction rate material?
2. What is the effectiveness of the five-tier test diagnostic instrument used in identifying misconceptions and multiple representation profiles of students in the reaction rate material?

2. Results and Discussion

Diagnostic tests are one of the instruments that educators can use in learning activities. Now, it has been developed and widely used by researchers to detect students' misconceptions, ranging from interviews, concept maps, open-ended or free-response questionnaires, collection of related words, pictures, multiple choice tests, and tests with many levels such as two. level, three levels, and four levels [16, 17]. Based on the results of a literature review, the development of multilevel multiple-choice diagnostic tests was caused by the discovery of several weaknesses at each level, including being unable to distinguish students' answers based on their own understanding from those who guessed the answers [18]. Therefore, teachers need to choose the right instrument to be applied to students in order to identify misconceptions that occur in a material. Using multiple representation diagnostic tests can improve students' understanding in learning chemistry, especially in understanding concepts and practicum activities in the laboratory [19].

The results of a review of several journals show that students' misconceptions can be identified using several types of instruments. Eight review articles were screened by conducting an initial step analysis in the introduction to find out the literature study and the plans used in the journal articles. Furthermore, an assessment of the effectiveness of the test instrument was carried out in each article as evidenced by the results of the effectiveness of the test instrument in identifying misconceptions. The following is a review of several articles regarding the test instrument used to identify students' misconceptions.

Table 1. Several test instruments are used to identify students' misconceptions.

No.	The Researcher's and Year	Research Instrument	Question Item Used	Research Result
1	(Akmali, 2018)	Four-tier diagnostic test	1. 14 questions in the Four-Tier Test format 2. The answers to the questions consist of 4 question items	The level of student misconceptions and the causes of student misconceptions can be identified, and the majority of misconceptions are due to the results of personal thoughts
2	(Putra et al., 2020)	five-tier diagnostic test	Consisting of 33 multiple choice item	The test instrument developed is feasible and meets the criteria and is appropriate for identifying misconceptions and causes of students' misconceptions
3	(Qodriyah et al., 2020)	Threee-tier diagnostic test	Three-tier diagnostic test item consisting of 30 question item	Student understanding can be classified into several criteria and student misconceptions can be identified in each concept
4	(Hakimah et al., 2021)	Google forms three-tier tests	21 Google forms three-tier test	Students' misconceptions can be identified through the instruments used
5	(Habiddin & Page, 2019)	Four-Tier Diagnostic Instrument	20 questions with a confidence level linked to both the question tier and the reason tier.	Students' misunderstandings can be categorize by considering students' confidence ratings, certain incorrect answers could be ascribed due to lack of knowledge or guesswork rather than to misconceptions.
6	(Anam et al., 2019)	Five-tier diagnostic test	Consists of multilevel multiple choices	Students' representation abilities mostly know the concept in macroscopic form and a little at the sub-microscopic level.
7	(Safitri et al., 2019)	Two-tier multiple choices question	Contained of 15 two-tier multiple choices question	Students have been able to connect the three levels of chemical representation as indicated by their ability to fully understand the concept.
8	(Bayuni et al., 2018)	Five-tier diagnostic test	Consists of multilevel multiple choices	The highest misconception of students is caused by their own thinking
9	(Rokhim et al., 2023)	Five-tier diagnostic test	Contained of 15 five-tier multiple choices question	The instrument is feasible and valid to use by looking at the test difficulty level, discriminating power, distractor effectiveness, item validity, empirical validity, and test reliability.
10	(Harahap & Novita, 2021)	Four-tier diagnostic test	Consists of multilevel multiple choices	Misconceptions occur in each sub-material with various causes.

Based on the results of the review that has been carried out, identifying misconceptions and students' representation abilities can use various types of diagnostic test instruments including multiple-choice tests and tiered multiple-choice tests. Representational ability is one way to understand chemical concepts as a whole [2]. Students who experience misconceptions need to be identified immediately in order to handle misconceptions so that students get maximum learning outcomes [10]. So that the use of multiple choice instruments can be collaborated with the three representations in order to determine the ability of students at the representation level [18]. The development of diagnostic test instruments involving chemical representations can be developed by providing levels of open questions [18, 20].

Basically, chemistry is easier to understand if students can represent it into three levels of representation including macroscopic, submicroscopic, and symbolic [2]. Understanding of concepts involving representations can be detected by using the level of trust or confidence of the

respondents in answering questions. So that the use of multilevel multiple choice instruments in several studies can be combined with the use of methods to test the abilities of each student. Identification of this understanding can be known through students' reasoning in answering questions at the first level and to detect students' lack of knowledge and understanding of concepts in the three representations. However, the use of multiple tier test instruments is rarely used by researchers in identifying students' representational competencies [7, 20, 21].

Each instrument in the research definitely has advantages and disadvantages in identifying students' abilities, especially in representational abilities. In order to complete the lack of test instruments that have developed, the researcher modified the instrument by combining and adding several other data collection instruments. One of the instruments used is the addition of questions from the sources of student answers and interviews. Interviews were conducted to find out students' conceptual understanding in more depth and to have

the opportunity to provide broader student answers. In addition, through interviews researchers can dig in depth to understand the profile of student representation in depth [18].

Table 1 shows that students' misconceptions can be identified with various kinds of multilevel diagnostic tests. The test instrument can also be combined with identifying students' representation abilities. The development of diagnostic test instruments currently has up to five levels. This test can diagnose misconceptions or misunderstandings in more detail and show what students think about these concepts. With the level of drawing, we can also find out the thoughts behind students' misconceptions, because the pictures they make are a reflection of their thoughts. The existence of innovation in this assessment allows the teacher to find out the development of students' representation abilities related to the level of understanding of students' representations in understanding chemical concepts and what are the learning difficulties in understanding chemical concepts [18, 22].

The results of the review that has been carried out indicate that the instrument used to identify students' misconceptions and representations must be able to explore students' answers in depth. To measure the depth of students' representational competence, research instruments can be linked to the aspects assessed to determine the extent of their abilities at the three levels of representation. Representational ability can be known through the answers and reasons why students answer and how confident students are with their answers.

Based on the results of the review conducted, the instruments used in identifying students' misconceptions and representations can be said to be effective in their use if these instruments can provide opportunities for students to translate one representation to another. Instrument results can provide information on how students move from one representation to another and to what extent individuals can interpret and translate a given representation using other representations [10, 18], [22]. In using the developed diagnostic test, it is necessary to have an empirical validation test to identify the items' difficulty level, the different power of the items, the percentage of distractor effectiveness, and to test the validity and reliability of the items [23].

Each instrument used in the study has its own characteristics. Researchers who use the same type of test instrument are not sure that the two test instruments can identify representational abilities in depth. If the instrument used aims only to identify students' misconceptions, then the instrument is not sufficiently used to identify students' representation abilities. Therefore, whatever type of instrument will be used in identifying representational abilities, if it does not involve aspects of ability that are assessed in the instrument, then the instrument will be less effective in identifying students' representational abilities.

Test instruments that contain aspects of the ability to be assessed can effectively provide information to researchers regarding students' understanding and abilities at the three levels of representation in order to gain meaningful understanding [6, 18, 22]. The number of questions in the test instrument does not guarantee that students' representation abilities can be identified properly. This can cause the quality of an instrument to be ineffective in identifying representational abilities because more and more questions make students not work on these questions effectively. So even though the instrument used is only a few questions, if students can solve them well, it can make research more

effective. Various causes such as associative thinking, prejudice, incomplete resonance, humanistic thinking, and intuition can occur in students who experience misconceptions about the reaction rate material [24].

3. Material and Methods

This study uses the SLR (Systematic Literature Review) method. The articles used in this systematic literature review were obtained through online databases, namely ERIC, SINTA, and Google Scholar. The keywords used included five-tier diagnostic test instruments, multiple representation profiles, and misconceptions about reaction rates. After the articles have been collected, a mapping of the articles is carried out as shown in Figure 1. The steps used are; 1) determine subject criteria and determine 2) search strategy; 3) search and screening to identify important studies; 4) describe and examine the selected articles; 5) describe, analyze, and synthesize studies. The search process for articles is limited to the last 10 years, namely from 2011 to 2021 with the criteria of articles from reputable journals indexed by Scopus (Q1 to Q4) and indexed by SINTA (Bachelor's Degree to Doctoral Degree). The article search criteria are based on the instrument used to identify misconceptions and the development of the instrument used to identify students' multiple representation abilities. Based on the results of the literature search and data reduction, 53 articles were obtained for analysis related to the research conducted. Furthermore, the articles that have been collected will be analyzed qualitatively using the Miles and Huberman model. The model consists of three steps, namely data reduction (data reduction), data display (data presentation), and conclusion drawing or verification (conclusion or verification) [25]. This reduction aims to remove unnecessary data and organize data.

4. Conclusions

Based on the literature review that has been carried out, there are several diagnostic test instruments used to identify students' misconceptions and representations. The research results show that the most widely used instrument is multilevel multiple choice tests with open questions. The instrument is considered effective because students can give students freedom to describe the representations that exist in their minds. Meanwhile, multilevel multiple choice instruments can be combined with other instruments so as to explain students' answers in a deeper understanding of concepts and representations.

In addition, the researcher also found an instrument that was considered effective in identifying misconceptions and representations, namely a test instrument that could identify in-depth misconceptions and representations that included the three levels of representation. Various instruments have their advantages and disadvantages. Innovating by developing and combining the instruments used can strengthen the results of the data obtained and minimize deficiencies that occur so as to better identify students' misconceptions and representations.

Researchers hope that this research can develop test instruments that can identify students' misconceptions and representations well. One of the test instruments that can be modified in order to identify misconceptions along with their causes and representation abilities is the five-tier diagnostic test instrument. By carrying out a combination of five-tier

diagnostic tests with interviews, it is expected to produce quality instruments in identifying misconceptions and their
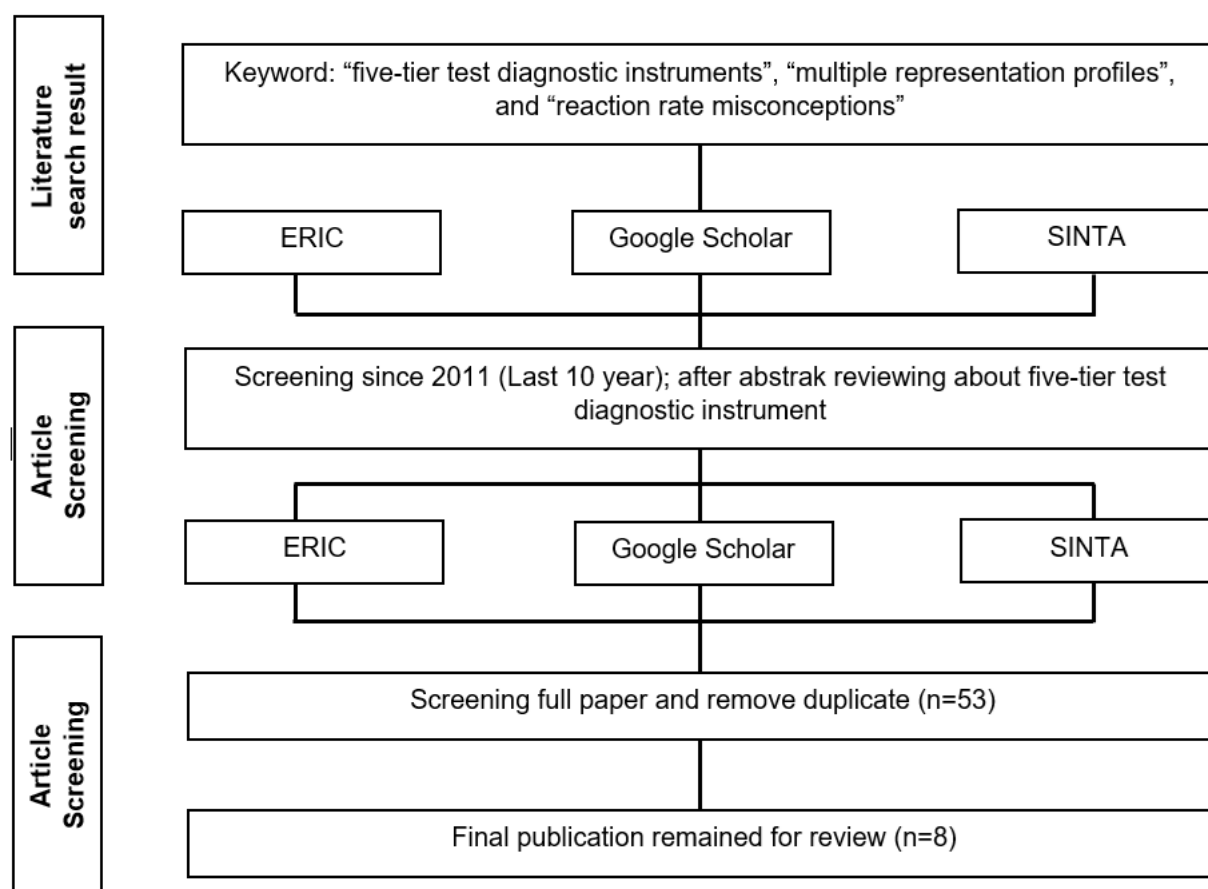
causes and students' representation abilities.

Fig. 1. Flowchart of the article search process.

Author Contributions

Hayuni Retno Widarti and Deni Ainur Rokhim contributed with conceptualization, formal analysis, investigation, methodology and writing – original draft. Deni Ainur Rokhim contributed with investigation, visualization, writing – original draft and writing – review & editing. Sutrisno contributed with writing – review & editing.

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