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Mental Models in Chemistry Concept: A Systematic Review

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Abstract: Mental models in chemistry concepts are defined as student's comprehension of three levels of chemical representations, including macroscopic, submicroscopic, and symbolic levels. This study aims to identify, review, and evaluate research concerning mental models in chemistry concepts through specific research questions. The research method used is a systematic literature review (SLR) by analyzing relevant articles from Google Scholar, Eric, Scopus, and Crosscref, focusing on publications from the the past decade (2013–2023). A total of 52 articles were obtained from the analysis based on the inclusion and exclusion criteria. The findings indicate that most studies aim to understand students' mental model profiles related to chemistry concepts. High school students are predominantly involved as research samples. The most used data collection tool is diagnostic tests. Mental models are primarily studied in physical chemistry, particularly in chemical equilibrium, adopting various theories, especially the Sendur, Toprak, and Pekmez (2010) model. Factors influencing the formation of students' mental models include internal factors such as prior knowledge, experiences, attitudes, and motivations, and external factors such as the environment, incomplete textbooks, and inappropriate teaching strategies.

Keywords: Chemistry concepts; Mental model; Systematic literature review

Introduction

Chemistry is a branch of science with a fairly high level of difficulty (Widarti et al., 2022). Chemistry encompasses a multitude of concepts, ranging from simple to complex and spanning from concrete to abstract (Devi & Azra, 2023). The abundance of abstract concepts often complicates students' understanding, as real-life contexts are not always presented during instruction (Ilyasa & Dwiningsih, 2020). Additionally, the principle of learning chemistry in schools requires students to understand chemical concepts well, not only memorizing theories, formulas, and chemical reactions (Retiyanto et al., 2023). Consequently, students frequently develop their own interpretations of natural phenomena in chemistry, many of which may not align with the perspectives of chemists (Laliyo, 2011). Thus, to master the concept of chemistry, a deep and comprehensive understanding of the concept is needed. This understanding is determined by students' ability to transfer and connect between macroscopic, submicroscopic, and symbolic levels in explaining a phenomenon (Lathifa, 2020).

The abstractness of chemical concepts can be easily understood through three levels of representation, namely macroscopic, submicroscopic, and symbolic, which is the paradigm in chemistry (Johnstone, 1991, 1993, 2000). The macroscopic level refers to phenomena that can be observed directly through experiments or that occur in everyday life. The submicroscopic level relates to the particulate level to explain macroscopic phenomena such as the movement of electrons, molecules, particles, or atoms. The symbolic level consists of various kinds of representations in the form of images, algebraic forms, or computational forms (Chittleborough & Treagust, 2007; Coll & Treagust, 2003). The three levels are interrelated and cannot be

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separated in chemistry learning (Katmiati & Rahmi, 2021). Each level of multiple representations (macroscopic, submicroscopic, and symbolic) is not superior to each other, but each level complements each other in chemistry concepts (Johnstone, 2000; Mindayula & Sutrisno, 2021). Therefore, these three levels should be explicitly taught to ensure that students easily comprehend the taught chemistry concepts (Zikri & Handayani, 2024). Additionally, by integrating the three levels of chemical representation, the process of learning chemistry becomes more meaningful (Becker et al., 2015).

Understanding the three levels of representation is termed a mental model (Jansoon et al., 2009). Learning that involves macro-submicro-symbolic phenomena can improve the mental models of students and the effectiveness of learning (Meutia et al., 2021). Chemical concepts depend on chemical representations and their contribution to the development of mental models. Students' ability to link the three levels of representation in chemistry will result in a more comprehensive understanding of a concept, which will then be stored in long-term memory as a complete mental model (Murni et al., 2022). The higher the students' mental models, the higher their understanding of chemical representations (Widayanti, 2021). Students' difficulties in connecting the three levels of representation cause them to tend to have unscientific mental models (Halim et al., 2013).

Mental models are intrinsic representations that emerge during cognitive processes, which can be objects, ideas, or notions to reason, describe, predict, or explain a phenomenon (Wang, 2007). Mental models are built through perception, imagination, or understanding of scientific discourse (Jansoon et al., 2009). In chemistry learning, Students use mental models to reason, describe, explain, predict phenomena, test new ideas, and present data based on their knowledge to communicate them to others or solve problems in learning chemistry (Sari et al., 2022).

Mental models are interesting to study because its affect cognitive functions and can provide valuable information for science education researchers about the concepts that learners have (Laliyo, 2011). Kurnaz et al. (2015) stated that an individual's mental model can be identified from expressions and actions that reflect their understanding of certain concepts. Therefore, each learner has a unique mental model (Atikah et al., 2023). Many factors influence the development of mental models, such as the way teachers communicate, and present chemical concepts and the learning resources used. In addition, there are internal factors outside the learning context that also influence students' mental models, such as daily experiences and students' cultural backgrounds (Wilandari et al., 2018).

Mental models are very important in science instruction, including chemistry instruction (Ulinnaja et al., 2019). Identifying mental models in chemistry learning is important for teachers to help them know how the students understand a concept, whether or not there is a mistake in their under-standing (Amalia et al., 2018). Mental models are essentially used to predict and solve problems in chemistry (Chittleborough & Treagust, 2007). For this reason, systematic research on the implementation of mental models in chemistry learning is needed, drawing from various existing studies to explore variations and potential developments, so that it can serve as a reference for others. Literature review studies on the theme of mental models in chemistry have been conducted by several researchers, including Wardah et al. (2020), who systematically reviewed research discussing mental model studies in chemical concepts, and Atikah et al (2023), focusing on factors influencing and instruments used to analyze students' mental models. However, neither of these studies addressed the evolving profiles of mental models among current students. Yet, understanding students' mental model profiles can reveal the extent of students' understanding of chemical concepts, whether leading to the formation of misconceptions or inconsistent or unknown concepts. Students with wrong conceptions (misconceptions) or unknown conceptions of the basis for taking them cause students to have incomplete mental models related to a concept (Hasanah et al., 2023). Therefore, it is very important to build a complete mental model for students (Sinaga, 2022). Additionally, information about students' mental models is crucial to be studied in the learning process. Because the learning process is an activity to form students' mental models (Dewi et al., 2023). By uncovering students' mental model profiles, it can assist teachers in designing classroom learning designs and evaluating their teaching in accordance with the identified student profiles.

Method

This research uses the systematic literature review (SLR) method. A systematic literature review is a literature review that follows a series of scientific methods to comprehensively identify and synthesize all studies and provide an assessment of what is known about a topic (Petticrew & Roberts, 2006). The purpose of SLR research is to identify, review, evaluate, and interpret all available research with specific relevant research questions (Damsi & Suyanto, 2023). The steps in implementing a systematic review are very well planned and structured so this method is very different from the method which is just to convey a literature study (Annisa et al., 2023). This research is prioritized on the students' mental models of chemistry concepts. This SLR research procedure adopted from Baloyi & Jordan (2016). The six steps of SLR in this study are presented in Figure 1.

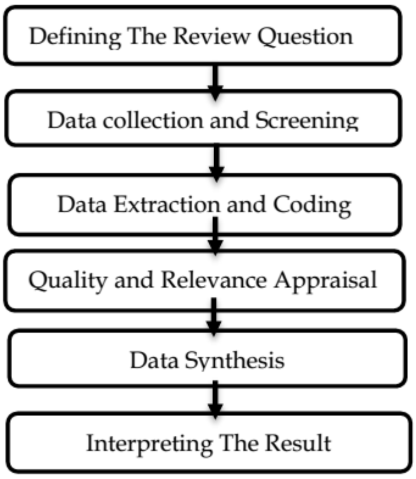

Figure 1. The steps of a systematic literature review

Defining The Review Question

The first step is to determine the boundaries and scope of the topic to be researched. This aims to develop a clear and directed research focus. The research questions posed serve as parameters or guidelines in the literature review process.

Table 1. Question Formulation in this Research

Number	Question
1.	What is the aim of some studies conducting research on mental models of chemistry concepts?
2.	Who is the subject of mental model research on chemistry concepts?
3.	What instruments are used to identify students' mental model profiles?
4.	On what chemistry concepts are students' mental models developed?
5.	What mental model theories are referred to in the study?
6.	What are the factors that influence students' mental models?

Data Collection and Screening

The second step aims to search the search database related to review questions. The article search was carried out online using the Publish or Perish application on the Google Scholar, Eric, Scopus, and Crosscref databases to identify and collect all studies relevant to the research to be carried out. Researchers search by using the keywords such as "mental models in chemistry concepts", "chemistry concepts", "mental models", "mental representation", "representation in chemistry concepts" and "misconceptions". Searching for articles using keywords ensures that the articles obtained from keyword points focus on the research objectives. Searching articles with the keyword produced 184 related articles.

Data Extraction and Coding

The article will go through the identification and screening stages according to the specified inclusion criteria. The inclusion criteria are literature in the form of scientific journals, research published during the last 10 years (2013-2023), Scopus and Sinta indexed journals, scientific journals using English or Indonesian, and the journal discusses mental models in chemistry concepts. The result in this steps are articles were selected based on consideration of the sustainability of the title, abstract, and inclusion criteria so that 57 articles were obtained that met the predetermined criteria.

Quality and Relevance Appraisal

This stage aims to ensure that the articles included in the study have adequate quality and relevance to the research objectives, thus making a meaningful contribution to the scientific understanding of the topic under investigation. We skimmed through the full-text articles to further evaluate the quality and eligibility of the studies. After careful review, a total of fifty-seven studies were obtained from the screening based on the inclusion and exclusion criteria. However, only 52 articles remained for analysis after undergoing the quality and eligibility assessment stage.

Data Synthesis

After selected articles, the next step was to synthesize the results from the relevant literatures.

Interpreting the Result

This step is the final step in the Systematic Literature Review. This step involves organizing and presenting the results of the literature review systematically in a research report or scholarly article.

Table 2. Screening Results of Article used in the Systematic Literature Review

Authors	Journal Name	Journal Ranking
Zarkadis et al. (2015); Akaygun (2016); Supasorn (2015)	Chemistry Education Research and Practice	Q1
Albaiti et al. (2022); Murni et al. (2022)	Journal of Turkish Science Education	Q2
Yildirir & Hatice (2018)	Journal of Baltic Science Education	Q2
Batlolona & Haryo (2023)	European Journal of Educational Sciences	Q3

Authors	Journal Name	Journal Ranking
Praisri & Chatree (2020)	International Journal of Learning, Teaching and Educational Research	Q3
Suparwati et al. (2023)	Jurnal Pendidikan Kimia Undiksa	Q4
Sunyono (2018)	Asia-Pacific Forum on Science Learning and Teaching	Q4
Suja et al. (2023); Amalia et al. (2018); Albaiti et al. (2016)	Jurnal Pendidikan IPA Indonesia	Sinta 1
Yoni et al. (2018); Suari et al. (2018)	Jurnal Pendidikan Kimia Indonesia	Sinta 2
Suja (2015)	Jurnal Pendidikan Indonesia	Sinta 2
Yuanphan & Prasart (2023); Handayanti et al. (2015)	Jurnal Penelitian dan Pembelajaran IPA	Sinta 2
Siregar & Antuni (2023); Cahya et al. (2019)	Jurnal Kependidikan	Sinta 2
Nurhasanah et al. (2022); Kiswandari & Achmad (2020)	Jurnal Tadris Kimiya	Sinta 2
Siregar & Yenni (2022); Lathifa et al. (2020)	Jurnal Inovasi Pendidikan Kimia	Sinta 3
Sodanango et al. (2021)	Jurnal Pendidikan: Teori, Penelitian, Pengembangan	Sinta 3
Wiji et al. (2016)	Paedagogia	Sinta 3
Sinaga (2022); Ulinnaja et al. (2019); Sunyono et al. (2014)	Jurnal Penelitian Pendidikan Sains	Sinta 3
Ibrahim et al. (2022); Rahmi et al. (2020)	Lantanida Jurnal	Sinta 4
Dewi et al. (2021); Dewi et al. (2018); Diantari et al. (2018); Eky et al. (2018); Pratiwi et al. (2018)	Jurnal Pendidikan Kimia Undiksha	Sinta 4
Supriadi et al. (2022); Supriadi et al. (2021); Supriadi et al. (2018)	Jurnal Pijar Mipa	Sinta 4
Meristin et al. (2021); Maisaroh et al. (2018); Suryani et al. (2015)	Jurnal Pendidikan dan Pembelajaran Kimia	Sinta 4
Pikoli et al. (2022)	Jambura Journal of Educational Chemistry	Sinta 4
Darrmiyanti et al. (2018); Wulandari et al. (2018); Andina et al. (2017)	Jurnal Riset Pendidikan Kimia	Sinta 4
Muti'ah et al. (2022)	Jurnal Ilmiah Profesi Pendidikan	Sinta 4
Supriadi et al. (2023); Ariani et al. (2020)	Chemistry Education Practice	Sinta 4
Katmiati & Chusnur (2021)	Jurnal Zarah	Sinta 4
Dillah & Suyono (2016)	Unesa Journal of Chemical Education	Sinta 4
Widayanti (2021)	Edukimia	Sinta 4

Result and Discussion

Results of Aim Theme

Based on the synthesis of 52 articles, it was found that research of mental models in chemistry concepts was conducted with various objectives. The theme of research objectives on mental models in chemistry concept is divided into six broad lines.

The results obtained indicate that the most important objective of the study is to identify mental model profiles. This shows that many studies explore the form of participants' mental models in understanding chemistry concepts. By studying and analyzing students' mental models, researchers could understand how students build concepts in the learning process (Ozcan & Gercek, 2015). Several studies on mental models show that many students have very simple mental models of chemical phenomena (Buckley & Boulter, 2000; Park, 2006; Wang, 2007). Knowing students' mental profiles becomes an important source of information for teachers to determine suitable learning strategies as well as the right media to help students build a complete understanding of a concept (Yudani et al., 2016).

Table 3. Result of Research Aim Theme in the Mental Model Studies

Aim of research	Percentage (%)
Identify mental model profiles	42.31
Investigate the factors that contribute to the formation of mental models (multi-representation ability, learning media, learning models, learning strategies, teaching materials, spatial ability, reasoning ability)	30.78
Develop learning models, learning resources, learning media and instruments to improve students' mental models	13.46
Researching the profile of mental models and causal factors formed alternative mental models	5.77
Investigate the interrelationship between chemical concepts and students' mental models	3.85
Identify relationships between misconceptions and mental models	3.85

The second major research objective was to investigate the factors that contribute to the formation of mental models. From the results of the article analysis, it was found that several factors contributed to the formation of mental models, such as multi-representation ability, learning media, learning model, learning strategy, teaching materials, argumentation skills, spatial ability, and reasoning ability. For the multi representation ability factor, Johnstone (1993) explained that abstract chemical concepts can be explained through three levels of representation in chemistry known as multiple representations. However, reality in the chemistry learning process emphasizes the macroscopic and symbolic levels, while the submicroscopic level is often ignored (Sukmawati, 2019). Efforts to improve students' ability to interpenetrate the three levels of representation can be done by applying appropriate learning strategies and media to develop students' representation skills and mental models (Suryani et al., 2015).

The third research objective is to develop learning models, learning resources, learning media, and instruments to improve students' mental models. It is important to develop models, learning resources, and learning media that are packaged by involving three levels of chemical phenomena (macroscopic, submicroscopic, and symbolic) so that they can have an impact on improving students' understanding of material or mastery of chemical concepts (Sunyono, 2018). The right learning strategy can overcome students' misunderstanding of a chemical material to fulfill learning objectives (Pikoli et al., 2022).

Based on the results obtained, there are still several research objectives for the study of mental models in chemical concepts, including investigating the relationship between chemical concepts and students' mental models. It is said that understanding chemical concepts depends on chemical representations and contributes to the development of students' mental models (Chittleborough, 2004; Halim et al., 2013). Another research objective is to identify the relationship between misconceptions and mental models. It is undeniable that mental models are closely related to misconceptions; many studies have linked the two (Rahmi et al., 2020; Suja, 2015). Students' mental models are important for teachers to identify because they can help them know how students understand a concept, whether there are errors in their understanding or not. This is supported by Tümay (2014) statement that, by knowing students' mental models, misconceptions can be diagnosed.

Result of Subject Theme

Based on table 4, it was found that most of the mental models in chemistry concept research involved student in high school level. However, mental model research also involves junior high school students, university students, and chemistry teachers. Chemistry concepts are generally tiered concepts that develop from simple concepts to complex concepts. Chemistry concepts studied at the university level are a continuation of chemistry concepts at the high school level based on basic chemistry concepts in integrated science lessons at the junior high school level (Yoni et al., 2019). According to Handayanti et al. (2015), the higher the level of education, the mental model of the three levels of representation in chemistry, especially the microscopic level, will increase and be in accordance with scientific concepts.

Table 4. Result of Research Subject Theme in the Mental Model Studies

Research Subject		Percentage (%)
Student	University	26.92
	High School	65.38
	Middle school	5.77
Chemistry Teacher		1.92

In fact, according to the results of research by Pratiwi et al. (2018), only 8.37% of chemistry concepts taught in high school are understood by prospective chemistry teacher students in the form of scientific mental models, while the rest are classified as alternative (unscientific) mental models. The same situation is also shown in the research of Yoni et al. (2019), which found that of high school students' understanding of basic chemistry concepts taught in junior high school, only 6.64% are scientifically correct. While the remaining 93.36% is an alternative mental model, including 44.22% classified as misconceptions, The findings of this study have implications for chemistry learning in higher education, especially for prospective chemistry teachers. As the spearhead of chemistry education in the future, they must have a conceptual model related to the chemical concepts they will teach students. Learning chemistry concepts must cover the three levels of chemistry, namely the macroscopic, submicroscopic, and symbolic levels, and build the linkage of the three levels in the memory of students in the form of mental models (Suja et al., 2021).

Result of Instrument Theme

Students' mental models need to be analyzed to determine how students understand chemical concepts at the macroscopic, submicroscopic, and symbolic levels (Katmiati & Rahmi, 2021). Students' mental models can be analyzed using an assessment instrument. Many ways are done by various researchers in exploring mental models, including by giving questions in combination, both reasoned multiple choice and description, interviews, and classroom observations (Adbo & Taber, 2009; Buckley & Boulter, 2000; Harrison & Treagust, 2000; Jansoon et al., 2009; Park & Light, 2009; Wang & Barrow, 2011).

Table 5. Result of Research Instrument Theme in the Mental Model Studies

Instrument	Percentage (%)
Diagnostic test	34.62
Ope-ended question	21.15
Essay question	21.15
Multiple choice question	9.62
Drawing test	5.77
Interview	3.85
Questioner	1.92
Observation sheet	1.92

Based on the results in Table 5, the most widely used instrument is the diagnostic test instrument. Diagnostic tests are used to see students' ability to integrate the three levels of representation in chemistry and find out the misconceptions of students related to certain concepts. According to Wang (2007), investigating mental models using diagnostic tests requires researchers to create puzzles and interpret learners' responses to a series of questions to reveal their views on certain concepts. Researchers usually use a method in the form of the Diagnostic Test of Mental Models (TDM). The types of TDM used include two-tier multiple choice, open-ended responses, interviews with probing questions and drawings, predict, observe, explain (POE), interview about events (IAE), and so on.

Besides using diagnostic tests, mental models were also explored through open-ended questions, essay tests, multiple choice, drawing tests, interviews, questionnaires, and observation sheets. All the instruments used by researchers to identify students mental models have advantages and disadvantages. Therefore, many types of mental model research use multiple data collection tools in one study, which is intended to enrich the data (Wardah & Wiyarsi, 2020). For example, Albaiti et al. (2022) study used an essay mental model test and an interview test to identify students' mental models. Interviews are used to collect data using descriptive sentences stated by respondents so that researchers can learn how they develop interpretations of responses to something (Kirbulut & Geban, 2014). The results of the interview test are used by researchers to strengthen the results of the mental model test, which can describe the mental models that students have.

Result of Chemistry Concept Theme

Based on Table 6, it is known that mental model research most often examines concepts in the scope of physical chemistry, namely 22 studies. The most studied physical chemistry concept is the concept of chemical equilibrium. Chemical equilibrium is a chemical concept that is considered difficult by students and teachers because it is abstract (Karpudewan et al., 2016; Raviolo & Garritz, 2009). The concept of chemical equilibrium is difficult to teach or learn because it has a very complex material that is related to the concepts of reaction rate and oxidation-reduction reactions and requires a complete understanding at the macro, micro, and symbolic levels (Mensah & Morabe, 2018).

Table 6. Result of Research Chemistry Concept Theme in the Mental Model Studies

Scope	Subject	Percentage (%)
Physical Chemistry	Equilibrium	13.46
	Rate of reaction	9.62
	Redox and electrochemical reactions	3.85
	Chemical reaction	3.85
	Chemical and physical properties	3.85
	Thermochemistry	1.92
	Coloid	1.92
	Colligative properties	1.92
	Electrochemistry	1.92
Analytical Chemistry	Electrolyte and non-electrolyte solutions	11.54
	Acid base	7.69
	Hydrolysis	5.77
	Solubility	1.92
Basic Chemistry	Atomic structure	9.62
	Atomic theory	1.92
	Basic concepts of chemistry	1.92
	Basic laws of chemistry	1.92
Inorganic Chemistry	Chemical bonding	3.85
	Molecular modeling	3.85
Organic Chemistry	Structure and properties of organic compounds	1.92
	Functional groups (alcohol)	1.92
	Stereochemistry	1.92
	Hydracarbon	1.92

Research conducted by Özmen (2008) shows that students have alternative mental profiles at all levels of chemical equilibrium material. Especially in dynamic equilibrium and reversible reaction sub-materials (Praisri & Faikhamta, 2020; Raviolo & Garritz, 2009; Sinaga, 2022). Students' incomprehension in linking the three levels of chemistry causes incomplete student understanding so that they have alternative mental models (Diantari et al., 2018). Therefore, it is necessary to design learning strategies in such a way that they can develop students' mental models.

In the scope of analytical chemistry, there are 14 articles that discuss it. One of the most researched topics in analytical chemistry to examine students' mental models is electrolyte and nonelectrolyte solution material. Electrolyte and non-electrolyte solution material is one of the topics in chemistry that requires understanding of concepts and analytical skills (Experenza et al., 2019) and requires the interconnection of three levels of chemical representation in understanding it (Iqbal et al., 2020).

In the scope of basic chemistry, there are 8 articles that discuss it. One of the topics in the scope of basic chemistry that is most studied by developing students' mental models is atomic structure material. The concept of atomic structure is a major concept in science learning, and the concept is abstract, so how to teach and learn about atomic theory must be considered properly, especially in having a strategy by utilizing visualization (Light & Swarat, 2009). Understanding the complex and abstract phenomena of atomic structure needs to involve submicroscopic and symbolic representations (Hilton & Nichols, 2011). Understanding atomic structure is a challenge for students who may develop alternative conceptions or frameworks, naïve theories, or intuitive beliefs (Akaygun, 2016).

Result of Mental Model Theory

Based on Table 7, it can be seen that the most widely used mental model theory to describe students' mental model profiles is Sendur et al (2011) mental model theory, which can be categorized into four, namely: No Response (NR), if students do not choose an answer and provide any explanation; Specific Misconceptions (SM), if the answer and explanation are not scientifically acceptable; Partially Correct (PC), if the answer is scientifically correct, but the explanation or reasoning is incorrect; or the answer is not scientifically correct, but the explanation is correct; and Scientifically Correct (SC), if the answer and explanation are scientifically correct. Furthermore, in general, the first three mental models are referred to as alternative mental models, while the fourth mental model is a scientific model or conceptual model. Conceptual mental models are mental models that are scientifically appropriate (complete understanding). Meanwhile, alternative mental models are mental models that are not scientifically appropriate, including those that only have some concepts. Alternative mental models owned by students indicate the incompleteness of students' understanding of a concept (Adbo & Taber, 2009).

Table 7. Result of Research Mental Model Theory Theme in the Mental Model Studies

Theory	Mental model category	Percentage (%)
Sendur et al. (2010)	*No Response (NR), *Specific Misconceptions (SM), *Partially Correct (PC), *Scientifically Correct (SC)	28.85
Kurnaz & Eksi	*Scientific Mental Model, *Synthetic Mental Model, *Initial Mental Model,	17.31
Park & Light (2009)	*Early Mental Model, *Intermediate Mental Model 1, *Intermediate Mental Model 2, *Intermediate Mental Model 3, *Target Mental Model,	7.69
Johnstone (1991)	*Macroscopic model *Sub-microscopic models *Symbolic models	5.77
Lin & Chu (2007)	*Scientific Model (SM), *Phenomenon Model (PM), *Character-Symbol Model (CSM), *Inference Model (IM)	3.85
Adbo & Taber (2009)	*Conceptual mental model *Alternative mental model	3.85
Albaiti (2017)	*Type 1 Intact mental model of the student, *Type 2 Partial student mental model *Type 3, Partial student mental model *Type 4 Partial student mental model. *Type 5 The mental model of the student is incomplete.	1.92
Johnson-Laird (1983)	*Model mental statis, *Model mental dinamis	1.92
Chi and Roscoe (2002)	*Correct mental model (CMM). *Incomplete correct mental model (ICMM).	1.92

Theory	Mental model category	Percentage (%)
	*Complete faulty mental model (CFMM). *Faulty mental model (FMM). *Idiosyncratic mental model (IMM). *No response (NR).	
Wang (2007)	*Medium *Good *Very good	1.92
Coll & Treagust (2003), Park & Light (2008), Körhasan & Wang (2016)	*Target mental model (TMM), *Partial mental models (PMM), *The mixed mental model (MMM) *Alternative mental models (AMM) *The unexplored mental model (UMM)	1.92
Other		21.15

However, several studies show that most students have alternative mental models or incomplete mental models (Eky et al., 2018; Kiswandari & Ridwan, 2020; Pratiwi et al., 2018; Sodanango et al., 2021; Suari, 2019; Sucitra et al., 2016). The formation of alternative mental models is caused by students' inability to visualize structures and processes at the submicroscopic level and to connect them with other levels of chemical representation (Ibrahim et al., 2022). Students' inability to think analytically-synthetically about the correlation between macroscopic and types of particles at the submicroscopic level, as well as imaginative thinking related to the symbolic level, leads to difficulties in constructing mental models at the three levels of chemistry (Davidowitz & Chittleborough, 2009). As a result, the mental models formed in students' minds are alternative mental models, which include partial accuracy and misconceptions (Suja et al., 2021). Therefore, many mental model studies analyzed are related to alternative mental models and the factors causing them. The occurrence of alternative mental models is due to several aspects, which are categorized into two aspects: external and internal aspects (Suja, 2015).

Other mental model theories also adopted by some researchers are Kurnaz & Eksi, Park & Light, Johnstone, Lin & Chiu, Adbo & Taber, Albaiti, Johnson-Laird, Chi & Roscoe, and Wang. However, the trend of mental model studies on chemistry concepts from year to year is more adopting Sendur et al.'s mental model theory, Kurnaz & Eksi's theory, and Park & Light's theory. This is because the categories given in this theory are clear and can be applied to various chemical concepts that researchers want to identify. In addition, there are also several articles that do not use any theory, but researchers develop their own mental model categories according to the chemical concepts identified. Such as the research of Cahya et al. (2019) analyzing the mental models of prospective chemistry teachers on the concept of the degree of dissociation, which is categorized into three, namely the scientific model of the degree of dissociation, the model without the notion of dissociation, and the initial mole number error model.

In addition, Siregar et al. (2023) developed mental models by adapting previously existing theories, namely the concepts of Coll et al. (2003) and Park et al. (2009), Park et al. (2008), and elaborated on the concepts of Körhasan et al. (2016) and obtained four categories of mental models, namely the target mental model (TMM), partial mental models (PMM), the mixed mental model (MMM), alternative mental models (AMM), and the unexplored mental model (UMM). Thus, the categorization of mental models can be adjusted to the concept to be identified. Mental model categorization does not have to use categories in existing theories (Atikah et al., 2023).

Result Factor That Affects Mental Model

Based on the synthesis of 52 articles, it was found that students' mental models in chemistry concepts are influenced by many factors. The theme of factors that affect mental models in the studies is divided into eleven categories, which are presented in Table 8. Supriadi et al. (2018) explained that in the learning process, students will experience the assimilation and accommodation stages in the formation of concepts as students' initial knowledge related to something they learn. However, the concepts formed in students' minds must be correct or complete concepts so that students can absorb, master, and remember the material they learn for a long time. Understanding the concept makes it easier for students to solve problems because they will be able to relate to and solve these problems armed with the concepts, they already understand (Diantari et al., 2018).

In addition to prior knowledge, the formation of mental models is also influenced by experiences, attitudes, and problems faced by students (Suja et al., 2017). Students' understanding and experience in building mental models are influenced by student characteristics based on students' daily experiences, social environment, and cultural background (Andina et al., 2017; Gay, 2000).

Students' learning experiences when studying formally at school also influence mental models. Supriadi et al. (2022) stated that a person's mental model develops and occurs continuously throughout the development of a person's life, including students' learning experiences at each level of education. So far, the learning process that students get at the elementary, junior high, and high school levels applies a verification approach, where learning is dominated by providing material by the teacher and proving the concepts, they get through practicum activities. In addition, learning evaluations carried out at the elementary, junior high, and high school levels are only limited to the cognitive domain and are conceptual and algorithmic in nature. Thus, the learning process and evaluation obtained by students have not been able to guide them in solving problems related to everyday life. This is one of the reasons for the delay in the development of students' mental models (Ariani, 2020).

Table 8. Result of Research Factor that Affects Mental Model Theme in The Mental Model Studies

Factor	Author
Incomplete understanding at the submicroscopic level	Rahmi et al. (2020); Dillah & Suyono (2016); Wiji et al. (2016)
Internal and external factors causing the formation of alternative mental models	Batlolona & Souisa (2023); Dewi et al. (2018); Diantari et al. (2018); Pratiwi et al. (2018);
Complete understanding and able to integrate all three levels of representation in chemistry	Murni et al. (2022); Nurhasanah et al. (2022); Supriadi et al. (2021); Widayanti (2021); Lathifa et al. (2020); Praisri & Faikhamta (2020); Eky et al. (2018); Suari et al. (2018); Yoni et al. (2018); Albaiti et al. (2016) Handayanti et al. (2015); Suja (2015); Supasorn (2015); Suryani et al. (2015);
The initial knowledge possessed by students also greatly influences the development of mental models of learners	Yuanphan & Nuangchalerm (2023); Ariani et al (2020); Supriadi et al. (2018);
The learning model used by teachers is one of the factors that can improve mental models	Dewi et al. (2021); Maisaroh et al.(2017)
The use of media in the chemistry learning process can help students develop mental models	Siregar & Wiyarsi (2023); Supriadi et al. (2023); Muti'ah et al. (2022); Siregar & Kurniawati (2022); Ulinnaja et al. (2019); Akaygun (2016);
Mental models are influenced by students' interest and learning drive, explanations by teachers and learning resources used by students in understanding concepts, learning approaches	Pikoli et al. (2022)
Student understanding and experience are influenced by the characteristics and environment around students.	Albaiti et al. (2022); Supriadi et al. (2022); Kiswandari & Ridwan (2020); Amalia et al. (2018); Wilandari et al. (2018); Andina et al. (2017); Darmiyanti et al. (2017); Sunyono et al. (2014);
Mastery of the previous concept as a whole in three levels of representation can help students in building mental models.	Cahya et al. (2019)
The role of the teacher in the learning process	Suja et al. (2023); Suparwati et al. (2023); Ibrahim et al. (2022); Sinaga (2022); Meristin et al. (2021); Sodanango et al. (2021); Yildirir & Demirkol (2018);
Experience, training, learning involving three levels of representation in chemistry	Sunyono (2018)

Learning motivation also influences students' mental models. Learning motivation is one of the important components that must exist in students. If student learning motivation is high, student enthusiasm and learning outcomes will also be high, and vice versa (Sanjiwani et al., 2018). Other factors that can affect students' mental models include learning strategies and models and processing teaching materials in the learning process (Sari, 2021). In addition, Suja (2015) stated that mental models are also influenced by internal and external factors. Internal factors include students' low understanding of the three levels of chemistry (macroscopic level, submicroscopic level, and symbolic level) and their interconnections, low interest and motivation to learn, and low student concept meaning. Meanwhile, external factors include incomplete textbooks (packages) used and inappropriate teaching strategies applied by teachers.

Based on the results of the analysis of mental model research on chemistry concepts, researchers provide recommendations related to research with the same theme for future researchers: that research to identify student mental model profiles must continue to be carried out to maintain the consistency of students' scientific mental models, especially on chemistry concepts. Samples in the study of mental models should be prioritized by chemistry education students as prospective teachers who have an important role in the process of developing students' scientific mental models in the learning process. From this study, data were obtained related to the number of data collection instruments used to identify students' mental profiles, which can be a source of information for other researchers to use several data collection tools at once in one study in order to obtain more comprehensive findings. For the most part, mental models have almost been researched in all chemistry concepts, but more in-depth research should be conducted on all chemistry concepts to identify students' mental profiles and difficulties experienced by students in understanding the concept. Regarding mental model theory, most studies use the same mental model theory. Therefore, it is necessary to renew the theory of mental models, especially in chemistry learning. The factors identified in this study can be a source of reference for teachers to design the right learning process for developing students' scientific mental models.

Conclusion

Based on the results and discussions from the research on mental models in chemistry concepts, it can be concluded that the main objective of this research is to identify students' mental model profiles related to chemistry concepts. The research samples mostly involve high school students from various grade levels. The most used data collection tool is diagnostic tests, which serve to assess students' ability to integrate three levels of representation in chemistry and identify students' misconceptions related to specific concepts. Mental models are predominantly studied in the field of physical chemistry, especially in the topic of chemical equilibrium, by adopting various theories of mental models from different experts. One of the widely used theories is the mental model theory proposed by Sendur, Toprak, and Pekmez (2010), which categorizes mental models into four types: No Response (NR), Specific Misconceptions (SM), Partially Correct (PC), and Scientifically Correct (SC). Factors influencing the formation of students' mental models include internal factors such as prior knowledge, experience, attitudes, and motivation, as well as external factors such as the learning environment, incomplete textbooks, and inappropriate teaching strategies.

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