

Analysis of Students' Thinking Processes in Chemistry Problem Solving: A Literature Review of Learning Difficulties in Senior High School

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Abstract

Chemistry learning difficulties among senior high school students often arise due to the abstract and hierarchical nature of chemical concepts, which require strong reasoning and problem-solving skills. These difficulties are closely related to students' thinking processes when understanding concepts and solving problems. This study aims to analyze patterns of students' thinking processes that contribute to learning difficulties, identify the stages where obstacles most frequently occur, and summarize recommended instructional strategies. This research used a descriptive qualitative literature review of 20 selected journal articles. The findings show that students' thinking processes are generally unsystematic, as they tend to apply formulas without sufficient conceptual understanding. The most dominant obstacles occur at the conceptual and mathematical stages, followed by procedural and representational difficulties. Recommended strategies include diagnostic assessments, strengthening prerequisite concepts, contextual learning, and integration of multiple chemical representations.

Keywords: thinking processes, chemistry learning difficulties, senior high school students, literature review

1. Introduction

Chemistry learning at the senior high school level is characterized by abstract, hierarchical, and interconnected concepts, which require students to understand basic concepts accurately in order to learn more advanced topics effectively (Evangelista et al., 2022). This condition often causes chemistry to be perceived as a difficult subject, as students are required to integrate conceptual understanding, procedural skills, and mathematical abilities in solving chemistry problems (Utami et al., 2021). Several studies have reported that a significant proportion of students experience difficulties in learning chemistry, with more than 50% of students showing inadequate understanding of fundamental concepts in various topics (Basyiroh et al., 2022; Evangelista et al., 2022). Learning difficulties in chemistry are evident in various topics that require mastery of fundamental concepts and calculation skills, such as stoichiometry, acid-base reactions, equilibrium, solubility, and hydrolysis (Hayati et al., 2018; Utami et al., 2021; Basyiroh et al., 2022).

Chemistry learning difficulties are not only reflected in low achievement scores but are also indicated by misconceptions or incorrect conceptual understanding. For example, in the topic of Lewis structures, students experience difficulties in determining electron configurations, valence electrons, Lewis symbols, and the final Lewis structures of compounds, indicating conceptual obstacles in understanding the relationships among prerequisite concepts (Kristiana et al., 2020). For instance, a considerable number of students fail to correctly identify valence electrons and bonding patterns, which leads to incorrect structural representations and misconceptions at the conceptual level (Kristiana et al., 2020). Similar difficulties are found in the topic of the common ion effect on solubility, where students fail to build scientific reasoning about the relationship between the addition of common ions, equilibrium shifts, and their connection to Q_{sp} and K_{sp} (Sibarani et al., 2019). A comparable condition is also observed in chemical equilibrium, where the greatest difficulties occur in understanding dynamic equilibrium and equilibrium constants, influenced by internal factors such as conceptual mastery and intelligence (Basyiroh et al., 2022).

These learning difficulties are closely related to students' thinking processes when understanding and solving chemistry problems. Students' thinking processes may be hindered at the conceptual stage when they fail to understand concepts or incorrectly relate prerequisite concepts. Difficulties may also arise at the procedural or algorithmic stage when students struggle to organize solution steps, at the mathematical stage when they have weak calculation skills, and at the representational stage when they fail to interpret chemical symbols, models, or representations (Hayati et al., 2018; Utami et al., 2021). Previous studies also indicate that these difficulties are interconnected, where weaknesses in conceptual understanding often lead to errors in procedural and mathematical stages, ultimately affecting the overall problem-solving process (Evangelista et al., 2022). Studies employing diagnostic instruments such as two-tier, three-tier multiple-choice tests, and testlets have been able to identify both the location of learning difficulties and the incorrect thinking patterns of students through answer-reason analysis and interviews (Kristiana et al., 2020; Basyiroh et al., 2022; Evangelista et al., 2022). This highlights the importance of examining students' thinking processes in a more structured manner, as conventional assessments are often insufficient to capture the underlying causes of learning difficulties. Therefore, a literature study that synthesizes findings from various studies is needed to obtain a comprehensive understanding of students' thinking processes that contribute to learning difficulties in chemistry.

Based on these considerations, this study was conducted as a literature review of 20 selected journals. This study aims to analyze the patterns of senior high school students' thinking processes in chemistry learning that contribute to learning difficulties, identify the stages of thinking that most frequently experience obstacles in terms of conceptual, procedural/algorithmic, mathematical, and representational aspects, and summarize the instructional strategies recommended in the literature to improve students' thinking processes and minimize chemistry learning difficulties (Basyiroh et al., 2022; Lestari et al., 2024). By synthesizing findings from multiple studies, this research is expected to provide a more comprehensive and evidence-based understanding of students' thinking processes and support the development of more effective chemistry learning strategies.

2. Methods

This study employed a literature review using a descriptive qualitative approach. The literature review was conducted by analyzing research findings related to learning difficulties

in chemistry among senior high school students, particularly those that reveal students' thinking processes in solving chemistry problems. These difficulties include misconceptions, procedural errors, and mathematical calculation errors. The review focused on studies that used diagnostic and structured evaluation instruments, such as two-tier multiple-choice tests, three-tier multiple-choice tests, and testlets, because these instruments are able to identify the location and types of students' learning difficulties more specifically (Kristiana et al., 2020; Basyiroh et al., 2022; Evangelista et al., 2022).

The data sources consisted of 20 selected journal articles relevant to chemistry learning at the senior high school level. The articles were chosen because they discussed learning difficulties in various chemistry topics, such as Lewis structures (Kristiana et al., 2020), limiting reagents in stoichiometry (Hayati et al., 2018), the common ion effect on solubility (Sibarani et al., 2019), chemical equilibrium (Basyiroh et al., 2022), and difficulties in solving acid–base problems (Utami et al., 2021). In addition, some articles examined the factors contributing to learning difficulties from both internal and external aspects, as well as instructional conditions (Lestari et al., 2024). The selected articles were predominantly conducted in Indonesia, reflecting the context of chemistry learning in senior high schools. In terms of indexing, the articles were primarily derived from national journals, many of which are accredited under the Indonesian national indexing system (SINTA). This selection ensures the contextual relevance of the findings to the Indonesian educational setting.

Data collection was carried out through three stages: identification of relevant articles, selection based on their relevance to the research focus, and determination of 20 articles as the primary data sources. The selected articles met the following inclusion criteria: (1) the research subjects were senior high school students, (2) the studies focused on chemistry learning difficulties and/or conceptual understanding, (3) the studies were empirical research, and (4) the studies contained data that could be used to interpret students' thinking processes through answer patterns, reasoning, or interviews. This stage is consistent with studies emphasizing the importance of diagnostic instruments in identifying students' learning difficulties in more detail, as such difficulties are not always reflected in final scores (Kristiana et al., 2020; Basyiroh et al., 2022). The articles were retrieved through an online database search using Google Scholar as the primary search engine, supported by keywords such as “chemistry learning difficulties”, “misconceptions in chemistry”, and “students' thinking processes”. The selection process emphasized relevance to the research focus and the credibility of national academic publications.

Data analysis was conducted using thematic analysis through a coding process of the findings from each article. The findings were classified into four stages of thinking process obstacles: conceptual, procedural/algorithmic, mathematical, and representational difficulties. These patterns were then synthesized to identify the thinking processes that most frequently contributed to learning difficulties, as well as the instructional strategies recommended in the literature. The strategies included the use of diagnostic tests for remedial instruction, strengthening prerequisite concepts, contextual learning, variations in teaching methods, and collaborative learning as alternatives to reduce chemistry learning difficulties (Evangelista et al., 2022; Lestari et al., 2024; Hidayanti et al., 2020).

3. Result and Discussion

3.1 Patterns of Students' Thinking Processes Leading to Chemistry Learning Difficulties

The synthesis of 20 selected articles indicates that chemistry learning difficulties among senior high school students are closely related to students' thinking processes when solving problems. In many cases, students do not start from conceptual understanding, but directly apply formulas or procedures. This pattern causes difficulties when students face problems that require reasoning or conceptual application. For example, in chemical equilibrium topics, students tend to memorize the characteristics of equilibrium without understanding the meaning of dynamic processes, which leads to errors in problem-solving (Basyiroh et al., 2022). The main patterns of students' thinking processes that lead to learning difficulties are summarized in Table 1.

Table 1. Patterns of Students' Thinking Processes

Thinking Pattern	Main Characteristics	Impact on Learning	Source
Memorization based thinking	Memorizing formulas without meaning	Errors in contextual problems	Kristiana et al.
Partial thinking	Focusing on only one aspect	Failure to solve complex problems	Febriani et al.
Pseudo-procedural thinking	Following steps without conceptual understanding	Systematic errors	Evangelista et al.
Non-integrative thinking	Separated chemical representations	Repeated misconceptions	Hayati et al.

Table 1 shows that students' difficulties are strongly influenced by unstructured thinking patterns. Memorization-based thinking leads students to rely on formulas without understanding the underlying concepts, making them prone to errors in contextual problems (Kristiana et al., 2020). Partial thinking indicates that students focus only on certain aspects, such as calculations, without understanding the overall concept (Febriani et al., 2018). Pseudo-procedural thinking reflects the tendency to follow solution steps mechanically, resulting in systematic errors (Evangelista et al., 2022). Meanwhile, non-integrative thinking shows that students fail to connect macroscopic, microscopic, and symbolic representations, which leads to recurring misconceptions (Hayati et al., 2018). These patterns confirm that incomplete conceptual understanding and weak representational integration are major causes of chemistry learning difficulties.

3.2 Stages of Thinking Processes that Most Frequently Experience Obstacles

In addition to general thinking patterns, the literature also reveals that students' difficulties can be classified into several stages of the thinking process. These obstacles occur at conceptual, procedural, mathematical, and representational stages. Each stage reflects a different type of difficulty, but they are interconnected and often appear sequentially. The stages of thinking process obstacles are summarized in Table 2.

Table 2. Stages of Thinking Process Obstacles

Thinking Stage	Type of Obstacle	Example of Error	Related Topic	Source
Conceptual	Misconception, weak prerequisite concepts	Misunderstanding dynamic equilibrium	Equilibrium	Basyiroh et al.
Procedural/algorithmic	Unsystematic steps	Incorrect solution sequence	Stoichiometry	Evangelista et al.
Mathematical	Calculation and conversion errors	Incorrect mass to mole conversion	Stoichiometry	Zakiyah et al.
Representational	Failure to connect macro-micro-symbolic levels	Misinterpreting reaction symbols	Hydrolysis	Hayati et al.

Table 2 shows that conceptual and mathematical obstacles are the most dominant. Conceptual obstacles are reflected in misconceptions and weak understanding of prerequisite concepts. For example, students often misunderstand the concept of dynamic equilibrium, treating it as a static condition (Basyiroh et al., 2022). Procedural obstacles occur when students cannot determine the correct sequence of steps in problem-solving, as shown in studies using testlets where students fail from the initial steps (Evangelista et al., 2022). Mathematical obstacles appear when students struggle with calculations or unit conversions, especially in stoichiometry (Zakiyah et al., 2018; Evangelista et al., 2022). Representational obstacles occur when students cannot connect macroscopic, microscopic, and symbolic representations, which leads to incomplete understanding of chemical concepts (Hayati et al., 2018). These findings suggest that conceptual weaknesses often trigger other types of difficulties in subsequent stages.

3.3 Recommended Instructional Strategies to Improve Students' Thinking Processes

The literature also highlights several instructional strategies that can help improve students' thinking processes and reduce learning difficulties. Most studies emphasize the importance of diagnostic assessment and meaningful learning approaches. These strategies aim to identify students' misconceptions and support conceptual understanding rather than focusing solely on final answers. The recommended strategies are summarized in Table 3.

Table 3. Recommended Instructional Strategies

Instructional Strategy	Obstacle Addressed	Form of Implementation	Source
Two-tier/ Three-tier test	Conceptual	Misconception diagnosis	Kristiana et al.
Testlet	Procedural	Analysis of thinking steps	Evangelista et al.
Contextual learning	Conceptual	Real-life problem contexts	Prayunisa
Strengthening prerequisite concepts	Conceptual & Mathematical	Review of basic concepts	Ariani et al.

Table 3 shows that diagnostic assessments such as two-tier, three-tier, and testlet instruments are effective in identifying students' misconceptions and thinking obstacles. These tools enable teachers to detect errors at specific stages and design appropriate remedial instruction (Basyiroh et al., 2022; Evangelista et al., 2022). Studies have shown that more than 50% of students experience misconceptions that are not detected through conventional assessments, with diagnostic instruments revealing detailed patterns of incorrect reasoning in

students' responses (Kristiana et al., 2020; Basyiroh et al., 2022). Contextual learning is also recommended because it helps students connect abstract chemical concepts with real-life situations, thereby improving conceptual understanding and critical thinking (Prayunisa, 2020). For example, contextual-based instruction has been reported to improve students' conceptual understanding by enabling them to relate chemical concepts to everyday phenomena, resulting in more meaningful learning experiences (Prayunisa, 2020). In addition, strengthening prerequisite concepts is essential, as many learning difficulties stem from weak foundational understanding. Several studies indicate that students who lack prerequisite knowledge tend to experience repeated errors in subsequent topics, particularly in concepts that require hierarchical understanding such as equilibrium and stoichiometry (Basyiroh et al., 2022; Hayati et al., 2018). Overall, instructional strategies that focus on improving thinking processes are more effective than those that only emphasize procedural practice.

The findings of this literature review indicate that chemistry learning difficulties do not occur randomly, but are closely related to students' thinking processes. Students' thinking processes in chemistry involve several stages, including conceptual understanding, procedural planning, mathematical calculation, and representational interpretation. When one of these stages is disrupted, it affects the entire problem-solving process and leads to learning difficulties (Evangelista et al., 2022; Basyiroh et al., 2022). This pattern is consistently reported across studies, where errors at the conceptual stage frequently lead to subsequent errors in procedural and mathematical stages, indicating that students' thinking processes are sequential and interdependent.

Conceptual obstacles appear to be the primary source of difficulty. Many students develop misconceptions because they do not fully understand prerequisite concepts. For instance, students often interpret equilibrium as a static condition rather than a dynamic process (Basyiroh et al., 2022). In fact, studies report that a considerable proportion of students misunderstand equilibrium concepts, particularly in distinguishing between dynamic and static systems, which significantly affects their ability to solve related problems (Basyiroh et al., 2022). Similar patterns are observed in Lewis structure topics, where students struggle with electron configurations and valence electrons, which are essential prerequisites (Kristiana et al., 2020). These findings highlight the hierarchical nature of chemical concepts.

Procedural and mathematical obstacles further reinforce these difficulties. Students frequently fail to organize solution steps logically, especially in stoichiometry problems (Evangelista et al., 2022). Research findings indicate that many students make errors in structuring solution steps, such as incorrect sequencing of procedures and failure to identify relevant variables in problem-solving tasks (Evangelista et al., 2022). Mathematical weaknesses, such as incorrect conversions or calculation errors, also disrupt the thinking process (Hayati et al., 2018). These errors often include mistakes in unit conversion and numerical calculations, which hinder students from obtaining correct final answers even when they understand the underlying concepts (Hayati et al., 2018). Additionally, representational obstacles occur because students are unable to connect symbolic representations with microscopic particle-level explanations.

The literature consistently suggests that diagnostic assessment is essential for identifying students' thinking obstacles. Instruments such as two-tier, three-tier, and testlet tests provide detailed information about students' reasoning, enabling teachers to design more appropriate instructional interventions (Kristiana et al., 2020; Basyiroh et al., 2022; Evangelista et al., 2022). These instruments not only identify whether students answer correctly or

incorrectly but also reveal the reasoning behind their answers, allowing for more targeted and effective remediation strategies (Kristiana et al., 2020). Contextual learning and the strengthening of prerequisite concepts are also recommended to build meaningful understanding.

Overall, chemistry learning difficulties among senior high school students are primarily caused by obstacles in conceptual and mathematical thinking, which subsequently lead to procedural and representational difficulties. Therefore, instructional strategies should focus on improving students' thinking processes through diagnostic assessment, contextual learning, strengthening prerequisite concepts, and integrating multiple chemical representations. However, these recommended instructional strategies are most directly applicable to the Indonesian context or similar educational environments, and further studies are needed to examine their applicability in broader regional or global contexts.

4. Conclusion

This literature review of 20 selected studies shows that chemistry learning difficulties among senior high school students mainly result from thinking processes that are not yet systematic. Students tend to rely on formulas without sufficient conceptual understanding, which leads to errors when solving conceptual problems. The most dominant obstacles occur at the conceptual and mathematical stages, followed by procedural and representational difficulties. To address these issues, the literature recommends the use of diagnostic assessments, strengthening prerequisite concepts, and applying contextual learning approaches to improve students' thinking processes.

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6. References

- Ariani, Z., Rizaldi, D. R., Fahrurrozi, M., Ratnasari, B. D., & Fatimah, Z. (2024). Analisis Faktor-Faktor Penyebab Kesulitan Belajar Siswa pada Pelajaran Kimia Materi Senyawa Hidrokarbon di MA Plus Nurul Islam Sekarbela. *Action Research Journal*, 1(3), 216-224. <https://doi.org/10.63987/arj.v1i3.147>
- Afriani, N., & Ningsih, L. (2022). Analisis Kesulitan Belajar Siswa pada Materi Struktur Atom. *Konfigurasi: Jurnal Pendidikan Kimia dan Terapan*, 6(2), 102-108. <http://dx.doi.org/10.24014/konfigurasi.v6i2.18617>
- Evangelista, E., Ariani, S. R. D., & Hastuti, B. (2022). Analisis Kesulitan Belajar Siswa Kelas X MIPA Di SMA Negeri 1 Purwodadi pada Materi Stoikiometri dengan Instrumen Teslet pada Pembelajaran Jarak Jauh. *Jurnal Pendidikan Kimia*, 11(2), 211-220. <https://doi.org/10.20961/jpkim.v11i2.63974>
- Fajrin, S., Haetami, A., & Marhadi, M. A. (2020). Identifikasi Kesulitan Belajar Kimia Siswa pada Materi Pokok Larutan Asam dan Basa di Kelas XI IPA2 SMA Negeri 1 Wolowa Kabupaten Buton. *Jurnal Pendidikan Kimia FKIP Universitas Halu Oleo*, 5(1), 27. <http://dx.doi.org/10.36709/jpkim.v5i1.13106>

Fatmawati, N., Kurniawan, R. A., & Kurniati, T. (2019). Analisis Kesulitan Belajar Berdasarkan Gaya Belajar Siswa Kelas X IPA pada Mata Pelajaran Kimia di MAS Al-Mustaqim Arang Limbung. *Ar-Razi Jurnal Ilmiah*, 791.

<https://garuda.kemdiktisaintek.go.id/documents/detail/1259328>

Febriani, G., Marfu'ah, S., & Joharmawan, R. (2018). Identifikasi Konsep Sukar, Kesalahan Konsep, dan Faktor-Faktor Penyebab Kesulitan Belajar Hidrolisis Garam Siswa Salah Satu SMA Blitar. *J-PEK (Jurnal Pembelajaran Kim)*.

<https://journal2.um.ac.id/index.php/j-pek/article/view/6274>

Genes, A. J., Lukum, A., & Laliyo, L. A. (2021). Identifikasi Kesulitan Pemahaman Konsep Larutan Penyangga Siswa di Gorontalo. *Jambura Journal of Educational Chemistry*, 3(2), 61-65. <https://doi.org/10.34312/jjec.v3i2.11911>

Hidayanti, E., & Savalas, L. R. T. (2020, September). Keterampilan Kolaborasi: Solusi Kesulitan Belajar Siswa SMA dalam Mempelajari Kimia. In *Prosiding Seminar Nasional Pendidikan Inklusif* (Vol. 1, No. 1, pp. 1-7). unram.ac.id

Kristiana, E., Sidauruk, S., & Meiliawati, R. (2020). Kesulitan Siswa Kelas X MIA SMA Negeri di Kota Palangka Raya Tahun Ajaran 2018/2019 dalam Memahami Konsep Struktur Lewis Menggunakan Instrumen Two-Tier Multiple Choice. *Jurnal Ilmiah Kanderang Tingang*, 11(1), 200-208. <https://doi.org/10.37304/jikt.v11i1.87>

Khasanah, U. F., Parubak, A. S., & Larasati, C. N. (2019). Analisis Kesulitan Belajar Kimia Peserta Didik Kelas XI IPA di SMA Yapis Manokwari. *Arfak Chem: Chemistry Education Journal*, 2(1), 77-84. <https://doi.org/10.30862/accej.v2i1.74>

Kristin, N., Astuti, A. P., & Wulandari, V. A. (2019). Analisis Kesulitan Belajar Kimia Materi Hidrokarbon (Study Kasus SMA Negeri di Semarang). *EDUSAINTEK*, 3. <https://doi.org/10.30862/accej.v2i1.74>

Lestari, C., Hakim, A., & Savalas, L. R. T. (2024). Identifikasi Kesulitan Belajar Siswa pada Pelajaran Kimia Kelas XI MIPA di MAN 2 Mataram. *Chemistry Education Practice*, 7(2), 350-357. unram.ac.id

Pepteti, S., & Latisma, D. J. (2022). Deskripsi Kesulitan Belajar Siswa Kelas XI MIPA SMAN 2 Solok Selatan Pada Materi Hidrolisis Garam. *Jurnal Pendidikan Mipa*, 12(3), 402-409. <https://doi.org/10.37630/jpm.v12i3.629>

Prayunisa, F. (2022). Analisa Kesulitan Siswa Kelas XI Dalam Pembelajaran Kimia di SMAN 1 Masbagik. *Journal of Classroom Action Research*, 4(3), 147-150. unram.ac.id

Prayunisa, F., & Mahariyanti, E. (2022). Analisa Kesulitan Siswa SMA Kelas X dalam Pembelajaran Kimia pada Pendekatan Contextual Teaching And Learning Berbasis Two Tier Multiple Choice Instrument. *Jurnal Ilmiah Global Education*, 3(1), 24-30. <https://doi.org/10.55681/jige.v3i1.167>

Sibarani, M., & Sidauruk, S. (2019). Kesulitan Siswa Kelas XI IPA SMA Negeri Palangka Raya Tahun Ajaran 2018/2019 dalam Memahami Konsep Pengaruh Penambahan Ion Senama Terhadap Kelarutan. *Jurnal Ilmiah Kanderang Tingang*, 10(2), 201-214. <https://doi.org/10.37304/jikt.v10i2.33>

Sidauruk, S., Abudarin, A., & Hayati, S. Kesulitan Siswa Memahami Pereaksi Pembatas di SMA Kabupaten Barito Utara dan Kota Palangka Raya Tahun Pelajaran 2015/2016. *Jurnal Ilmiah Kanderang Tingang*, 9(2), 114-132. <https://doi.org/10.37304/jikt.v9i2.11>

- Susanti, S., Dongoran, F. R., Sibuea, P. A., & Aulia, S. (2025). Tingkat Kesulitan Konseptual dan Praktis dalam Pembelajaran Kimia: Studi Di SMA Negeri 6 Medan. *Sindoro: Cendikia Pendidikan*, 16(2), 11-20. <https://doi.org/10.99534/c2b87t40>
- Utami, S. N. N., Melati, H. A., & Somantri, E. B. (2021). Identifikasi Kesulitan Belajar Siswa Kelas XI IPA dalam Menyelesaikan Soal-Soal Larutan Asam dan Basa di Sekolah Menengah Atas Negeri 2 Sungai Raya. *Eksistensi*, 3(1). <https://doi.org/10.29406/eksis.v3i1.3344>
- Zakiah, Z., Ibnu, S., & Subandi, S. (2018). Analisis Dampak Kesulitan Siswa pada Materi Stoikiometri Terhadap Hasil Belajar Termokimia dan Upaya Mengurangnya dengan Metode Pemecahan Masalah. *EduChemia: Jurnal Kimia dan Pendidikan*, 3(1), 119-134. <http://dx.doi.org/10.30870/educhemia.v3i1.1784>