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Learning Chemical Bonds in Terms of Identifying Difficulties, Misconceptions, Learning Media, and Learning Models: A Systematic Literature Review

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Abstract: This research aims to determine and describe the identification of difficulties, misconceptions, learning media, and learning models on chemical bonds. The method used in this research is the systematic literature review method. Article search results starting from 2014 to 2024 were selected gradually and systematically. The results of this research show that students' difficulties and misconceptions can be minimized by applying learning models and media. It is evident from several articles studied that they are able to answer research questions, namely: How to identify difficulties in chemical bonds among students? what are the misconceptions that occur in chemical bonds? What are the appropriate learning models for chemical bonds? and What are the appropriate learning media for chemical bonds? The results and findings in several articles show that difficulties and misconceptions in chemical bonds can be minimized by applying learning models and media to reduce misconceptions about chemical bonds.

Keywords: Chemical bonding; Identifying difficulties; Learning media; Learning models; Misconceptions

Introduction

Chemistry is a science that studies structure, matter, composition, properties, changes, and the energy that accompanies these changes. Someone studies chemistry with the aim of better understanding the conceptual basics, applying concepts in solving problems in chemistry (Wahdan et al., 2017). Chemistry subjects contain a lot of material which is arranged sequentially and is related to the competencies studied. One of the materials studied is chemical bonds. Chemical bonding is one of the concepts in learning chemistry (Azura & Copriady, 2017). Chemical bonding material is usually grouped into four sub-themes, namely ionic bonds, covalent bonds, metallic bonds, and intermolecular forces. Chemical bonding explains how atoms form bonds, both from the same and different atoms. The concepts in chemical bonds are abstract, so they are contextually difficult to apply (Widarti et al., 2018). Apart from being abstract, chemical bonding material is a basic concept that students must understand correctly, so that they do not experience difficulties in studying chemistry further (Openhotman et al., 2017). Also, when teachers content knowledge and pedagogical content knowledge of chemical bonding are limited or superficial, they generally prefer the traditional approach instead of alternative pedagogical ones taking students alternative conceptions and difficulties into account and may cause the development of normative ideas about bonding and bonding models (Hunter et al., 2022).

Difficulty learning chemistry cannot be separated from conceptual errors, both the concept of chemical bonding material and the concept of supporting material that underlies chemical bonds. The level of learning difficulty can be measured one way by looking at the learning outcomes of students (Utami, 2021). Students' learning difficulties are caused by internal and external factors. Internal factors include low understanding of concepts and interest in learning, while external factors include the way teachers manage learning, peers, and others (Muderawan et al., 2019). A good, broad and deep

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understanding of the concept allows students to apply it, so understanding this concept is important for students. Correct explanations in chemistry material must be built on correct concepts so that students do not experience misconceptions (Meida & Harun, 2015). Each student has different concepts, due to concepts obtained from different experiences and inaccurate information sources. Concepts that are not in accordance with the knowledge obtained by students have an impact on the learning process. This affects students, because the concepts taught are contrary to actual scientific theory (Rahayu & Fitriza, 2021). These conflicting concepts lead to the formation of "misconceptions" which are interpreted as wrong understanding, alternative concepts, non-scientific concepts and bad scientific knowledge (Vrabec & Prokša, 2016). Misconceptions that occur among students are caused by students, teachers, learning media, and teachers' teaching methods. Chemical bonding material requires a high level of conceptual understanding. Therefore many people face misconceptions, especially in understanding this subjects (Gultom et al., 2023).

The use of learning media is important so that students understand the material. Learning media helps and enlivens the learning atmosphere which makes it easier for students to understand. The choice of media must be in accordance with the learning objectives (Noviani & Istiyadji, 2017). In studying chemical bonds, students have certain tendencies in the process of understanding concepts. Learning media can be used by students to easily understand abstract subjects (Hutabarat et al., 2021). Through learning media, students' understanding of concepts can be built so that misconceptions do not occur.

Misconceptions can be identified through diagnostic tests and the use of learning models. Diagnostic tests are assessment tools used to determine students' difficulties and causes of difficulties. The forms of diagnostic tests that are often used are interviews, open-ended tests, multiple choice tests, and level multiple choice tests (Rohmah et al., 2022). Apart from diagnostic tests, misconceptions can be reduced through the use of learning models. The learning models that can be used are *ECIRR* (*Elicit*, *Confront*, *Identify*, *Resolve*, *Reinforce*) and the *Conceptual Change* learning model. The *ECIRR* learning model is a model designed to reduce misconceptions, especially at the identify and reinforce stages. In the identify stage, students are aware that misconceptions have occurred and in the reinforce stage, students are given an understanding of the actual concept so that the wrong concept can be replaced (Warsito et al., 2021). Meanwhile, the Conceptual Change model requires students to discover new concepts that are understandable, logical and useful before conceptual restructuring can occur (Meida & Harun, 2015). In an effort to show novelty in research and provide solutions in chemistry learning, this research was conducted to look at students' learning difficulties and misconceptions by applying learning media and learning models in order to minimize the problems experienced by students.

Method

The systematic literature review (SLR) method was used in this research to examine the difficulties and misconceptions in learning chemical bonds by applying suitable learning models and media. The data sources in this research are articles from various journals for 10 years regarding the identification of difficulties, misconceptions, as well as media and learning models for chemical bonds with the identified parameters which can be seen in Table 1.

Table 1. Parameters Studied

Parameters	Description
Identify difficulties in learning chemical bonds	To see the difficulty of learning chemical bonds for students
Misconceptions about learning chemical bonds	To see misconceptions about learning chemical bonds among students
Learning model for chemical bonding	To see a learning model that is suitable for learning chemical bonds
Learning media for chemical bonds	To see learning media that is suitable for learning chemical bonds

Step 1: Question Formulation

This first step is to determine the scope to develop a clear research focus. This research tries to answer questions based on the needs of the selected topic, namely: how to see the difficulties in learning chemical bonds experienced by students?; How to see the misconceptions of learning chemical bonds experienced by students?; and How to see what models and media are suitable in order to reduce difficulties and misconceptions by students?

Step 2: Locating Studies

The second step of SLR is finding, selecting, assessing, and related to the question. The target of this research is the theme of learning chemical bonds in terms of identifying difficulties, misconceptions, media and learning models. These keywords are used to search for articles both national and international from 2014 to 2024. The search process uses Google Scholar, Publish or

Perish and Scopus. Retrieved articles are saved in PDF format and synchronized with Zotero.

Step 3: Study Selection and Evaluation

This stage is carried out to ensure whether the data obtained is suitable for use in SLR research or not. This publication search is relevant to the chosen topic, namely learning chemical bonds. The following is a literature review scheme in Figure 1.

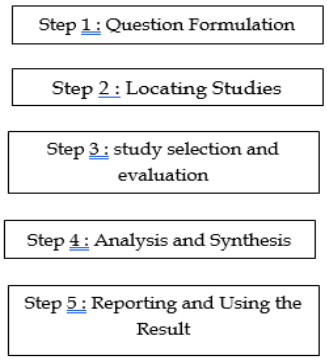

Figure 1. Five Steps of systematic literature review adapted from (Denyer & Tranfield, 2009)

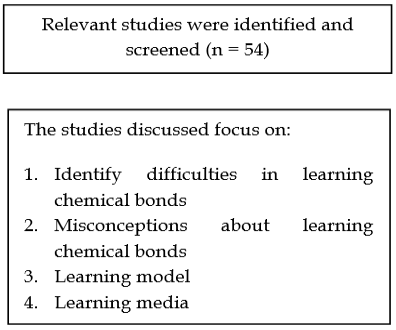

Figure 2. The systematic literature review scheme

Step 4: Analysis and Synthesis

After selecting articles, the next step is to carry out data synthesis with the aim of analyzing and evaluating research results from various literature according to parameters related to the study of chemical bonds. Data synthesis is carried out in research in the form of a narrative.

Step 5: Reporting and Using the Result

The reporting stage is the final stage in a systematic literature review. This stage includes writing the results of the literature review systematically in written form.

Result and Discussion

The results were obtained from several journals reviewed, resulting in several interrelated discussions. Results and discussion include identification of students' learning difficulties, misconceptions, use of learning media and application of learning models to chemical bond.

Identifying Students' Learning Difficulties in Chemical Bonding

Students' difficulties in learning chemical bonds cannot be separated from misconceptions both about the chemical bond itself and the concepts that precede the chemical bond material, namely the atomic structure and the underlying periodic system of elements. The material on chemical bonds is an abstract concept, so students always encounter misconceptions related to the formation of chemical bonds (Prodjosantoso et al., 2019).

Table 2. Identifying Students' Learning Difficulties in Chemical Bonding

Authors (year)	Title	Information
(Prodjosantoso et al., 2019)	The Misconception Diagnosis on Ionic and Covalent Bonds Concepts with Three Tier Diagnostic Test	Students' difficulties in learning chemistry are seen from students' mistakes in mastering the concept of chemical bond formation. The most common conceptual errors consist of: a. Determine the process of bond formation in compounds b. Determining the polarity of compound and molecule c. Determination of boiling points in covalent bonds
(Mezia, 2018)	*Identifikasi Kesulitan Belajar Siswa pada Materi Ikatan Kimia Siswa Kelas XB SMA Negeri 1 Siantan Kabupaten Mempawah*	The learning difficulties experienced by students in chemical bonding are: a. Determine ionic bonds b. Determine covalent bonds and covalent coordination
(Sari et al., 2020)	The Difficulties of X Grade High Svhool Students in Palangka Raya City Academic Year of 2018/2019 in Understanding Chemical Bond Concept using Two-Tier Multiple Choice	Students' learning difficulties in sub-material are : a. Electronic configuration and determine the number of valence electron b. describe Lewis structures c. write the molecular formula d. determine the tendency of an element to reach stability e. determine atoms following the octet/duplet rule f. predict the formula of the compound formed g. predict bond types based on Lewis structures

Authors (year)	Title	Information
(Sampurna et al., 2020)	Profil Penguasaan Konsep Ikatan Kimia pada Siswa Kelas X SMA Negeri 4 Palangka Raya Tahun Ajaran 2017/2018	The difficulty and low mastery of concepts in sub-material are: a. describe the Lewis structure and determine the chemical formula for triple covalent bond compounds b. coordination covalent bond process c. formation of metallic bonds and properties of metal-bonded compounds
(Pérez et al., 2017)	Misconceptions on Chemical Bonding: A Comparative Study between High School and First Year University Students	Learning difficulties in sub-material are: a. distinguish between ionic and covalent bonds b. electrostatic forces of chemical bonds c. Molecular polarity and molecular geometry d. Intra and intermolecular forces

Table 3. Difficulties that cause Misconceptions in College Students

No	College Students misconceptions
1	The formation of a covalent bond involves the transfer or handover of electrons from one atom to another
2	In the formation of a polar covalent bond, the more electropositive atom is larger in size, while the more electronegative atom is smaller in size.
3	Ionic bonds can occur in non-metallic homodiatomic compounds
4	Nonpolar covalent molecules, the size of the bonded atoms is not the same as the size of the atoms that form it

Students' learning difficulties in chemical bonding in several general subjects, namely the tendency of an element to reach stability, describing Lewis structures, predicting the formula of the compound formed, predicting the type of bond in a compound, and predicting the shape of the molecule. The difficulties experienced by students are caused by several factors, difficulties in connecting concepts and conceptual errors. Conceptual errors are not only experienced by high school students, they can also be experienced by college students. The misconceptions experienced by students regarding submicroscopic chemical bonds are as follows (Pikoli, 2018).

Misconceptions of Chemical Bonding

Chemical bonding is an abstract concept, so students always encounter conceptual errors and difficulties in studying chemical bonds. Students' misconceptions regarding chemical bonding can interfere with students' subsequent knowledge, because the concepts in chemical bonding are interrelated with each other. Chemical bonding consists of ionic, covalent, metallic bonds and geometric shapes. The research results were obtained after conducting a literature study. The data obtained comes from journals. The following are misconceptions that occur regarding chemical bonding (Zulkhairi, 2022).

Students can also experience misconceptions about the concept of prerequisites before entering the concept of chemical bonds (Noviani & Istiyadji, 2017). If prerequisite concepts cannot be understood, there is a possibility of experiencing misconceptions. For example, students do not understand the prerequisite concepts regarding the relationships between atoms, molecules, ions but understand the concept of ionic bonds. This happens because the concept of chemical bonds has a low dependence on the relationships of atoms, molecules and ions and is not the only prerequisite concept needed to understand the concept of chemical bonds. Misconceptions occur because basically students have brought initial concepts before participating in the learning process and sometimes these initial concepts do not match the actual concept (Istiqomah et al., 2021). The following Table 5 presents journals regarding chemical bonds misconceptions.

Table 4. Misconceptions of Chemical Bonding

Sub material of Chemical Bonds	Misconceptions
Stability of elements and octet rule	a. Noble gas elements easily bond with other elements b. The nitrogen atom can form five bonding electron pairs
Lewis structures	a. The Lewis structure represents the atomic number of an element b. In the Lewis structure of HCl, the valence electrons used are balanced between the H atom and the Cl atom
Chemical bonds	a. The polarity of a bond depends on the number of valence electrons in each atom involved in the bond b. Ionic bonds overemphasize the electron transfer process c. Breaking bonds releases energy and forming bonds requires energy d. Ionic bonds consist of various electrons
Molecule shape and molecule polarity	a. Lone pairs of electrons do not affect the shape of the molecule

Sub material of Chemical Bonds	Misconceptions
	b. Non-polar molecules are only formed when the atoms in the molecule have the same electronegative
Intermolecular forces	a. The intermolecular forces in polar compounds are van der Walls forces
	b. Hydrogen bonds will occur when the N atom in one molecule interacts with the H atom in another molecule
	c. Intermolecular bonds are forces that are only available in covalent compounds

Table 5. Identify Chemical Bonding Misconceptions

Authors (year)	Title	Information
(Istiqomah et al., 2021)	Identifikasi miskonsepsi materi ikatan kovalen pada mahasiswa kimia tahun pertama universitas negeri malang menggunakan tes diagnostik two-tier	Misconceptions occur in the sub-elements that form covalent compounds, Lewis structures, double bonds, coordinating covalent bonds, polar covalent bonds and molecular polarity, molecular shape, and intermolecular forces.
(Karim et al., 2022)	Identifikasi Miskonsepsi Ikatan Kimia Menggunakan Diagnostic Test Multiple Choice Berbantuan Certainty of Response Index	There is a high misconception in the sub-material that ionic bonds, single, double, triple covalent bonds, covalent coordination and metallic bonds are formed.
(Setiawan & Ilahi, 2022)	Identifikasi miskonsepsi menggunakan tes diagnostik *three tier*.	Students tend to experience misconceptions on the subtopics of metallic bonding and the concept of atomic stability.
(Hasanah et al., 2023)	Students' Mental Model Profile on Chemical Bonding Concept Using a Two-Tier Mental Model Diagnostic Test (TDM-Two-Tier)	The misconception that builds students' mental models lies in the sub-material that ionic bonds, covalent bonds and chemical bonds only affect solubility and do not affect the tendency of boiling points and melting points.
(Islami et al., 2019)	Identifikasi Miskonsepsi Siswa pada Konsep Ikatan Kimia Menggunakan Tes Four-Tier Multiple-Choice (4TMC)	Misconceptions obtained from the four tier multiple choice instrument test on chemical bonding material are categorized as low.

As a result of reviewing several journals, there are several sub-topics, namely ionic bonds, single covalent, double, triple, covalent coordination and metallic bonds. This material experiences misconceptions because students are still unable to determine the bonds or compounds that are formed and are still unsure about whether a compound is an ionic or covalent bond (Karim et al., 2022). Identifying students' misconceptions must be free from errors. These errors occur because students don't understand the concept, don't know the concept, or guess the answer. Students' misconceptions must be grouped into weak, medium or high levels. Determining whether students' misconceptions are significant or not aims to avoid students' answers being chosen by chance (Islami et al., 2019).

Students who experience misconceptions and do not understand the concepts are students who have difficulty learning chemical bonds. Apart from students, teachers can also experience misconceptions about chemical bonds. For example, in intermolecular forces. Teachers experience misconceptions due to poor teaching strategies or inability to build conceptual knowledge (Kwarteng et al., 2021). When teaching chemical bonding, teacher should consider the thermodynamic aspects to justify the stability of substances and the electrostatic model to elucidate the nature of the interactions (Pazinato et al., 2021). Many teachers are not aware of conceptual errors because their level of awareness is low (Fatokun, 2016). What can be done is that teachers must have a high level of awareness and learn and teach constructively. In addition, teachers must carry out improvement activities. Remedial activities aim to ensure that students who experience misconceptions can understand the material as a whole (Setiawan & Ilahi, 2022). Not only are remedial activities given to students, but teachers must provide alternative concepts according to the sub-material that has misconceptions.

Multiple Choice Tests

Students' conceptual understanding of chemical bonding material can be seen from the average percentage of students who answered correctly in each sub-material category (Widarti et al., 2018). To learn the correct concept you need to understand the concept first. Several methods are used to determine students' understanding of concepts, including interviews, *open ended* tests, concept maps, multiple choice tests used in misconceptions (Sen & Yilmaz, 2017).

Multiple choice tests can be diagnostic tests and parallel tests. Diagnostic tests are divided into two tiers, three tiers, four tier, and the highest tier is five tiers.

Some studies use diagnostic test instruments such as two tier multiple choice (Faris et al., 2020). There were 17 multiple choice questions, and misconceptions were obtained with a percentage of the concept of a stable electron arrangement of 20.8%, the concept of Lewis structures of 22.9%, the concept of ionic bonds of 33.3%, the concept of covalent bonds of 37.5%, the concept of covalent bond coordination was 31.3%, the concept of metallic bonds was 33.3%, the concept of physical properties of compounds was 30.6%, and overall 31.1% was categorized as moderate. The largest percentage lies in the covalent bond sub-material, because the initial concepts obtained by students are wrong in drawing conclusions, giving rise to misconceptions. Misconceptions among students need to be analyzed according to the pattern of students' answers to each question item. Two tier diagnostic test questions developed into three tier diagnostic questions.

Three tier diagnostic test is equipped with the *CRI* technique (Mellyzar, 2021). Three tier test contains the first part, namely questions about material concepts, the second part is the reasons referring to the first question, and the third part is the level of confidence in the second part. The questions given to students contain ten indicators to test students' understanding. Of the ten test indicators, it can be classified that 29.50% of students understand the concept of chemical bonds, while 62.77% experience misconceptions. Three tier diagnostic test can be used as an instrument to determine students' level of understanding and misconceptions.

Another multiple choice test is a parallel test. Parallel tests are considered better because the questions are made similar but not the same, so that comprehension tests can avoid possible influences in the form of practice or memorization, and they are carried out in parallel so that differences in conditions can be avoided. The overall concept of chemical bonds is still low in this parallel test (Openhotman et al., 2017). Students' abilities are relatively low in understanding the concept of ionic and covalent bonds.

Learning Medias

Ineffective learning can hinder the achievement of learning goals. To achieve success in achieving learning goals, learning variations are needed, one of which is learning media. Learning media has a role as information carrier technology that can be used for the learning process. Learning chemistry, especially chemical bonding, is material that contains abstract concepts, so learning media is needed in the form of an application that can express these abstract concepts. One of the learning media is Learning Object (LO). The LO is provided in the form of a link, so it is easy to access. This LO contains two representations, namely, a submicroscopic representation allowing students to see a picture of chemical bonds from the application and a symbolic representation showing a comparison between molecules designed by students with typical chemical structures (Muljana et al., 2020).

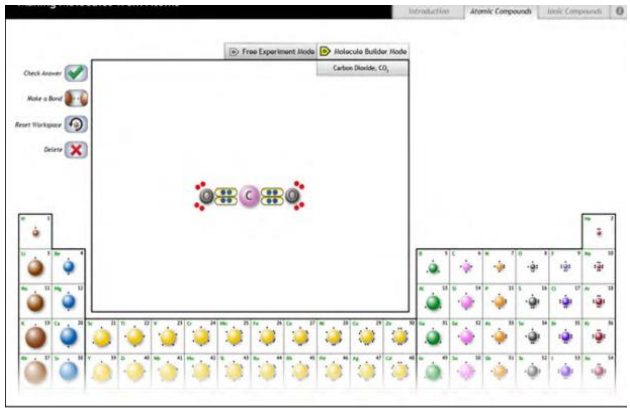

Figure 3. Learning object include learning media

Other learning media such as C-Bonds interactive media can reduce misunderstandings experienced by students with the Conceptual Change Text strategy. The Conceptual Change Text strategy is basically learning to change students' concepts due to the phase of creating conceptual conflict in this learning strategy (Kumalaningtias & Sukarmin, 2019). Providing *Conceptual Change Text* is believed to mean that a new concept that can be accepted scientifically is more meaningful because it contains many scientific concepts. Meanwhile, the interactive media C-Bonds is a medium that can visualize abstract chemical bond, making it easier for students to understand chemical bond. The use of interactive learning media is effective if it can increase students' understanding of concepts. C-Bonds interactive learning media is designed using the easy-to-access Adobe Flash *action script 3* application (Sa'diyah & Sukarmin, 2021).

Figure 4. C-Bonds interactive learning media

The learning media developed is widely used in chemical bonding which is presented in Table 6.

Table 6. Learning Media of Chemical Bonding

Authors (year)	Title	Information
(Sundari & Silitonga, 2022)	Penerapan media Interaktif *Articulate Storyline* dalam pembelajaran Ikatan Kimia	Interactive media Articulate Storyline is effective and efficient for student learning outcomes.
(Nurillah et al., 2023)	Penggunaan Media *Augmented Reality* Berbasis Android terhadap Peningkatan Prestasi Belajar Siswa pada Materi Ikatan Kimia	Augmented Reality media can visualize abstract objects into concrete ones and its use can improve student learning achievement.
(Harahap et al., 2021)	Hasil Belajar dan Persepsi Peserta Didik pada Materi Ikatan Kimia Melalui Pembelajaran Berbasis Multimedia Interaktif *Collisions* di Masa Pandemi Covid-19	Collisions interactive multimedia-based learning contains material on covalent bonds, ionic bonds, atoms, ions, and others which can provide visualization and have a positive influence on learning outcomes and student perceptions.
(Dalimunthe & Dalimunthe, 2023)	Implementasi Media Pembelajaran Berbasis Web pada Materi Ikatan Kimia	web media features are equipped with materials, online quizzes, and chemical bond learning videos to stimulate students to be interested in learning.
(Mutammimah & Udaibah, 2022)	The Development of Learning Media Petuah Kimia (A Digital Chemistry Bond Material)	Chemistry Advice learning media is a comic about chemical bonds including ionic, covalent and metallic bonds, as well as octet and duplet rules, Lewis structures and formal charges which were developed online.
(Luxford & Bretz, 2014)	Development of the Bonding Representations Inventory to Identify Student Misconceptions about Covalent and Ionic Bonding Representations	The Bonding Representations Inventory was developed to measure misconceptions in representing chemical bonds
(Kuit & Osman, 2021)	CHEMBOND3D e-Module Effectiveness in Enhancing Students' Knowledge of Chemical Bonding Concept and Visual-spatial Skills	This module interprets two important concepts in chemical bonds, namely Lewis structures and VSEPR to determine the shape of ions or molecules and bond angles.
(Latifa et al., 2023)	Pengembangan Video Pembelajaran Berbasis Pembelajaran Kontekstual untuk Peningkatan Keterampilan Berpikir Kritis Siswa pada Materi Ikatan Kimia	Contextual learning-based learning videos on Chemical Bonding material are needed to support students' understanding so they can practice critical thinking skills.
(Danin & Kamaludin, 2023)	Development of Google Sites Based Learning Media on Chemical Bonds with Multilevel Chemical Representation	Google sites-based learning media on chemical bonds can make it easier for teachers to explain the representation of chemical bonds and make it easier for students to understand chemical bond.
(Tanjung & Louise, 2024)	Development of Student Worksheets with Discovery Learning Models Based on Augmented Reality in Chemical Bonding Materials to Increase Learning Motivation and Learning Outcomes	Student worksheets that are integrated with the Augmented Reality-based Discovery Learning model are very suitable for increasing student motivation and learning outcomes.

Chemical bonding requires a high level of understanding, so a real picture is needed through animated videos, pictures, or other things. Based on a journal review, media is needed that can visualize abstract objects into concrete ones so that you know how atoms, ions, ionic bonds and covalent bonds are formed (Nurillah et al., 2023). Visualization of learning media allows students to see images in two or three dimensions so that they are more interactive and increase student motivation, interest and learning outcomes (Dalimunthe & Dalimunthe, 2023).

Learning Models

Learning models that prioritize students as the center in the learning process and reduce misconceptions are the *conceptual change* learning model and the *ECIIR* model. The *conceptual change* model is a learning model that changes existing concepts, so that learning is not just about collecting new facts or new skills. The *conceptual change* learning model consists of four steps, namely are expressing students' concepts which aims to help teachers and help students recognize and clarify the ideas and understanding they have, discussing and evaluating concepts which aim to enable students to clarify and revising existing concepts, creating conceptual conflicts with students' concepts so that students are more open to subsequent conceptual

changes, assisting conceptual restructuring which aims to be able to reflect on knowledge and see differences between students' concepts and scientific concepts so that this occurs change.

There are differences before and after implementing the *conceptual change* model (Meida & Harun, 2015). Before implementing the *conceptual change* learning model, there were many misconceptions. The average percentage of students who know the concept, don't know the concept, and have misconceptions respectively is 41.56%, 12.67%, and 45.78%. This shows that the concept was answered incorrectly by students with a high level of confidence. After implementing the *conceptual change* learning model, the average percentage of students who knew the concept, did not know the concept and had misconceptions respectively was 95.11%; 1.33%; and 3.56%. Most of the misconceptions experienced by students shift towards knowing the concept after implementing *conceptual change*. There are students who still maintain their initial concepts, this occurs because the imbalance caused by the cognitive conflict process has not yet reached a balanced state. Students who experience a shift in misconception towards not knowing the concept, because students are not confident in answering questions even though they have chosen the correct answer or do not understand the concept completely (Fitria & Suyono, 2016). Misconceptions will shift towards knowing if there is continuous guidance and scaffolding to achieve balance so that students will accommodate their concepts into scientific concepts and assimilate them so they can be applied well (Meida & Harun, 2015).

The next learning model designed to reduce misconceptions is the *ECIRR* model. In the *ECIRR* model, there is an *identify* stage and a *reinforce* stage. In the *identify* stage, students are aware that a misconception has occurred and continue with the *reinforce* stage, namely providing actual concepts so that the wrong concept can be replaced. The implementation of this learning model is carried out by studying in groups, because they compare their thoughts with their friends to experience development in thinking and understanding a concept. The *identify stage*, students experience cognitive conflict so that students are aware of misconceptions. After students are aware of misconceptions, then at the *reinforce* stage students are given reinforcement of the concept so that it becomes a correct understanding (Warsito et al., 2021). Implementing a learning model that suits the characteristics of students is one effort to improve learning outcomes and is presented in Table 6.

The learning models applied in chemical bonding are the *Problem Based Learning* model, *Guided Discovery*, *Numbered Heads Together Cooperative* Type, *Project Based Learning*, and others. The results of a review of several journals regarding the application of this learning model can improve learning achievement, learning outcomes, and students' activeness in discovering concepts and problem solving (Irfandi, 2022). Learning models can be integrated into teaching materials such as student worksheets. Student worksheets are integrated with learning models to achieve predetermined goals.

Table 7. Models and Learning Strategies Applied to Chemical Bonding

Authors (year)	Title	Information
(Rosmalawati & Musdalifah, 2023)	Penerapan Model *Problem Based Learning* untuk Meningkatkan Hasil Belajar pada Mata Pelajaran Ikatan Kimia	Application of the Problem Based Learning model with a scientific approach-TPACK can improve student learning outcomes. This model can increase learning activities and students give positive responses and enjoy learning chemical bonds.
(Asmandhani, 2023)	Penerapan Model *Problem Based Learning* untuk Meningkatkan Hasil Belajar pada Materi Ikatan Kimia	The application of the Problem Based Learning model brought a positive response because it provided very satisfying results in terms of enthusiasm for learning and activeness in improving student learning outcomes.
(Irfandi, 2022)	Efektivitas Model Pembelajaran Penemuan Terbimbing (*Guided Discovery*) untuk Mencapai Ketuntasan Hasil Belajar Siswa di Kelas X TKJ SMK Bina Profesi Pekanbaru pada Materi Ikatan Kimia	Guided Discovery model is effective because it can create a learning atmosphere that involves active and independent students in discovering concepts, understanding and solving problems. Guided Discovery model has a significant influence on the learning process and outcomes.
(Nursafitri et al., 2019)	Pengaruh Pemberian Kuis diakhir Pertemuan pada Model Pembelajaran Kooperatif Tipe *Numbered Heads Together* terhadap	Giving quizzes to classes that apply the Numbered Heads Together type cooperative learning model causes student learning outcomes to be better than without giving quizzes. Indicators of complete

Authors (year)	Title	Information
	Hasil Belajar Siswa kelas X MAN LAPPARIAJA	learning such as the formation of metallic bonds and their relationship with the physical properties of metals, the polarity of several compounds and the electronegativity of elements.
(Hidayat & Suyono, 2016)	Meremediasi Siswa yang Memiliki Beban Miskonsepsi Tinggi pada Ikatan Kimia dan Persepsi Rendah Menggunakan Strategi Analogi	Misconceptions can be overcome by remedial learning using analogy strategies and there is a shift towards knowing the concept
(Yulianti, 2022)	Penerapan Model Pembelajaran *Project Based Learning* pada Materi Ikatan Kimia Kelas X di SMA Negeri 1 Labuhanhaji Timur	Application of this model increases learning achievement, demands independence in completing assignments, and improves student learning outcomes in chemical bonding material

One of them is an inquiry-based student worksheet which is designed to develop students' abilities in investigating objects, symptoms and problems related to chemical bonds. Inquiry-based student worksheets on chemical bonds have been proven to increase student activity and learning achievement (Istiqomah & Salirawati, 2023). Apart from that, teachers can use learning approaches such as *Nature of Science* in students' worksheets for studying chemical bonds with the aim of training students' critical thinking skills (Dewitasari & Rusmini, 2023).

Conclusion

Based on the results of a systematic literature review that has been carried out regarding the identification of difficulties, misconceptions, learning models and learning media in learning chemical bonds, it can be concluded that the results of the review of journal articles prove that difficulties and misconceptions in learning chemical bonds can be minimized by using models and media proper learning. To learn the concept of chemical bonding well, you need to understand the concept correctly. Misconceptions (misconceptions) can be identified by providing diagnostic tests or parallel tests. Conceptual errors obtained by students can be reduced by providing learning media and applying learning models that are suitable for chemical bonding material. Teachers and students can improve learning so that there are no misconceptions.

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The authors declare no conflict of interest

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