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Systematic Literature Review: Multiple-tier Diagnostic Instruments in Measuring Student Chemistry Misconceptions

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Abstract: Misconception is a conception of someone who is not by scientific concepts recognized by experts. One way to identify students' misconceptions is by conducting tests using diagnostic instruments. This study aims to identify misconceptions in chemistry learning as well as the most widely used types of multiple-tier diagnostic instruments. The research method used is a systematic literature review (SLR) by analyzing relevant research results from the Google Scholar and ERIC databases of 47 articles based on their suitability with the research theme within the last seven years (2016-2022). The systematic literature review method reviews articles systematically by following the steps that have been determined. The research findings show that students' misconceptions mostly occur in the buffer solution material with the most widely used diagnostic instrument, namely the three-tier multiple-choice (50%). The dominant cause of students' chemical misconceptions occurs due to students' internal factors in the form of a mismatch between students' preconceptions and the concepts taught by experts and strategies for applying learning models that are often used as a method to reduce students' chemical misconceptions such as the application of the Dual Situated Learning Model (DSLM) as well as implementing the Elicit, Confront, Identify, Resolve, Reinforce (ECIRR) model.

Keywords: Misconception; Systematic literature review; Multiple-tier diagnostic instruments.

Introduction

Chemistry is a science that plays an important role because various phenomena in life can be explained logically. Chemistry is one of the natural sciences that is abstract and complex so that in learning requires a deeper understanding (Sariati et al., 2020). Chemistry consists of three aspects, namely macroscopic aspects (something that can be seen), microscopic (something that is not visible) such as the particles that make up substances, and symbolic (Apriadi et al., 2019). Therefore, chemistry is one of the subjects that require more reasoning and comprehension skills to connect and relate these three aspects. The facts that occur in the field state that most students consider chemistry to be a difficult and boring subject (Muderawan et al., 2019). Plus most of the chemistry material consists of mathematical concepts and calculations that require literacy and numerical skills so most students have difficulty understanding chemical concepts (Priliyanti et al., 2021). In addition, students also experience difficulties in connecting the chemical concepts they acquire which leads to low student learning outcomes (Zakiyah et al., 2018).

Learning is said to be meaningful if students can connect the knowledge they have with the new knowledge they get. Initial knowledge is a concept that is owned by every student. This initial concept is built by students when obtaining new information or knowledge. However, students sometimes often experience difficulties or confusion when associating or connecting the knowledge they already have with the new information they get. Thus, the knowledge that is built is sometimes wrong or not the knowledge

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conveyed by experts and ultimately creates a misconception. According to Suparno (in Mukhlisa, 2021), misconception is a conception of someone who is not by scientific concepts recognized by experts.

Every concept or material in a lesson is related to one another. If there is a mistake in understanding a concept, it will affect the understanding of future concepts. Therefore, students' misconceptions are a crucial issue that needs to get more attention from educators or teachers. The misconception is different from not understanding a concept, not understanding a concept means a situation where knowledge of a concept is not owned by students, while misconception means a situation where students believe their understanding of a concept but this understanding is different from the concept conveyed by experts.

Misconceptions are not errors that come from ignorance but misconceptions are understandings that are obtained incorrectly which result in an imperfect understanding (Maulidiyah et al., 2021). Misconceptions need to be identified and analyzed as an initial effort to be further eliminated or reduced because with misconceptions, further concepts can be disrupted. If students' initial understanding is correct, then students can understand other concepts. Vice versa, if students' initial understanding is inaccurate, it will affect their understanding of other concepts.

Chemistry is one of the subjects that often causes students to experience misconceptions. The existence of chemical misconceptions in students has become a task and concern for teachers because misconceptions that are sustainable and not resolved will have an impact on the success of student learning in achieving the expected learning objectives. The teacher should provide evaluation questions that can measure or identify whether students do not understand the concept or experience misconceptions about the material being taught. Furthermore, if there are students who experience misconceptions, the teacher must immediately address and remediate student misconceptions (Maison et al., 2020).

One way to identify students' misconceptions is by conducting tests using diagnostic instruments. The diagnostic instrument is one of the instruments used to diagnose or identify misconceptions in students' understanding of concepts which are then used as material for improvement (Ardiansah et al., 2017). Diagnostic instruments can analyze and describe students' actual understanding, including their reasoning abilities and their level of confidence in their answers (Lestari et al., 2021).

This means that the diagnostic instrument can be used as an effective instrument in evaluating student performance and misconceptions. Therefore, it is necessary to carry out systematic review research related to multiple-tier instruments to measure students' misconceptions so that a synthesis can be obtained from all relevant research results related to the types of multiple-tier instruments which are widely used in measuring misconceptions, chemical material which is most often a misconception, factors that cause misconceptions to methods to reduce student misconceptions.

Many types of diagnostic instruments have been developed, both tests and non-tests such as performance tests, interviews, essays, and open or closed multiple choice. The focus of the discussion on research is the diagnostic instrument in the form of multiple-tiers which is a form of multiple-choice test consisting of several levels such as two-tiers, three-tiers to four-tiers. The use of multiple-tier diagnostic instruments is more effective than the usual multiple choice. Whereas, ordinary multiple-choice tests are only able to measure students' cognitive abilities without knowing how well students understand a concept.

The research results that have been carried out are still in the form of individual studies by certain researchers, so they need to be analyzed to further obtain more comprehensive information regarding students' misconceptions about chemistry learning and the diagnostic instruments used. That way, it can produce a recommendation for researchers, educators, and future educators to be able to apply diagnostic instruments so that students' misconceptions can be diagnosed or identified earlier. Based on this, it is deemed necessary to carry out a systematic review of the results of research that examines students' misconceptions about learning chemistry and its diagnostic instruments.

Method

This study uses the Systematic Literature Review method by identifying and systematically reviewing journals. Systematic review is a very rigorous procedure in identifying, assessing, and synthesizing all relevant research results related to research questions, certain topics, or phenomena of concern by using strategies to limit bias (Kitchenham, 2004).

The research focus is on the analysis or identification of students' misconceptions in chemistry learning and multiple-tier diagnostic instruments in measuring students' chemical misconceptions. The data collected comes from the Google Scholar and ERIC databases in the last eight years, from 2015 to 2022. There were 47 articles reviewed that were obtained using the keywords chemical misconceptions, multiple-tier diagnostic instruments, and diagnostic instruments in measuring chemical misconceptions.

The articles used in answering research questions are national and international articles indexed by Scopus and Sinta. The criteria for selecting the articles reviewed were based on: (1) the focus of discussion on analysis or identification of chemical misconceptions (2) diagnostic instruments multiple-tiers (3) article publications in the last 8 years (2015-2022), and (4) Scopus indexed journals (Q1-Q4) and Sinta (S1-S5). Therefore, articles that did not meet these criteria were not selected.

Inside steps, systematic literature review according to Siswanto (2010) consists of formulating a research question, conducting a systematic literature search, screening and selecting appropriate research articles, analyzing and synthesizing qualitative findings, and presenting findings.

The research questions formulated are What is the most widely used multiple-tier diagnostic instrument?, What is the chemical material that most often becomes a student's misconception?, What are the factors that cause students' chemical misconception?, and What are the ways or methods to reduce students' chemical misconceptions? After the research questions were formulated, a literature search process was carried out Google Scholar and ERIC databases 95 articles were obtained and the selection or screening was carried out according to the selection criteria so that 47 articles were indexed by Scopus and Sinta. The process of selecting or screening articles for review using the Prisma standard can be seen in Figure 1.

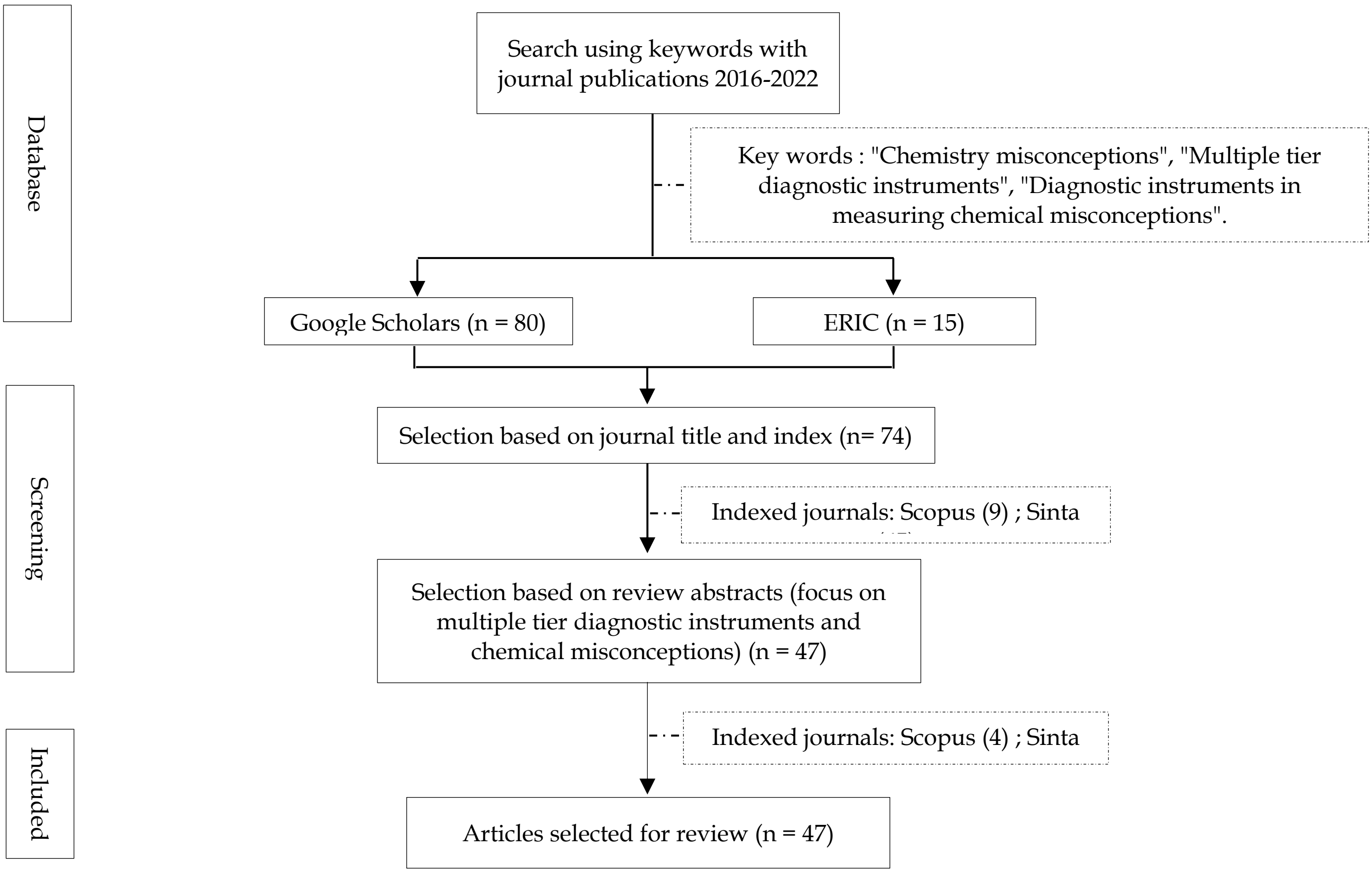

Figure 1. Flowchart of the Article Selection Process

Result and Discussion

The research was conducted using the systematic literature review method by reviewing as many as 47 articles ted based on predetermined categories. The following is the distribution of article publications reviewed by year from 2016 to 2022 in Figure 2. Based on Figure 2, it can be seen that the publication of articles on multiple-tier diagnostic instruments in measuring student chemistry misconceptions has increased and decreased from 2016-2022. The most published articles in 2020 were 10 articles, then in 2017-2018, there were 7 articles, followed in 2016 and 2019 with 6 articles and 4 articles in 2022. The years 2020 to 2021 are the years with the most article publications. One of the reasons was because that year learning was carried out online due to the coronavirus disease (Covid-19) pandemic according to the Minister of Education and Culture circular letter No. 4 of 2020 that during the Covid-19 emergency period, learning was carried out through distance learning (Handayani, 2020). This affects teaching and learning activities so that students cannot participate in learning optimally and they lack interest and motivation of students in participating in learning because the learning methods and models used by teachers are less creative (Mapada et al., 2022). This shows that students' chemical misconceptions still have the potential to be researched. As for articles that fall into categories after screening, they can be listed in Table 1.

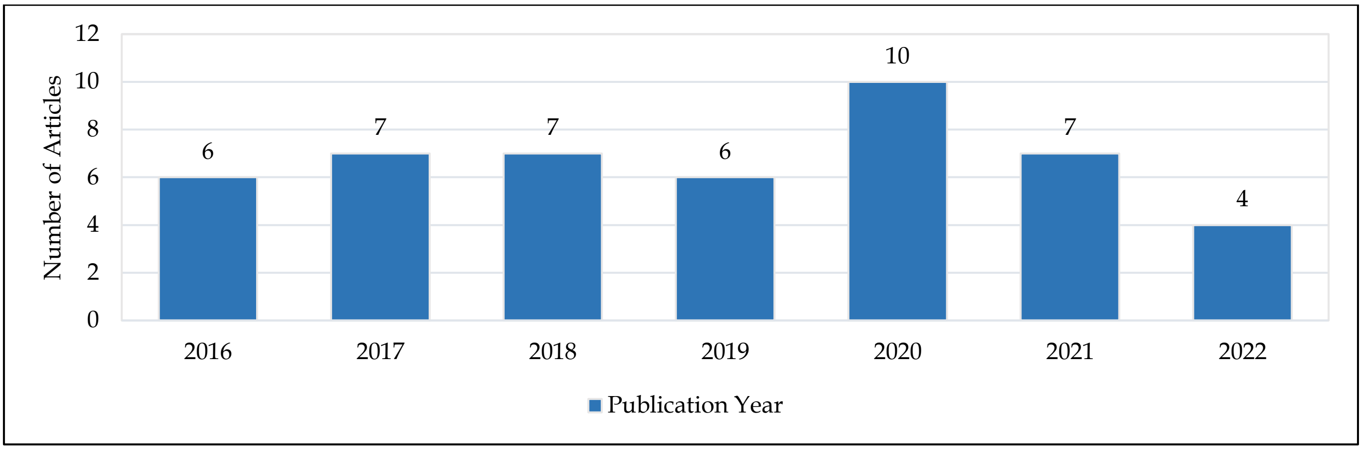

Figure 2. Published Articles of Multiple-Tier Diagnostic Instruments in Measuring Students' Chemistry Misconceptions

Table 1. Results of Screening or Selection of Articles by Category

Journal Title	Authors	K1	K2	K3	K4	K5	Quality
Analisis Prior Knowledge Konsep Asam Basa Siswa Kelas XI SMA untuk Merancang Modul Kimia Berbasis REACT	(Gazali & Yusmaita, 2018)	√	√	√	√	√	Eligible
Identifikasi dan Analisis Miskonsepsi Siswa Menggunakan Three-Tier Multiple Choice Diagnostic Instrument pada Konsep Kesetimbangan Kimia	(Monita & Suharto, 2016)	√	√	√	√	√	Eligible
Miskonsepsi Ditinjau dari Penguasaan Pengetahuan Prasyarat untuk Materi Ikatan Kimia pada Kelas X	(Noviani & Istiyadji, 2017)	√	√	√	√	√	Eligible
Telaah Topik Stoikiometri SMA: Miskonsepsi dan Strategi Pembelajarannya	(Anugrah., 2019)	√	√	√	√	√	Eligible
Diagnosa Miskonsepsi Siswa SMA Negeri 1 Telaga Gorontalo pada Materi Termokimia	(Sihaloho, Hadis, Kadir Kilo, et al., 2021)	√	√	√	√	√	Eligible
Analisis Miskonsepsi Asam Basa pada Pembelajaran Konvensional dan Dual Situated Learning Model (DSLM)	(Amry & Rahayu, 2017)	√	√	√	√	√	Eligible
Analisis Miskonsepsi Siswa Kelas XI SMA pada Materi Larutan Penyangga Menggunakan Instrumen Tes Three Tier Multiple Choice	(Nurhujaimah et al., 2016)	√	√	√	√	√	Eligible
Analisis Miskonsepsi Siswa SMA pada Materi Hidrolisis Garam dan Larutan Penyangga	(Maratusholihah, Rahayu, Fajaroh, et al., 2017)	√	√	√	√	√	Eligible
Miskonsepsi materi larutan penyangga	(Nurhidayatulah & Prodjosantoso, 2018)	√	√	√	√	√	Eligible
Keefektifan Pembelajaran POGIL dengan Strategi Konflik Kognitif untuk Mengurangi Miskonsepsi pada Materi Laju Reaksi Kelas XI SMA	(Ni'mah et al., 2020)	√	√	√	√	√	Eligible
Identifikasi miskonsepsi siswa pada topik ikatan kimia serta perbaikannya dengan pembelajaran model ECIRR (Elicit, Confront, Identify, Resolve, Reinforce)	(Warsito et al., 2020)	√	√	√	√	√	Eligible

Journal Title	Authors	K1	K2	K3	K4	K5	Quality
Penerapan model pembelajaran ECIRR untuk mereduksi miskonsepsi pada materi kesetimbangan kimia kelas XI MIA di SMA Negeri 1 Pacet	(Khomaria & Nasrudin, 2016)	√	√	√	√	√	Eligible
Identifikasi Miskonsepsi Siswa Pada Materi Laju Reaksi dan Perbaikannya Menggunakan Model Pembelajaran Learning Cycle 5e dengan Strategi Konflik Kognitif	(L. A. Lestari et al., 2021)	√	√	√	√	√	Eligible
Analisis Kesalahan Konsep Mahasiswa Kimia pada Kajian Pokok Hidrolisis Garam Menggunakan Tes Pilihan Ganda Empat Tingkat	(Maulidiyah et al., 2021)	√	√	√	√	√	Eligible
Model Instrumen Test Diagnostik Two Tiers Choice untuk Analisis Miskonsepsi Materi Larutan Penyangga	(Antari et al., 2020)	√	√	√	√	√	Eligible
Representasi Kimia untuk Mereduksi Miskonsepsi Siswa pada Materi Redoks Melalui Penerapan Model Pembelajaran Inkuiri Terbimbing Berbantuan LKS	(Andrianie & Wardani, 2018)	√	√	√	√	√	Eligible
Identifikasi Miskonsepsi Siswa Kelas XI SMA Negeri 4 Malang pada Materi Hidrokarbon Menggunakan Instrumen Diagnostik Three Tier	(Romadhona et al., 2020)	√	√	√	√	√	Eligible
Analisis Miskonsepsi Menggunakan Tes Diagnosa Three-Tier Multiple Choice pada Materi Stoikiometri	(Ayu Lestari et al., 2021)	√	√	√	√	√	Eligible
Analisis Miskonsepsi Siswa Kelas XI SMA pada Materi Larutan Penyangga Menggunakan Instrumen Tes Three Tier Multiple Choice	(Nurhujaimah et al., 2016)	√	√	√	√	√	Eligible
Analisis Miskonsepsi pada Konsep Hidrolisis Garam Siswa Kelas XI SMAN 1 Telaga	(Sihaloho, Hadis, Kadir Kilo, et al., 2021)	√	√	√	√	√	Eligible
Mereduksi Miskonsepsi Materi Kesetimbangan Kimia Melalui Penerapan Strategi Predict Discuss Explain Observe Discuss Explain (PDEODE)	(Wati & Novita, 2021)	√	√	√	√	√	Eligible
Analisis Miskonsepsi Siswa Kelas XI SMA Negeri 1 Banawa Tengah pada Pembelajaran Larutan penyangga Dengan CRI (Certainty of Response Index)	(Jannah et al., 2016)	√	√	√	√	√	Eligible
Identifikasi dan Analisis Miskonsepsi pada Materi Ikatan Kimia Menggunakan Instrumen Tes Diagnostik Three-Tier	(Setiawan et al., 2017)	√	√	√	√	√	Eligible
Analisis Miskonsepsi Peserta Didik Kelas XI SMAN 1 Gowa pada Materi Larutan Penyangga Menggunakan Instrumen Three Tier Diagnostic Test.	(Al Qadri et al., 2019)	√	√	√	√	√	Eligible
Analisis Kemampuan Pemahaman Siswa pada Konsep Larutan Penyangga Menggunakan Three Tier Multiple Choice Tes	(Maksum et al., 2017)	√	√	√	√	√	Eligible
Analisis Miskonsepsi Larutan Penyangga dengan Tes Pilihan Ganda Empat Tingkat pada Siswa	(Wahab et al., 2022)	√	√	√	√	√	Eligible
Identifikasi Miskonsepsi Siswa Kelas XI IPA 1 di SMA Negeri 3 Gorontalo Utara pada Konsep Larutan Penyangga	(Monoarfa et al., 2017)	√	√	√	√	√	Eligible
Analisis Miskonsepsi Asam Basa Menggunakan Instrumen Multirepresentasi Diagnostic Test Berbasis Web	(Wahyuningtyas et al., 2020)	√	√	√	√	√	Eligible
Identifikasi Miskonsepsi Materi Kesetimbangan Kimia Menggunakan Tes Diagnostik Pilihan Ganda Tiga Tingkat (Three-Tier Multiple Choice) pada Peserta Didik Kelas XI MIA SMA Negeri 2 Pekanbaru	(Akbar et al., 2019)	√	√	√	√	√	Eligible
Penggunaan Tes Diagnostik Three-Tier Test Alasan Terbuka untuk Mengidentifikasi Miskonsepsi Larutan Penyangga	(Kustiarini et al., 2019)	√	√	√	√	√	Eligible

Journal Title	Authors	K1	K2	K3	K4	K5	Quality
Misconception Profile of High School Student on Electrolyte and Non-Electrolyte Solution Using Pictorial-Based Two-Tier Multiple Choices Diagnostic Test	(Nahadi et al., 2020)	√	√	√	√	√	Eligible
Misconceptions of High School Students in Salt Hydrolysis Topic Using a Three-Tier Diagnostic Test (TTDT)	(Prianti et al., 2020)	√	√	√	√	√	Eligible
Sensitivity of Two-Tier and Three-Tier Tests in Detecting Student's Misconceptions of Chemical Bonding	(Ebiati et al., 2020)	√	√	√	√	√	Eligible
Identifikasi Miskonsepsi Siswa Kelas X Pada Topik Reaksi Redoks	(Apriadi et al., 2019)	√	√	√	√	√	Eligible
Identifikasi Miskonsepsi Siswa Kelas Xi Ipa Pada Materi Larutan Penyangga Menggunakan Two-Tier Diagnostic Instrument di SMA Sabilal Muhtadin Banjarmasin	(Mapada, Roro Ariessanty Alicia Kusuma Wardhani, & Khairunnisa, 2022)	√	√	√	√	√	Eligible
Penggunaan Two-Tier Multiple Choice Diagnostic Test Disertai CRI untuk Menganalisis Miskonsepsi Siswa	(Noprianti & Utami, 2017)	√	√	√	√	√	Eligible
Analisis Miskonsepsi pada Materi Larutan Penyangga Menggunakan Two-Tier Diagnostic Test	(Gultom et al., 2019)	√	√	√	√	√	Eligible
Analisis Miskonsepsi Peserta Didik pada Materi Hidrolisis Garam dalam Pembelajaran dengan Model Guided Inquiry	(Damayanti et al., 2021)	√	√	√	√	√	Eligible
Penggunaan Multimedia Interaktif dalam Meminimalisasi Miskonsepsi Siswa pada Materi Pokok Larutan Penyangga	(Fitria et al., 2016)	√	√	√	√	√	Eligible
Penggunaan Instrumen Lembar Wawancara Pendukung Tes Diagnostik Pendeteksi Miskonsepsi untuk Analisis Pemahaman Konsep Buffer-Hidrolisis	(Hidayah et al., 2018)	√	√	√	√	√	Eligible
Identifikasi Miskonsepsi Materi Kesetimbangan Kimia pada siswa SMA Menggunakan Tes Three Tier Berbasis Web	(Permatasari et al., 2022)	√	√	√	√	√	Eligible
Identifikasi Miskonsepsi Ikatan Kimia Menggunakan Diagnostic Test Multiple Choice Berbantuan Certainty of Response Index	(Karim et al., 2022)	√	√	√	√	√	Eligible
The Misconception Diagnosis on Ionic and Covalent Bonds Concepts with Three Tier Diagnostic Test	(Prodjosantoso et al., 2019)	√	√	√	√	√	Eligible
Eliminating Misconceptions on Reaction Rate to Enhance Conceptual Understanding of Chemical Equilibrium Using EMBE-R Strategy	(Jusniar et al., 2020a)	√	√	√	√	√	Eligible
Identifying Students' Misconceptions of Acid-Base ConceptsmUsing a Three-Tier Diagnostic Test: A Case of Indonesia and Thailand	(Mubarokah et al., 2018)	√	√	√	√	√	Eligible
Misconceptions in Rate of Reaction and their Impact on Misconceptions in Chemical Equilibrium	(Jusniar et al., 2020b)	√	√	√	√	√	Eligible
Analysis of Students Misconception in Chemical Equilibrium Material Using Three Tier Test	(Khairunnisa & Prodjosantoso, 2020)	√	√	√	√	√	Eligible

Information:
Eligible: For articles used in research because they meet the five criteria for selecting articles to be reviewed

Multiple-tier Diagnostic Instrument

Search results by keyword also provide information about diagnostic instruments to detect chemical misconceptions. As a teacher, the task is not only to convey the concept but also to transfer or plant the concept correctly. Early diagnosis of students' misconceptions can reduce or even eliminate students' chemical misconceptions. The use of multiple-tier diagnostic instruments in diagnosing or analyzing students' chemical misconceptions can be seen in table 2.

Table 2. Forms of a Multiple-Tier Diagnostic Instrument for Chemical Misconceptions

Instrument	Total	Percentage (%)
Two Tiers	21.00	43.75
Three Tiers	24.00	50.00
Four Tiers	3.00	6.25
Total	48.00	100.00

Based on table 2, it can be seen that students use the most articles related to the analysis or identification of chemical misconceptions by students form of a multiple-tier diagnostic instrument is a three-tier instrument with 24 articles, then a two-tier instrument with 21 articles and there are 3 articles using a four-tier instrument.

The first step that must be taken is that the teacher must first know the initial concept of students so that it can stimulate learning that allows students to understand the concept (Sihaloho et al., 2021). Based on the research results in Table 2 regarding the form of multiple-tier diagnostic instruments used in measuring students' chemical misconceptions, there are 3 forms of instruments, namely two-tier, three-tier, and four-tier diagnostic instruments. The instrument with the most number used in measuring chemical misconceptions is the three-tier diagnostic instrument. This is because the three-tier test has a higher sensitivity than the two-tier test. The use of the two-tier test has not been able to analyze the abilities and understanding of students' concepts well while the three-tier test is more effective in analyzing students' understanding because this instrument can analyze how well students understand a concept and can help teachers to find out how students' knowledge is in-depth (Ebiati et al., 2020).

Despite using the three-tier diagnostic instrument being more widely used in measuring student misconceptions but the four-tier diagnostic instrument also needs to be applied more widely because it has advantages in categorizing student misconceptions. Where, in the three-tier diagnostic instrument the level of confidence in the first stage is in the form of answers and the second stage is in the form of reasons asked simultaneously even though the differences in students' answers to stages one and stage two also result in differences in the levels of confidence in the two stages so that the analysis of the combination of answers is still not specific, different from the instrument. four-tier diagnostic where the level of confidence in the first and second stages is asked separately so that the analysis of the combination of answers is more specific in grouping students who understand concepts, and misconceptions (Nurulwati & Rahmadani, 2020). Because of these advantages, the use of the four-tier diagnostic instrument has begun to be applied by several studies in measuring students' chemical misconceptions (Maulidiyah et al., 2021; Wahab et al., 2022; Wahyuningtyas et al., 2020).

Every instrument used both in assessment and research, including multiple-tier diagnostic instruments, definitely has advantages and disadvantages in measuring chemical misconceptions. Therefore, in its development, this instrument is sometimes combined or combined with other methods. One of the most frequently chosen methods is the Certainty of Responses Index (CRI) method (Arsyad et al., 2016). CRI (Certainty of Response Index) is a method developed to distinguish students who understand concepts, experience misconceptions, and do not know concepts, where this method requires students to choose the level of confidence in their answers to the questions given (Apriadi et all, 2018). Students have understood the concept of the student answers being correct and give a high CRI (3, 4, or 5). Students experience misconceptions if the student's answers are wrong and give a high CRI (3, 4 or 5) (Jannah et al., 2017). Therefore, the CRI (Certainty of Response Index) method is expected to be a consideration for conducting misconception analysis research (Monoarfa et al., 2017).

In addition, to support the data generated through a multiple-tier diagnostic test, interviews were conducted as a further effort for students who experience misconceptions (Arsyad et al., 2016). Collaboration between multiple-tier diagnostic tests and other diagnostic methods such as interviews can provide useful information about the conceptual understanding of the research population, in this case, students (Wahyuningtyas et al., 2020). Through interviews, it can be seen the level of understanding of students through the confidence of students in responding to answers that have been answered in the previous multiple-tier test (Ni'mah et al., 2020). The use of diagnostic instruments multiple-tier is also used on a web-based basis so that it is no longer in the form of a paper test. The Google Forms feature can be utilized. It’s easy to access by anyone because it only requires an internet network and an email address. Apart from remembering that today's era requires both teachers and students to be literate in technology, the use of web-based instruments can also save time in processing data, as well as make time efficient in identifying misconceptions in students (Permatasari et al., 2022).

Student Chemistry Misconceptions

Chemistry is one of the sciences that is closely related to everyday life so in the process students already have the initial concept. Sometimes the concepts that have been constructed by students themselves through these experiences are different from the actual concepts as well as with chemical material which are interrelated to one another. Chemical materials that become students' misconceptions can be seen in table 3.

Based on table 3, it can be seen that 12 chemical materials become students' chemical misconceptions which are identified using a two-tier, three-tier, and four-tier diagnostic instrument. Buffer solution material is the material that most often becomes a misconception among students where out of 47 articles there are 13 articles which state that students experience misconceptions about buffer solution material which is distributed in 8 articles that analyze misconceptions of buffer solutions using a two-tier diagnostic instrument, 4 articles using the three-tier diagnostic instrument and 1 article using a four-tier diagnostic instrument.

The materials in chemistry are interrelated with each other so students find it difficult to master and allow misconceptions to occur (Gultom et al., 2019). Table 3 shows that 11 chemical materials cause misconceptions in students. 12 articles state that the chemical concept that most often causes misconceptions is a buffer solution. This is because the buffer solution is one of the abstract and complex chemical materials, so understanding it requires a good and clear understanding. The characteristics of this material can make it difficult for students to understand the buffer solution material (Maratusholihah et all, 2017). Based on the 12 articles that have been reviewed, it can be seen that the indicators in the buffer solution material are: (1) understanding of the buffer solution, (2) the components of the buffer solution, (3) the working principle of the buffer solution, (4) calculation of the pH and pOH of the buffer solution, and (5) the role of buffer solution.

Most student misconceptions occur in the indicators for calculating pH and pOH of buffer solutions where students do not understand the calculation of getting pH and pOH values when adding acid or base(Jannah et al., 2017; Kustiarini et al., 2019; Mapada et al., 2022; Nurhidayatulah & Prodjosantoso, 2018; Nurhujaimah et al., 2016). This is because the buffer solution contains many mathematical concepts in the form of pH and pOH calculations and theoretical concepts in the form of understanding, components, principles, and roles of buffer solutions that students need to understand (Al Qadri et al., 2019). Therefore, the probability of student misconceptions about buffer solution material often occurs and is still very high.

Table 3. Chemical Materials that Become Students' Misconceptions

Multiple-tier Diagnostic Instrument	Theory	Writer
Two-tier diagnostic instrument	Acid Base	(Gazali & Yusmaita, 2018; Wutsqo Amry & Rahayu, 2017)
	Chemical Bonds	(Noviani & Istiyadji, 2017; Warsito et al., 2020)
	Reaction rate	(Ni'mah et al., 2020)
	Redox Reaction	(Andrianie et al., 2018; Apriadi et al., 2019)
	Stoichiometry	(Anugrah, 2019)
	thermochemistry	(Sihaloho, Hadith, Kilo, et al., 2021)
	Electrolytes and Non Electrolytes	(Nahadi et al., 2020; Noprianti & Utami, 2017)
	Buffer Solution	(Dewi Antari et al., 2020; Fitria et al., 2016; Gultom et al., 2019; Hidayah et al., 2018; Jannah et al., 2017; Maratusholihah et al., 2017; Melinda Mapada et al., 2022; Nurhidayatulah & Prodjosantoso, 2018)
	Salt Hydrolysis	(Maratusholihah et al., 2017)
Three-tier diagnostic instrument	Chemical equilibrium	(Monita & Suharto, 2016; Akbar et al., 2019; Jusniar et al., 2020b; Khomaria & Nasrudin, 2016; Permatasari et al., 2022; Wati & Novita, 2021)
	Buffer Solution	(Kustiarini et al., 2019; Maksum et al., 2017; Nurhujaimah et al., 2016; Al Qadri et al., 2019)
	Chemical Bonds	(Ebiati et al., 2020; Karim et al., 2022; Prodjosantoso et al., 2019; Setiawan et al., 2017; Warsito et al., 2021)
	Reaction rate	(LA Lestari et al., 2021)
	Hydrocarbons	(Qodriyah et al., 2020)
	Stoichiometry	(EA Lestari et al., 2021)
	Salt Hydrolysis	(Damayanti et al., 2021; Prianti et al., 2020)
	Acid Base	(Mubarokah et al., 2018)
Four-tier diagnostic instrument	Salt Hydrolysis	(Maulidiyah et al., 2021)
	Buffer Solution	(Wahab et al., 2022)
	Acid Base	(Wahyuningtyas et al., 2020)

Factors Causing Students Chemistry Misconceptions

Through a multiple-tier diagnostic instrument, students' misconceptions and the causes of chemical misconceptions can be seen as shown in Table 4. Factors that cause chemical misconceptions in students are divided into two factors, namely internal factors (from within the students) and internal factors external (from outside the learner). The causes of students' misconceptions can be seen in Table 4.

Based table 4 can be seen out of 47 articles, there are 13 articles which state that the dominant factors that cause students' chemical misconceptions come from internal factors, which consist of students' preconceptions, associative thinking, student motivation, ability to understand and analyze, students' interest in learning, lack of courage to ask questions, and inappropriate intuition. In addition, 7 articles stated that misconceptions were caused by external factors consisting of teacher learning methods, learning textbooks, teacher explanations, learning situations and learning methods.

One of the internal factors in the occurrence of student chemical misconceptions is the incompatibility between students' preconceptions and the concepts taught by experts. This is because each student has different thoughts and learning experiences so the thoughts and reasoning of students are different from the perceptions or thoughts of experts (Ade Monita & Suharto, 2016; Damayanti et al., 2021; Fitria et al., 2016; Setiawan et al., 2017). Thus, if it is connected to new material, it causes interference between the right and wrong concepts that have just been learned, resulting in an incomplete or imperfect understanding (Maulidiyah et al., 2021). Therefore, teachers should pay attention to the initial concepts that students have before the learning process so that the concepts that students have do not differ from the scientific concepts that should be.

In addition to the preconception factors that students have, associative thinking is also one of the internal factors that students experience misconceptions because students do not fully understand the terms or symbols contained in the instrument so mistakes or misconceptions occur when associated with terms contained in everyday life (Ade Monita & Suharto, 2016; Damayanti et al., 2021).

Student's misconceptions can also come from external factors. One of the external factors that often cause students' misconceptions is the learning methods and models used by teachers in the learning process which are less creative and still conventional. This causes students to tend to be passive in participating in the learning process so that they do not understand the material transferred by the teacher and resulting in students' understanding being less precise (Mapada et al., 2022). The selected learning should make it easier for students to understand the concept of the material by stimulating students to be more active in constructing their knowledge and training students thinking skills so that learning activities are not only carried out by memorizing the material (Ade Monita & Suharto, 2016).

Each student has different cognitive abilities, so not all students have the same learning suitability when applying the learning model proposed by the teacher, which ultimately affects students' understanding of concepts. (Al Qadri et al., 2019). In addition, the learning model used does not link macro, micro, and symbolic aspects in maximizing students' understanding of chemical material (Gultom et al., 2019). Some textbooks used by students are also indicated to cause chemical misconceptions because the language used in textbooks is too high-level and difficult for students to understand (Nurhidayatullah et all, 2018). As well as the handbook used contains incomplete material, causing students to have an imperfect understanding of a concept (Noprianti & Utami, 2017).

Table 4. Factors Causing Chemical Misconceptions

	Causes of Misconceptions	Writer
Internals	Student preconceptions Associative thinking Student motivation Lack of ability to understand and analyze Interest in learning students Lack of courage to ask Imprecise intuition	(Monita & Suharto, 2016; Apriadi et al., 2018; Ayu Lestari et al., 2021; Damayanti et al., 2021; Fitria et al., 2016; Jannah et al., 2016; Maria Stephanie et al., 2019; Melinda Mapada, Roro Ariessanty Alicia Kusuma Wardhani, Khairunnisa, et al., 2022; Noprianti et al., 2017; Nurhidayatulah & Prodjosantoso, 2018; AR Al Qadri et al., 2019; Setiawan et al., 2017; Wahyuningtyas et al ., 2020)
External	Teacher Learning Method Learning Textbook Teacher explanation Learning Situation Learning model	(Monita & Suharto, 2016; Jannah et al., 2016; Maulidiyah et al., 2021; Nurhidayatulah & Prodjosantoso, 2018; Al Qadri et al., 2019; Setiawan et al., 2017; Wahyuningtyas et al., 2020)

Methods for Reducing Misconceptions

Student misconceptions can be overcome or reduced by several methods that can be applied in the learning process. The application of the learning model is the most widely used method for reducing students' chemical misconceptions in some materials, which can be seen in table 5.

Based on table 5, it can be seen that of the 47 articles reviewed, 11 articles explained methods for reducing students' chemical misconceptions, whereas 6 articles mentioned the most effective method, namely the application of learning models, including the application of learning models. Dual Situated Learning Model (DSLM), application of the POGIL learning model with cognitive conflict strategies, application of the ECIRR learning model, application of the Learning Cycle 5E learning model with cognitive conflict strategies, application of the LKS-assisted guided inquiry learning model based on chemical representations, and application of the Conceptual Change learning model. In addition, students' misconceptions can also be reduced by implementing learning strategies including implementing the Predict Discuss Explain Observe Discuss Explain (PDEODE) strategy, implementing learning through multiple representation interconnection, and implementing experiments in the laboratory.

Table 5. Methods for Reducing Misconceptions

Misconception Reduction Method	Theory	Writer
Application of the Dual Situated Learning Model (DSLM) learning model	Acid-base	(Amry & Rahayu, 2017)
	Buffer solution	(Maratusholihah et al., 2017)
Application of the POGIL learning model with cognitive conflict strategies	Reaction rate	(Ni'mah et al., 2020)
Application of the ECIRR learning model	chemical bond	(Warsito et al., 2020)
	Chemical equilibrium	(Khomaria & Nasrudin, 2016)
Application of the Learning Cycle 5E learning model with cognitive conflict strategies	Reaction rate	(LA Lestari et al., 2021)
Application of the guided inquiry learning model assisted by LKS based on chemical representations	Redox	(Andrianie et al., 2018)
Implementation of the Predict Discuss Explain Observe Discuss Explain (PDEODE) strategy	Chemical equilibrium	(Wati & Novita, 2021)
Application of the Conceptual Change learning model.	chemical bond	(Setiawan et al., 2017)
Application of learning through the interconnection of multiple representations	thermochemistry	(Sihaloho et al., 2021)
Application of experiments in the laboratory	thermochemistry	

The application of the learning model is one of the most widely used methods, including the application of the Dual Situated Learning Model (DSLM) learning model. This learning model is one of the innovation models that exist because of a change in the learning paradigm from teacher-centered to student-centered. This learning approach emphasizes that learning starts from two things, namely concepts that students believe in and concepts that are accepted by the scientific community (Amry et al., 2017). Teachers should pay attention to students' understanding of concepts before carrying out learning activities so that students understanding can match scientific understanding (Ade Monita & Suharto, 2016).

The Dual Situated Learning Model can also be implemented with the help of animation so that it can prevent chemical misconceptions better. In this learning model, students' prerequisite concepts are reformulated or replaced, which means students' misconceptions will be replaced with scientifically correct concepts (Maratusholihah et al., 2017). The Dual Situated Learning Model can be applied to buffer solution learning as a chemical material that causes the most misconceptions as discussed earlier because it is effective in reducing student misconceptions (Maratusholihah et al., 2017).

Another model that is widely applied and considered effective in reducing students' chemical misconceptions is the ECIRR learning model (Elicit, Confront, Identify, Resolve, Reinforce). This model can encourage students to be aware of the misconceptions that exist in themselves and be able to understand the correct concepts so that misconceptions can be reduced (Khomaria & Nasrudin, 2016). At the identify stage students will feel a mismatch of concepts which results in students realizing that there has been a misunderstanding between the concept they have and the actual concept. Furthermore, at the reinforcement stage students are given reinforcement of concepts that have been corrected so that the wrong concept can be replaced with correct understanding resulting in changes in students' understanding of concepts (Warsito et al., 2021). In addition to applying learning models, another effective method is used to reduce and even eliminate students' chemical misconceptions, namely by applying various learning methods, such as laboratory experiments and multiple representation interconnection (Sihaloho et al., 2021).

Conclusion

Based on the results and discussion that has been done, with the topic of research on multiple-tier diagnostic instruments in measuring students' chemical misconceptions, it can be concluded that students' chemical misconceptions in the last seven years have increased and decreased, which means that research on chemical misconceptions in students is still a research potential. The instrument with the most number used in measuring chemical misconceptions is the three-tier diagnostic instrument. This is because the three-tier test has a higher sensitivity than the two-tier test. Use the three-tier diagnostic instrument is more widely used in measuring student misconceptions but the four-tier diagnostic instrument also needs to be applied more widely because it has advantages in categorizing student misconceptions. The chemistry concept that most often causes misconceptions is that of buffer solutions. Most student misconceptions occur in the indicators for calculating pH and pOH of buffer solutions where students do not understand the calculation of obtaining pH and pOH values when adding acids or bases. The problem of chemical misconceptions still often occurs in students. The dominant cause of students' chemical misconceptions occurs due to students' internal factors in the form of a mismatch between students' preconceptions and the concepts taught by experts and strategies for applying learning models that are often used as a method to reduce students' chemical misconceptions such as the application of the Dual Situated Learning Model (DSLM) as well as implementing the Elicit, Confront, Identify, Resolve, Reinforce (ECIRR) model.

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The authors declare no conflict of interest.

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