23 (3), 2022, 1109-1111

Jurnal Pendidikan MIPA

e-ISSN: 2550-1313 | p-ISSN: 2087-9849

http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

Instruments in Identifying Representational Competence in Chemistry: A Systematic Literature Review

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Abstract: This literature review research aims to determine the instrument test in identifying representational competence in chemistry. The identified abilities involve how students can use, interpret, translate, and connect multiple representations to improve representation competence. The method used in this present study is SLR method by using meta-analysis approach by comparing information in some research literature study from 2011-2021 in the ERIC database, google scholar, and SINTA. Based on the results of research on 7 reviewed articles, it showed that several open-ended questions (57.14%) and multiple-choice instruments (57.14%) are the most widely used instruments to identify students' representational competence. The findings of the research show that there are several instruments that are combined with other instruments to strengthen the analytical method in obtaining data and completing the shortcomings of other instruments. In addition, there are several instruments made by aspects to measure how far the students' representational competence are. The information obtained from the use of the instrument can be used to determine the development of students' abilities in understanding chemistry using representations.

Keywords: representational competence in chemistry, instrument test, literature review.

Abstrak: *Penelitian literature review ini bertujuan untuk mengetahui efektivitas instrumen tes dalam mengidentifikasi kemampuan representasi dalam kimia. Kemampuan yang diidentifikasi melibatkan bagaimana pebelajar mampu menggunakan, menafsirkan, menerjemahkan, dan menghubungkan beberapa representasi untuk meningkatkan kompetensi representasi, Metode yang digunakan dalam penelitian ini yaitu metode SLR menggunakan pendekatan metaanalisis dengan membandingkan informasi pada beberapa studi literatur penelitian dari tahun 2011 sampai 2021 yang terdapat pada database ERIC, google schoolar, dan SINTA. Berdasarkan hasil penelitian pada 7 artikel yang direview menunjukkan bahwa beberapa instrumen pertanyaan terbuka (57,14%) dan pilihan ganda (57,14%) merupakan instrumen yang paling banyak digunakan untuk mengidentifikasi kemampuan representasi pebelajar. Temuan hasil penelitian menunjukkan bahwa terdapat beberapa instrumen yang dikombinasikan dengan instrumen lain untuk memperkuat metode analisis dalam memperoleh data dan dapat melengkapi kekurangan dari instrumen lain. Selain itu, terdapat beberapa instrumen dibangun oleh aspek-aspek untuk mengukur seberapa jauh kemampuan representasi pada pelajar. Informasi yang diperoleh dari penggunaan instrumen dapat digunakan untuk mengetahui perkembangan kemampuan pebelajar dalam memahami kimia menggunakan representasi.*

Kata kunci: *kompetensi representasi kimia, instrumen tes, tinjauan literatur.*

▪ INTRODUCTION

Chemistry is a part of science whose concepts are interconnected with each other and have knowledge with high complexity. If one of the concepts in chemistry cannot be understood by students well, then students tend to have difficulty in understanding the next concept (Kean & Middlecamp, 2010). The concepts in chemistry are often considered difficult by students because the concepts are abstract (Gabel, 1999). The

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DOI: http://dx.doi.org/10.23960/jpmipa/v23i3.pp1099-1111
Received: 14 April 2022
Accepted: 20 June 2022
Published: 29 June 2022

abstraction of concepts in chemistry, one of which is due to the existence of chemical concepts associated with phenomena that cannot be observed by students directly such as atoms, molecules, and ions. So that there are phenomena that cannot be seen and cannot be touched, it is necessary to draw a mental model for an appropriate molecular phenomenon. In visualizing, describing, and explaining chemical phenomena, communication is needed to represent these phenomena (Mathewson, 2005).

Phenomena in chemistry can be represented by a chemical triplet representation consisting of macroscopic, submicroscopic, and symbolic. Macroscopic refers to something tangible and observable; submicroscopic refers to particles, atoms, molecules, and ions that cannot be seen with the naked eye; and symbolic refers to chemical symbols, chemical equations used to communicate and explain from submicroscopic and macroscopic representations (Johnstone, 1993). Johnstone (1991) stated that in understanding the concept of chemistry, it is necessary to have multilevel thinking so that it can easily move between the three representations in understanding chemistry. However, students often still have difficulty using all three representations simultaneously. It is because in their learning the teachers often do not integrate between the three representations, thus making students have difficulty moving on the three representations in understanding chemical concepts (Gabel, 1999). In fact, to get a good understanding, students must be able to integrate the three representations (Chandrasegaran, 2007; Rahayu & Kita, 2010).

In general, a meaningful understanding of chemistry involves the ability of students which does not only involve the ability to understand chemical phenomena in the three representations (Talanquer, 2011). However, it also must be able to move in all three representations in terms of interpreting, visualizing, translating, integrating, and connecting several representations. Kozma & Russell (2005) proposed that these abilities are representational competencies.

Talanquer (2011) argued that to move on to the three representations, students have two types of knowledge, called experience, and model. The experiences and models that students have of course differ, one of which is in terms of translating one representation to another in understanding chemical concepts. In teaching, teachers can help and provide support to students in integrating the three representations so that students can move easily in terms of interpreting, visualizing, translating, and connecting several representations. As a facilitator, teachers can help by knowing students' initial representational competence in understanding chemical concepts through assessment activities. With the assessment, teachers can obtain information that is used to identify students' representational competence in understanding chemistry. In general, in identifying students' representational competence, instruments test can be used. The use of instruments test can make it difficult for the teacher to obtain information about student representation in obtaining a good understanding of concepts (Chang, 2018). However, in identifying it is necessary to have a test instrument that is connected to the three representations so that the test instrument can be used to measure the representation ability of students properly.

Based on the explanation above, this article aims to determine the effectiveness of the instrument in identifying students' representational competence. The results of the literature study compiled by the author were in the form of comparing several

instruments used in each article reviewed in identifying students' representational competence. The research questions of this article are:

1. What are the techniques used by researchers in identifying students' representational competence in chemistry?
2. How is the effectiveness of the instruments used in identifying students' representational competence in chemistry?

▪ METHOD

This research used a method of systematic Literature Review (SLR) method. This method is a method used to identify and interpret all research results that are in accordance with certain characteristics (Kilidar, 2005). In principle, this SLR is used to summarize research results. The results of the study were obtained from a systematic search for articles and there were clear criteria in the search for articles (Perry & Hammond, 2002).

In this study, to ensure that the process review was systematic, the Preferred Items for Systematic Review and Meta-Analysis (PRISMA) was used (Moher et al 2009). The steps used are; 1) setting subject criteria and defining 2) searching strategy; 3) searching and screening to identify important studies; 4) describing and researching the selected articles; 5) describing, analyzing, and synthesizing studies. In this study, the articles reviewed were obtained through literature studies on online databases, namely ERIC, Google Schoolar, and SINTA. The keywords used in the search process are, "Representational Competence in Chemistry", "Abilities Representation", and "Identify Representation". The process of searching the article was limited to the last 10 years, namely from 2011 to 2021 with the criteria for articles from reputable journals indexed by Scopus (Q1 to Q4) and indexed by SINTA (S1 to S3). While the search criteria are based on the instruments used to identify representational competence, identify representations to improve representational competence, and the development of instruments used to identify students' representational competence.

Based on the results of the literature search, 231 articles were obtained, but after the titles were analyzed, 50 articles related to representation competence, representation ability, and identification of multiple representations were obtained to improve representation ability. After the article was analyzed for its title and source, an abstract analysis was carried out and 21 articles related to the topic were obtained. However, of the 21 articles, 7 articles emphasized learning without an explanation of the instruments used, 2 articles focused more on learning media used to improve representation skills, and 5 articles emphasized book analysis in improving representation skills. So, from the 21 articles, only 7 articles were found whose content matched the criteria for the articles to be reviewed. The following is a flow chart for the article search process which can be seen in Figure 1.

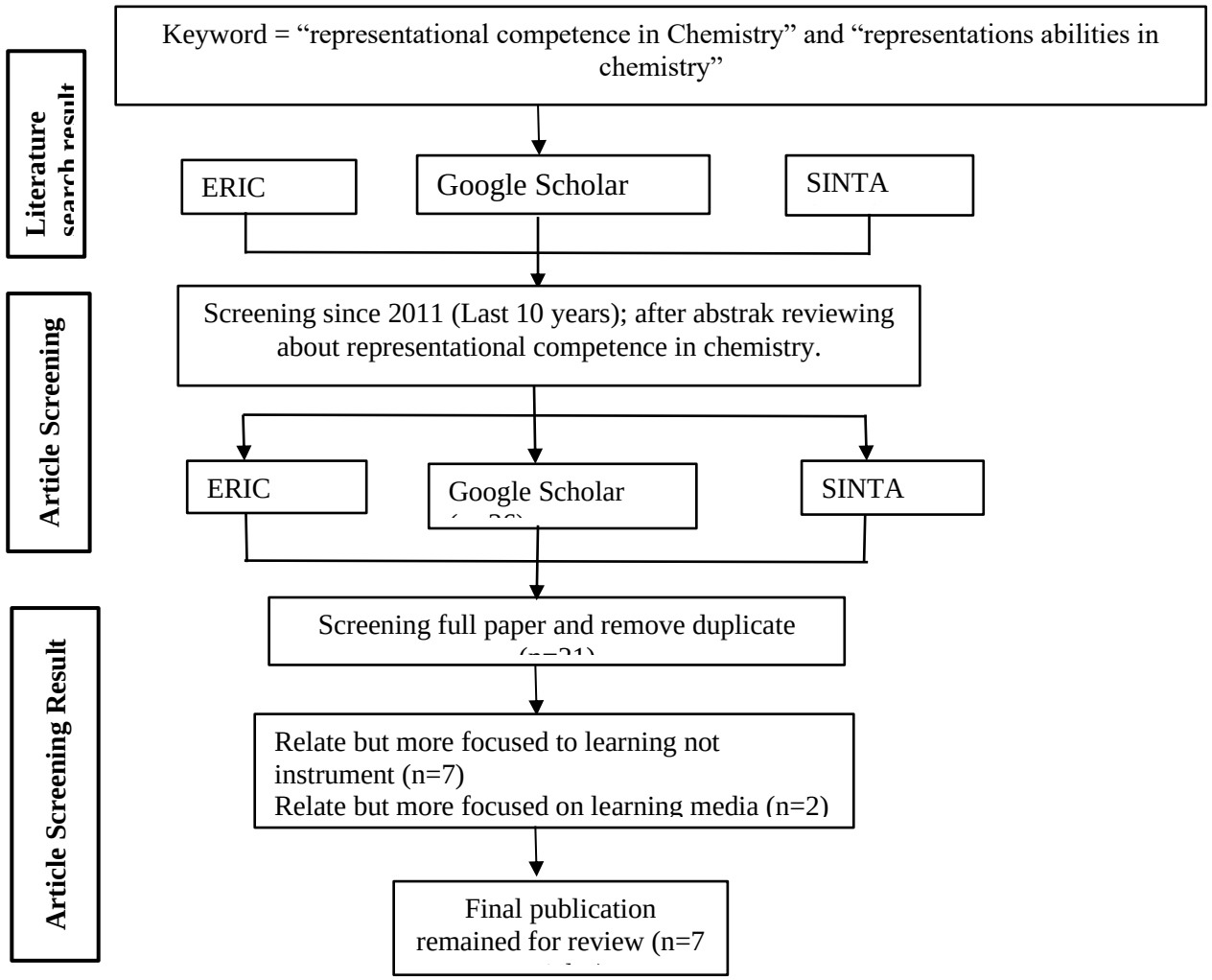

Figure 1. Flowchart of the article search process

▪ RESULT AND DISSCUSSION

Techniques for identifying the ability of chemical representation

Identification of chemical representation abilities is used to gain meaningful understanding through the ability of students to understand chemical phenomena at the three levels of representation (Talanquer, 2011). Interviews, multiple choice questions, open ended multiple choice, open-ended test, and multiple tier tests were found to be the most frequently used techniques in chemistry education research for the purpose of identifying representational competence. Based on the results of the review that has been carried out, in identifying representational competence, the researchers used several data collection techniques, either in the form of interviews or in the form of instruments, which are presented in Figure 2.

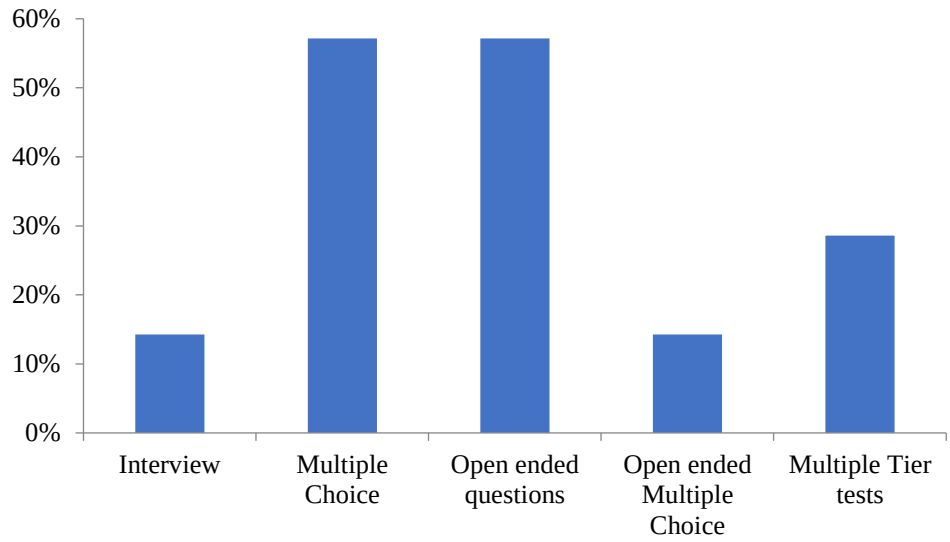

Figure 2. The proportion of data collection techniques used to identify representation ability

In Figure 2 showed the percentage of research instruments in the articles reviewed, called multiple choice instruments (57.14%), open-ended question (57.14%), open-ended multiple choice tests (14.28%), and multiple tier tests (28, 57%). Based on 7 articles that have been reviewed in this study, the most widely used research instruments are open-ended questions (28.57%) and multiple-choice tests (28.57%). However, based on the articles reviewed, some articles did not only use one data collection technique but used two data collection techniques at once to get better research results. Some researchers even add interviews as a second data collection technique with the aim of identifying misunderstandings and ambiguities of students' answers on written tests. The following table 1 presents the data collection techniques used in several articles that have been reviewed.

Table 1. Instruments test in the articles reviewed

No.	Author's Name and Year	Research Instrument	Question Items Used	Research Result
1	(Chi et al., 2018)	The CSRA (Chemical symbolic representation abilities) instrument uses multiple-choice instruments and constructed answer questions consisting of 4 levels including: 1) Students' ability to connect chemical symbols to macroscopic representations; 2) Students' ability to	1. Open multiple choice consists of 17-item questions. 2. The answer to questions consisting of 3 question items.	Student representation ability tends to increase with increasing grade levels from grade 10 to grade 11.

		understand the meaning of submicroscopic using chemical symbols; 3) Students' ability to understand and interpret chemical symbols between macroscopic and submicroscopic representations; 4) Students' ability to use symbolic representations to solve chemical problems.		
2	(Gkitzia et al., 2019)	The ability instrument on the three representations consists of 4 aspects, namely: 1) the ability to translate submicroscopic using macroscopic; 2) the ability to translate macroscopically using submicroscopic; 3) translating submicroscopic using symbolic; 4) translating symbolic using submicroscopic. Card-assisted semi-structured interviews (explore students' thinking in depth to obtain students' mental models on multiple representations).	Consisting of 11 multiple choice items.	The representation ability of 11th-grade and undergraduate students showed a significant difference. Scholars showed better abilities.
3	(Sim et al., 2014)	The TRC (Test of Representational Competence) instrument consists of 5 aspects of ability including; 1) The ability to interpret the meaning of chemical representations; 2) the ability to translate different representations at the same level 3) the ability to translate different representations between levels; 4) the ability to use	Question items consist of 1. Multiple choice in part A which consists of 25 items 2. open-ended questions in part B which consist of 7 question items	Students' representation ability increases when understanding of chemical concepts and representations increases.

		representations to produce explanations; 5) the ability to relate different representations between levels.		
4	(Hilton & Nichols, 2011)	Students' chemical representation ability instrument consists of 5 levels or aspects of representational ability including 1) the ability to use or produce a representation of a phenomenon based only on the physical features of the phenomenon and only use macroscopic features of a phenomenon to make an explanation; 2) the ability to use or produce a representation of a phenomenon based on its physical features which includes some symbolic elements and is familiar with formal representations but use its surface features in explanation; 3) the ability to use or generate representations and make explanations of observed physical feature phenomena and entities underlying unobserved processes, 4) the ability to use formal symbol systems to represent underlying and unobservable entities and processes, based on syntactic rules and meanings relative to phenomena and to use representations to explain a phenomenon, solve problems, or make predictions; 5) the ability to use one or	Which consists of 9 two-tier multiple-choice questions and 7 open-ended questions with short answers	The ability of conceptual understanding and representational competence of students increases. Analysis provide further evidence of students' ability to use multiple representations to explain macroscopic phenomena at the molecular level.

		more representations to explain the relationship between an appropriate physical bond and an underlying entity or process, being able to use certain representational features to warrant claims in social rhetoric.		
5	(Chang, 2018)	The VCM (Visualization Competence of matter) in the instrument is given survey items for example “from which media did you get the idea expressed in your drawing?" Television, textbooks, etc. Four Aspects of representational competence are identified when students use computer-based drawing tools: 1) The use of dynamic representations, 2) the use of visualization strategies, 3) the use of multiple representations, and 4) the use of adequate scientific concepts.	Which consists of 22 multiple choice items.	Student visualization increases with increasing grade level.
6	(Olimpo et al., 2015)	NPA (Newman Projection Assessment) Instruments Each uses a unique starting 4 and 5 carbon straight chain molecule in a diagrammatic form presented in the 2D conformation	Consisting of 24 multiple choice items	The ability to translate student representations shows a better improvement in the dashwedge to newman question, but the success rate in translating dashwedge to fisher related to the arrangement of substituents shows worse results.
7	(Irby et al.,	Using sort cards (cards)	Opened-questions	Student

2016)	consisting of 3 representations; 1) Macroscopic cards: the cards depict objects that can be visually observed; 2) Submicroscopic cards: depict models of atoms and molecules that fill space without associated symbols; 3) Symbolic card: displays chemical equations consisting of chemical formulas and chemical symbols.	using 9 cards	representation ability has developed significantly.
	Using RSCRDI (Representational System and Chemical Reaction Diagnostic instrument) is a two-tier diagnostic instrument.	15 items multiple-choice questions	

Based on the review that has been done, identifying representational competence can use various types of representation-based instruments test which include, multiple-choice tests, open ended multiple choice, open ended questions, and multiple tier test. Identifying representational competence is a way for students to use representations in understanding chemical phenomena (Kozma & Russell, 2005). The students in understanding chemical phenomena are not only required to be able to use representations, but students also need to be able to move between the three representations in interpreting, translating, and connecting between several representations (Chi et al., 2018). So that the use of multiple choice instruments can be used to navigate the ability of learners on the three representations (Gkitzia et al., 2019). Although the use of multiple choice can indeed be navigated, students cannot give reasons for the answers that have been chosen. In providing reasons for answers, researchers often use multiple choice instruments by providing open response columns, structured questions, or open ended questions which are considered more effective in assessing representational competence. The open response can explore students' thoughts based on the selected answers (Chi et al., 2018). In addition, the open response is an easy way to obtain data from a larger sample to identify different levels of representation to describe and explain chemical phenomena (Chandrasegaran, 2007).

Basically, representation skills are needed to understand the understanding of chemical concepts in the three representations (Talanquer, 2011). The understanding concept using representational competence can be detected by utilizing the level of confidence, or the respondent's certainty in answering questions. So that the use of multiple choice instruments and structured questions in several studies can be combined with the use of a method to test the ability of each student. One of these methods is Rasch analysis which is a statistical method to test the ability of each learner in testing the difficulty of the instrument for each item of the question. This analysis is used to

identify relevant information regarding student assessment. The article combines the instrument with Rasch analysis (Chi et al., 2018).

In addition to using open ended test in identifying representational competence, multiple tier test can be used, one of which is two-tier which is used to identify understanding concepts in the three representations (Hilton & Kim, 2011). The identification of this understanding can be known through the reasoning of students in answering questions at the first level and to detect the lack of knowledge and understanding of students' concepts in the three representations. However, the use of this multiple tier instrument test is rarely used by researchers in identifying students' representational competence (Susilaningsih et al., 2019).

Each instrument used in the study certainly has advantages and disadvantages in identifying the representational competence of students. To be able to complete the shortcomings of other instruments test, researchers tend to combine them with various other data collection techniques. One of the techniques used is interviews, which were carried out to find out an understanding of concepts in depth and can provide a lot of insight into the reasons for the answers chosen by students. In addition, interviews can be conducted to explore in-depth and can obtain students' mental models on several representations in depth (Gkitzia et al., 2019).

Table 1. shows that identifying representational competence can be connected to the aspects used to measure how deep students have representational competence, both in terms of translating between different representations, translating between the same representations, using representations to produce explanations, or connecting representations with representations (Kozma & Russell, 2005). The use of the aspects assessed in the instrument can determine how far and at what level the students' representational competence are (Chi et al., 2018; Gkitzia et al., 2019; Irby et al., 2016; Sim et al., 2014; Wang et al., 2017). If students are able to reach the highest level, then it shows that students' representational competence are high. The existence of this assessment aspect allows the teacher to know the development of students' representational competence related to what level of students' representational competence in understanding chemical concepts and what are the learning difficulties in understanding chemical concepts (Chi et al., 2018).

The results of the review that have been carried out indicated that the instrument used in identifying representational competence must be able to explore students' answers in depth. To measure the depth of students' representational competence, research instruments can be linked to the assessed aspects to find out how far their abilities are at the three levels of representation. The ability of representation can be identified through the answers and reasons why students answer and how sure students are with their answers.

Effectiveness of instruments to identify chemical representation ability

Based on the results of the review that has been carried out, the instrument used in identifying representational competence can be said to be effective in its use, if the instrument can examine how students are able to translate one representation into another. The results of the instrument can provide information on how students move from one representation to another and the extent to which individuals can interpret and translate the given representation using other representations (Chi et al., 2018; Gkitzia et

al., 2019; Irby et al., 2016; Sim et al., 2014; Wang et al., 2017; (Hilton & Nichols, 2011).

Each instrument used in the study has its own characteristics (see Table 1). Although the majority of researchers use multiple choice instruments and open-ended questions, not necessarily the two instruments are able to identify representational competence in depth. It can be proven that 1 out of 4 articles that use multiple choice instruments and open-ended questions did not involve any aspect of ability in the instrument, which means that these instruments only identify on the surface, not to what extent students can move on the three representations.

If the instrument used for identification purposes is only limited to the surface, it can make the use of the instrument less effective in identifying representational competence. Therefore, regardless of the type of research instrument used in identifying representational competence, if it did not involve any aspect of ability assessed in the instrument, then the instrument was less effective in identifying representational competence.

The instruments that involve aspects of the ability to be assessed can effectively provide information to the teachers about the understanding and abilities of students on the three representations to obtain meaningful student understanding (Chi et al., 2018; Wang et al., 2017). In addition, the number of question items is also not necessarily able to identify students' representational competence. This often makes the instrument less effective in identifying representational competence, because many questions sometimes make students not work on questions effectively. Even in working on one item, it is not necessary that students can translate and connect using all three representations (Gkitzia et al., 2019). Even though it uses a few questions, if students are able to do well, it will be more effective.

▪ CONCLUSION

Based on the review that has been done related to the ability of representation, there are several instruments used to identify the ability of representation. The results showed that the most widely used instruments to identify representational competence were open-ended questions and multiple-choice instruments. The two instruments are considered the most effective in knowing the representational competence of students because open-ended questions can give students freedom in writing their answers, compared to other instruments. Meanwhile, some multiple choice instruments were combined with interviews as a second instrument to explain students' answers.

In addition, the researcher also found several instruments that were built through aspects of measuring the depth of student representation. These aspects are used to find out how deep and far the students' representational competence are and at what level their representational competence are in understanding the chemical concepts associated with the three representations. If an instrument did not involve these aspects, it shows that the instrument used only identifies the surface, thus making the instrument less effective in identifying representational competence. Basically, to find out which instruments are effective in identifying representational competence, some of the instruments test used can involve valuable findings that are used to measure how deep students' abilities are in the three representations. Various instruments test have their respective advantages and disadvantages. Performing an integrated combination of

several instruments can strengthen analytical methods in obtaining data and can eliminate weaknesses found in other instruments, plus if in the instrument there are findings that can measure how deep the students' representational competence are.

This research is expected to be useful for researchers who will examine students' representational competence in chemistry. The findings in this study suggest that this research suggests further research, called; 1) the selection of instruments can be seen from the advantages and disadvantages; and 2) can combine other instruments to strengthen and improve the quality of the instrument.

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