

Unmasking Misconceptions: An Integrated Framework of Socratic Questioning and Alternative Assessment in Chemistry Education

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Abstract: Conventional chemistry assessments often emphasise factual recall over conceptual understanding, allowing misconceptions to persist undiagnosed and unaddressed. This study investigated the effectiveness of an integrated approach combining Socratic questioning with alternative assessments to reveal and address student misconceptions in chemistry. A single-group quasi-experimental design was implemented with 43 Malaysian Form Four students on the topics of acids, bases, and salts. The approach included a two-tiered multiple-choice diagnostic test, concept mapping, and semi-structured interviews with the participants. The results revealed that while post-test scores showed improvement, alternative assessments provided a more comprehensive picture of student understanding. Two-tiered items distinguished between valid reasoning and correct answers based on flawed logic. Concept maps exposed persistent, flawed knowledge structures, such as linking 'salt' directly to 'neutral.' The interviews revealed the origins of these misconceptions, including the tendency to conflate 'strong' with 'concentrated' based on everyday experiences. The study demonstrates that these alternative assessment tools complement each other in providing a holistic diagnosis of students' understanding, revealing specific misconceptions that remain hidden in conventional scoring. The combined tools offer a complex view of student

cognition that is unattainable through standard testing. A practical conceptual framework is proposed to help educators integrate Socratic dialogue with diagnostic assessment, shifting from assessment of learning to assessment for learning.

Keywords: *Alternative Assessment, Concept Map, Conceptual Understanding, Misconceptions, Two-Tiered Test.*

1. INTRODUCTION

Science education emphasises cultivating deep conceptual understanding rather than mere rote memorisation, to nurture critical thinking and the capacity to apply knowledge in practical contexts. Nevertheless, this objective remains challenging to achieve in numerous chemistry classrooms, where traditional teaching and assessment methods often inadvertently hinder progress. A predominant focus on factual recall and algorithmic problem-solving can lead students to possess a tenuous, superficial understanding of abstract topics, making them vulnerable to forming robust alternative conceptions or misconceptions. This issue is particularly evident in acid-base chemistry, a fundamental topic that is beset by well-documented student misunderstandings. Common misconceptions include the persistent beliefs that all salts are neutral or that the terms “strong” and “concentrated” are interchangeable when describing acids (Cyril, 2017; Taber, 2018). Such misconceptions are not only challenging to rectify but also actively obstruct the development of sound scientific conceptual frameworks.

Exacerbating this problem is the inherent limitation of traditional assessments. Conventional tests, which predominantly use single-answer multiple-choice items, often fail to delve into students’ reasoning (Sands, 2014). They can create an “illusion of understanding” by rewarding fortunate guesses or the application of flawed rules, leaving underlying misconceptions undiagnosed and unaddressed. To address this gap, this study proposes and examines an integrated framework that combines diagnostic assessment with targeted pedagogy. We propose that a multifaceted approach utilising alternative assessments—specifically, two-tiered diagnostic tests, concept maps, and semi-structured interviews—can reveal the specific nature and extent of hidden misconceptions among students.

Furthermore, we contend that Socratic Questioning is a uniquely appropriate pedagogical strategy to pair with diagnostic data, as its probing, inquiry-based nature is designed to challenge flawed reasoning and facilitate conceptual change. This study was guided by the following research questions to explore the efficacy of the integrated framework: What specific misconceptions regarding acids, bases, and salts are revealed through two-tiered tests, concept maps, and interviews that remain hidden in conventional scoring? How do these alternative assessment tools complement each other in providing a holistic diagnosis of students' understanding? How can Socratic questioning be effectively paired with these assessments to promote conceptual changes?

2. LITERATURE REVIEW

2.1 THE CENTRALITY AND CHALLENGE OF CONCEPTUAL UNDERSTANDING IN SCIENCE EDUCATION

Deep conceptual understanding is the cornerstone of scientific literacy, moving beyond rote memorisation to grasping core principles and their interrelationships (Hiebert & Lefevre, 1987). This understanding is particularly critical in chemistry, a subject characterised by abstract concepts that require students to integrate macroscopic, submicroscopic, and symbolic levels of thought (Taber, 2013; Perna & Wiedmer, 2019). The constructivist view of learning posits that students actively construct knowledge; however, this process is vulnerable to the development of robust and persistent alternative conceptions or misconceptions (Naeem Sarwar et al., 2024). These misconceptions are not mere factual errors but are often coherent, internally logical frameworks that differ from scientifically accepted models, ranging from simple misunderstandings to outright rejection of theory (Suprpto, 2020). Their resilience poses a significant challenge to meaningful learning in science education.

2.2 THE PERSISTENT PROBLEM OF MISCONCEPTIONS IN ACID-BASE CHEMISTRY

The topic of “Acids, Bases, and Salts” serves as a prime example of a domain in which misconceptions are particularly prevalent and well documented in both local and international contexts (Cyril, 2017; Chu & Hong, 2010). Research has consistently identified several key conceptual clusters within this topic that are prone to misunderstandings.

Macroscopic Properties: Students often hold erroneous beliefs about the observable properties of acids and bases, such as overgeneralizing the corrosiveness of all acids while underestimating the hazards of bases or misunderstanding the role of indicators (Elham et al., 2019).

Acid Strength: This is one of the most confusing concepts. Students frequently equate “strong acid” with “concentrated acid,” and incorrectly use pH as a direct measure of strength, confusing the concepts of strength (degree of ionisation) and concentration (amount of solute per volume) (Cyril, 2017; Susilaningsih et al., 2019).

Neutralisation: Despite its seemingly straightforward nature, students exhibit deep-seated misconceptions, such as the belief that “all salts are neutral,” that the resulting solution contains no H^+ or OH^- ions, or that only strong acids and bases can undergo neutralisation (Ivanoska & Stojanovska, 2021; Cyril, 2017).

Acid-Base Equilibrium: The abstract nature of equilibrium leads to misunderstandings, including the idea that the acidity constant is unaffected by temperature and that salts contain no hydrogen or hydroxyl ions (Cyril, 2017). A weak foundational understanding at this level can hinder the comprehension of advanced topics (Liliasari et al., 2018).

2.3 THE DIAGNOSTIC BLIND SPOT OF TRADITIONAL ASSESSMENT

Conventional assessment methods, such as standard multiple-choice tests, are often insufficient for diagnosing complex, layered misconceptions. They primarily assess factual recall and algorithmic problem-solving, creating an “illusion of understanding” (Caleon & Subramaniam, 2010; Fikri et al., 2022). Students may select the correct answer by guessing or using a flawed heuristic, even though their underlying reasoning is incorrect. This fundamental limitation underscores the need for assessment tools that can probe beneath the surface of a final answer to reveal the cognitive structures and justifications that define true conceptual understanding.

2.4 ALTERNATIVE ASSESSMENTS: A TRIANGULATED APPROACH TO DIAGNOSIS

To address the shortcomings of traditional tests, educators have turned to alternative assessments that provide a richer and more holistic diagnosis of student thinking.

Two-Tiered Diagnostic Tests: These instruments combine a multiple-choice question (first tier) with justification for that choice (second tier). This design is highly effective for identifying misconceptions because it requires students to reveal their reasoning and distinguish between factual luck and genuine understanding (Gurel et al., 2015). Their efficacy in uncovering hidden misconceptions has been demonstrated across various science subjects, including biology and chemistry (Taşçı, 2024; Ariyani & Rusilowati, 2023).

Concept Maps: As visual representations of knowledge structures, concept maps allow students to externalise the connections they perceive between concepts. They assess prior knowledge, the ability to link ideas, and the hierarchical organisation of knowledge, revealing gaps and erroneous links that written tests may miss (Schroeder et al., 2022; Novak & Gowin, 1984). Their utility in uncovering both scientific and alternative concepts in STEM education is well established (Wang, 2025).

Semi-Structured Interviews: Serving as a “gold standard” for qualitative diagnosis, interviews allow researchers to probe deeply into a student’s knowledge, experiences, and attitudes (Alshenqeeti, 2014). They provide the “why” behind the answers given in tests and concept maps, offering nuanced insights into the origin and nature of misconceptions that other tools can only hint at (Ariyani & Widiyatmoko, 2015; Kristianti et al., 2022).

These tools are complementary to each other. Two-tiered tests efficiently screen for misconceptions across a cohort; concept maps visualise the structure of knowledge; and interviews explore the depth of knowledge. Using these methods in tandem enables triangulation, providing a robust, multifaceted diagnosis that is far more comprehensive than any single method.

2.5 FROM DIAGNOSIS TO CHANGE: SOCRATIC QUESTIONING AS A PEDAGOGICAL ENGINE

Identifying misconceptions is the first step, and the pedagogical challenge is to promote conceptual change. Posner’s Conceptual Change Theory suggests that for a misconception to be replaced, learners must be dissatisfied with their existing conception, and the new concept must be intelligible, plausible, and fruitful (Amin et al., 2014). Socratic Questioning (SQ) is a powerful pedagogical strategy directly aligned with this goal.

SQ is a disciplined, inquiry-based dialogue that probes the meaning, justification, and logical strength of students’ claims (Oyler & Romanelli, 2014). It is not merely a method of questioning but a way to guide students to reflect on their own thinking. By exposing contradictions in their reasoning, SQ induces the dissatisfaction necessary for conceptual change. It then scaffolds the process of making new concepts intelligible and plausible by guiding students to construct their own understandings. Studies have shown that SQ fosters critical thinking and creates an inquiry-focused classroom environment (Duran & Dokme, 2016), and its structured application has been effective in improving cognitive outcomes in other fields (Clark & Egan, 2018).

2.6 SYNTHESISING THE FRAMEWORK AND IDENTIFYING THE GAP

The literature reveals a clear pathway: acid–base chemistry is plagued by persistent misconceptions that are often invisible to traditional assessments. A triad of alternative assessments, including two-tiered tests, concept maps, and interviews, can effectively unmask these hidden misunderstandings. Furthermore, Socratic Questioning provides a theoretically sound pedagogical mechanism for disrupting misconceptions and facilitating conceptual change. However, although these elements have been studied in isolation, research on their deliberate integration into a cohesive framework is lacking. The present study seeks to fill this gap by proposing and investigating an integrated model in which alternative assessments serve as the diagnostic core for identifying misconceptions. Socratic questioning serves as a pedagogical engine for identifying and resolving them. The synergy between precise diagnosis and targeted intervention offers a promising approach to achieving deep, meaningful conceptual change in chemistry education.

3. METHODOLOGY

3.1 DESIGN AND CONTEXT

This study used a single-group, time-series quasi-experimental approach in which one intact Form 4 Chemistry class served as its own comparison over time. The design was chosen because of access constraints that prevented a parallel control group and because it allows multiple observations before and after the instructional intervention (Socratic Questioning, SQ) during the Acids, Bases, and Salts (ABS) unit in the Malaysian KSSM curriculum.

3.2 PARTICIPANTS

The sample comprised $N = 43$ Form 4 students (16 male, 27 female) enrolled in Chemistry and present during the intervention. Participation was voluntary and aligned with standard school protocols.

3.3 INSTRUMENTS

Three classroom-compatible tools were used for assessment and data collection.

Diagnostic Tests: The study used a two-part assessment to evaluate students' comprehension of acid-base chemistry and identify misconceptions. A pre-test of eight true/false questions, derived from a previous assessment (Elham et al., 2019), gauged students' prior knowledge. Subsequently, a post-test with 18 questions, including 10 multiple-choice and eight two-part questions, was conducted, based on another assessment (Damanhuri et al., 2016). The two-part questions were significant as they required students to select an answer and provide a rationale, helping identify misconceptions that conventional scoring might miss. To ensure validity and reliability, the tests were reviewed by experts. The head of the chemistry panel verified that the questions aligned with the curriculum and measured the intended constructs. A pilot study with a comparable class identified ambiguous questions, assessed test duration, and performed preliminary analysis. This process ensured test clarity and reliability in practical settings. Although the differing content of pre- and post-tests posed challenges for reliability checks, adapting the tests from validated tests and a pilot study made them reliable for collecting meaningful data.

Concept maps: Concept mapping was employed as a methodological tool to understand students' cognitive processes by providing a visual representation of their thinking. Two mapping sessions were conducted—before and after instruction—to assess changes in students' knowledge of acids, bases, and salts. Students were given key concepts and asked to construct diagrams illustrating the interconnections among them. The concept maps were evaluated using Markham et al.'s (1994) framework. Maps were first categorised as valid or invalid based on task alignment. Valid maps were then assessed for complexity, receiving low, medium, or high scores based on the accuracy of concepts and organisation, including coherent structure and meaningful linkages. The framework evaluated conceptual accuracy, helping identify correct and incorrect understandings in students' thinking.

Semi-structured interviews: Interviews were conducted after tests and concept mapping sessions to understand student thinking. Six students were selected to represent low, medium, and high levels of understanding. This helped compare how students at different levels faced challenges and showed

strengths. The interviews focused on three areas: understanding why students gave certain test answers beyond mere correctness; examining how students interpreted terms such as “strong,” “neutral,” and “concentration” to identify misunderstandings; and having students explain the changes they made to their concept maps. This approach revealed how students built knowledge and where they succeeded or struggled in learning.

3.4 PROCEDURE

The sequence was as follows: conventional ABS instruction → pre-test + pre-concept map → instruction with SQ embedded across ABS lessons → post-test + post-concept map → semi-structured interviews with selected students. The SQ was used continuously in lessons to elicit assumptions, probe mechanisms (e.g., ionization, hydrolysis), and contrast everyday and scientific meanings (e.g., strong/weak vs concentrated/dilute).

3.5 DATA ANALYSIS

Data analysis emphasised straightforward summaries suited to the classroom research. Diagnostic test data were analysed using descriptive statistics (e.g., mean, median, range) and concept-level percentages correct to show changes from pre- to post-instruction. Item-level patterns in the two-tier portion were noted to indicate where justifications aligned or conflicted with scientific reasoning. Concept maps and interview data were analysed using thematic analysis, focusing on the presence or absence of key conceptual links (e.g., relationships among strong/weak, ionisation, pH, concentration; neutralisation, and salt hydrolysis) and students’ explanations of their choices. Themes from the maps and interviews were read alongside the test patterns to provide a coherent picture of students’ conceptual understanding and misconceptions following the SQ-supported unit.

4. FINDINGS

This study employed an integrated framework of Socratic questioning and alternative assessment to diagnose and address Form 4 students’ misconceptions of acid-base chemistry. The findings are presented according to three research questions, synthesising data from diagnostic tests, concept mapping, and interviews.

4.1 SPECIFIC MISCONCEPTIONS REVEALED BY ALTERNATIVE ASSESSMENTS

Conventional scoring of the diagnostic post-test showed an overall improvement, with average scores increasing by 79.5%. However, the two-tiered tests, concept maps, and semi-structured interviews revealed persistent misconceptions that simple multiple-choice scoring would have concealed. The triangulation of these data sources was critical to moving beyond superficial performance metrics and uncovering the robust, often hidden architecture of student misunderstandings. These misconceptions were predominantly clustered in four key conceptual areas:

Neutralisation: This was the most prevalent and deeply held misunderstanding. Interviews revealed a tenacious belief that “all salts are neutral,” often justified by daily experiences with table salt. Students also held the alternative conception that at the end of a neutralisation reaction, the solution is “empty,” containing neither H^+ nor OH^- ions.

Acid Strength: A significant conflation of concepts was observed. Students consistently equated “strong acid” with “concentrated acid.” Furthermore, the two-tiered test and interviews showed that many students used pH as the sole indicator of acid strength, misunderstanding the distinction between strength and concentration.

Macroscopic Properties: Although the surface-level understanding was good, deeper probing uncovered erroneous ideas. Some students believed that the mere presence of a hydrogen atom in a molecular formula (e.g., CH_4) implied acidity. Concept maps and interviews also showed a tendency to underestimate the corrosivity of bases, perceiving them as inherently less harmful than acids.

Acid-Base Equilibrium: This was the least frequently reported area of misconception, but interviews revealed critical gaps, such as the belief that the pH of pure water remains constant, regardless of temperature.

A compelling example of the power of triangulation is found in the data on macroscopic properties. While 95.3% of students correctly identified that soaps contain alkalis (post-test B7), the two-tiered reasoning revealed that 34.9% justified this with misconceptions like “Alkalis are soapy and so can wash away

stains.” This critical discrepancy between a factually correct answer and an incorrect underlying rationale, visible only through a two-tiered instrument, demonstrates that conventional assessments can significantly overestimate conceptual mastery. Subsequent interviews confirmed that these vernacular associations (“soapy” = “alkali”) were deeply ingrained, highlighting the qualitative value of interviews in explaining the quantitative patterns found in the tests.

4.2 COMPLEMENTARY ROLE OF ALTERNATIVE ASSESSMENT TOOLS

The three alternative assessment instruments functioned synergistically to provide a holistic diagnosis that no single tool could achieve. This multifaceted approach effectively triangulated the data, building a robust evidence base in which the strengths of one instrument compensated for the limitations of the others. To surface misconceptions masked by conventional scoring, we aligned the evidence across tools, as summarised in Table 1.

| Target Misconception | Two-Tier Evidence | Concept Map Evidence | Interview Evidence | Summary Inference |
|-------------------------------|--|---|--|--|
| Strength vs. Concentration/pH | B4 justifications assign partial ionisation to strong acids; pH is treated as a direct proxy for "strength." | Missing/incorrect links among strong/weak-ionisation-pH-concentration. | Language conflation of terms; limited prior foundation. | Conceptual conflation persists under totals; it requires ionization-centred SQ + map revision. |
| Neutralisation → Neutral Salt | Justifications assume neutrality irrespective of the parent acids/ bases. | One-step chains lacking parent strength/ hydrolysis nodes. | The generalisation "All salts are neutral" is based on daily experience. | The hidden schema explains the errors; SQ should force conditional predictions and hydrolysis mapping. |
| Heuristic Cleaning | B7 favours "soapy/alkali cleans" or "corrosive/acid cleans." | Mechanism nodes (e.g., saponification) are absent or unlinked to the substance class. | Home experiences narratives dominate the scientific mechanism. | Experience-first reasoning overrides mechanism; SQ to elicit evidence and counterexamples. |
| Composition-as-Definition | B5: "Any H compound is an acid." | Sparse/absent node for ionisation vs. composition. | Definition learned by keyword cues (e.g., presence of 'H'). | Requires explicit SQ separating composition from behaviour + exemplars/ non-exemplars. |

Table 1. Triangulation of Evidence from Alternative Assessments to Unmask Hidden Misconceptions

The key takeaway here is that different tools found the same hidden thinking patterns that regular tests missed. For example, a student might say “soap is basic” on a regular test. However, a two-part test showed they thought “soapy = alkali.” A concept map showed they did not connect this to how cleaning works. An interview showed this idea came from everyday life, not science. This detailed analysis helps teachers know where to focus their questions to fix misunderstandings. It helps students truly understand, not just give the right answers.

4.3 SOCRATIC QUESTIONING AS A CATALYST FOR CONCEPTUAL CHANGE

The integration of Socratic questioning proved effective in facilitating conceptual change, serving as both a pedagogical intervention and a metacognitive scaffold within assessment. The study design enabled clear triangulation of outcomes, showing that Socratic questioning directly addressed misconceptions identified by diagnostic instruments. Quantitative and qualitative data corroborated their positive impact. Improved test scores and increased complexity of concept maps evidenced their effect on cognitive gains. Survey results (mean > 3.0 across all domains) and interviews indicated that Socratic questioning enhanced critical thinking and engagement. Students reported that it “challenges you to think critically instead of just getting the answers straight away” and motivated them to prepare more thoroughly for class. The mechanism for conceptual change was evident in how Socratic questioning established a feedback loop with assessments. The probing questions directly mirrored the diagnostic process of two-tier tests and interviews, training students to question their assumptions and justify reasoning.

This study claims that Socratic questioning cultivates metacognitive skills necessary for students to self-diagnose misunderstandings. During lessons, students deconstructed their alternative frameworks. This created an environment where identifying misconceptions became the starting point for Socratic dialogue aimed at reconstructing scientifically sound concepts. In conclusion, triangulated data present a compelling case for this framework. The alternative assessments provided a “map” of misconceptions, while Socratic questioning served as the “engine” for conceptual journeying, guiding students from initial alternative conceptions toward scientifically valid understanding. This cycle of diagnosis and inquiry empowers students to become agents of conceptual change.

5. DISCUSSION

5.1 EFFICACY OF SOCRATIC QUESTIONING

The study demonstrated that Socratic questioning is a highly effective method for enhancing students' conceptual understanding, particularly in domains that require deeper conceptual reasoning, such as neutralisation, acid strength, and acid-base equilibrium. Socratic questioning prompts students to engage in critical thinking, formulate explanations, and justify their reasoning, thereby fostering deeper, more scientifically accurate comprehension.

Although some misconceptions regarding macroscopic properties, acid strength, neutralisation, and acid-base equilibrium persisted even after the Socratic Questioning intervention, notable improvements were observed in the students' capacity to construct new knowledge and conceptual understanding. Students reported positive outcomes, including enhanced critical thinking skills and improved comprehension, acknowledging that Socratic questioning challenged them to think more deeply rather than passively receiving answers (Amdan, 2025). By encouraging justified and analytical conclusions, this approach directly supports the objective of eliciting thorough explanations and justifications, thereby fostering conceptual growth among preservice teachers.

5.2 STRUCTURE OF KNOWLEDGE

Enhancements in the structure of knowledge, as evidenced by changes in concept maps, suggest improved organisation and interconnections, which are essential for sustained comprehension. Post-intervention analysis of the concept maps revealed a significantly positive trend. The percentage of invalid concept maps decreased by 63.6% (from 11 to 4) following the intervention. The number of valid concept maps increased by 21.9% (from 32 to 39). High-score concept maps (with scores of 20) showed an impressive 87.5% increase (from 8 to 15). A detailed comparison of students' concept maps from pre- to post-intervention illustrated this shift in understanding (ibid., 2025). Initially, Student X constructed a simple and direct concept map with limited branching and no clear hierarchy. After the intervention, the students' concept maps became significantly more complex and densely populated, displaying more branching and a clearer hierarchy of concepts. This transformation signifies deeper understanding and improved acquisition and retention of

new knowledge, demonstrating that Socratic Questioning helps students construct a robust conceptual understanding and a strong foundation of baseline knowledge. Concept maps effectively assess students' prior knowledge, their ability to link concepts, and how they organise information, thereby revealing gaps and enhancing their conceptual understanding.

5.3 PERSISTENT PITFALLS

Despite the overall positive impact of Socratic Questioning, the concept of acid strength consistently presents a persistent pitfall for students. Students frequently conflated pH, concentration, and strength, indicating a fundamental misunderstanding. For example, students often expressed beliefs such as, "I think pH indicates if acid is strong" and "strong acid is a concentrated acid". These results clearly illustrate the confusion between distinct chemical properties. Every day, heuristics and vocabulary exacerbate this challenge. The vernacular barrier, where words like 'strength', 'concentrated', and 'diluted' are often used synonymously in daily language, directly influences students' scientific understanding and contributes to these misconceptions. Without guided interrogation, these everyday associations can mislead students, making it difficult for them to grasp the precise scientific definitions and relationships between pH, concentration, and acid strength. The interviews conducted in this study identified acid strength as a concept that students retained a high level of misconception about.

6. IMPLICATIONS AND RECOMMENDATIONS

The significant implications and recommendations of the findings of this study are as follows:

6.1 IMPLICATIONS FOR CLASSROOM TEACHERS

This study demonstrates that conceptual understanding is multifaceted and cannot be gauged using conventional tests alone. Therefore, teachers must adopt a diagnostic mindset and use a toolkit of strategies to uncover and address the root causes of student misunderstandings. Table 2 summarises the key recommendations for direct classroom applications, followed by a detailed rationale for each.

| Misconception Focus | Socratic Questioning (SQ) Prompt Example | Complementary Classroom Activity |
|-----------------------------------|--|---|
| Neutralisation & Salt pH | "Will the salt from a strong acid and a weak base be acidic, basic, or neutral? Justify based on the ions present." | Use pH probes to test solutions of different salts (e.g., NH_4Cl , CH_3COONa , NaCl) and map results against parent acid/base strength. |
| Acid Strength vs. Concentration | "How can a 0.1 M HCl solution be more acidic than a 2.0 M CH_3COOH solution? Explain at the particle level." | Use particle diagrams to contrast the ion concentration in a strong-dilute acid versus a weak-concentrated one. |
| Vernacular Traps (e.g., 'Strong') | "What does 'strong' mean in everyday language? How does its scientific meaning in chemistry differ?" | Co-construct a "Concept Contrast Wall" or glossary explicitly comparing terms like Strong/Weak (ionisation) vs. Concentrated/Dilute (amount). |
| Making Thinking Visible | "Based on our discussion, how would you now revise the connections in your initial concept map?" | Implement 5-minute concept map tasks at the start and end of a lesson to externalise and track changes in conceptual links. |

Table 1. Triangulation of Evidence from Alternative Assessments to Unmask Hidden Misconceptions

Methodological Rationale: Implementing Targeted Socratic Questioning
The SQ prompts in Table 2 were designed to move beyond factual recall and probe reasoning. For instance, the question of salt pH forces students to apply the concept of hydrolysis, which is often the missing link in understanding why neutralisation does not always produce a neutral solution. Active cognitive engagement is crucial for disrupting flawed mental models.

Theoretical Rationale: Scaffolding Language and Formative Assessment.
Complementary activities are grounded in constructivist and language-aware pedagogy. The "Concept Contrast Wall" directly addresses the theoretical implication that vernacular meanings interfere with the formation of scientific concepts. Similarly, using quick concept maps as formative assessment tools aligns with the methodological implication that thinking must be externalised for assessment and refinement. Providing sentence stems (e.g., "I know it is a strong acid because it _____ completely in water...") scaffolds the language that all students need to articulate complex chemical reasoning.

6.2 IMPLICATIONS FOR DEPARTMENTS AND TEACHER EDUCATORS

The effective implementation of Socratic Questioning (SQ) and alternative assessment requires systemic support beyond individual teachers. School departments and teacher education programs must build capacity by moving beyond workshops to foster sustained, collaborative, skills-based professional learning focused on pedagogical techniques and assessment literacy.

Micro-skills Professional Development: Replace theoretical sessions with practical training focused on SQ implementation. This includes practising question stems, maintaining productive wait time, and—through video clubs or peer observation—developing the skill to use student responses to probe rather than lead to predetermined answers.

Cultivating a Diagnostic Assessment Culture: Shift from solely summative assessment to an integrated diagnostic approach. Teachers can collaboratively design and analyse students' responses to two-tier questions to identify patterns of misconceptions. It is critical to legitimise qualitative data from concept maps and student interviews as evidence of understanding, granting them equal status to quantitative test scores.

These concerted efforts help institutions create an environment where teachers receive continuous support in developing skills to diagnose and address student misunderstandings.

6.3 IMPLICATIONS FOR CURRICULUM AND NATIONAL ASSESSMENT

To maximise engagement without reinforcing flawed intuitive reasoning, curriculum and assessment design must adopt a more critical approach to real-world context. While using familiar examples such as soaps, detergents, and soil pH is highly engaging, it is pedagogically insufficient if it does not actively confront the heuristic assumptions these contexts can trigger. Theoretically, this necessitates a curriculum that deliberately pairs these contexts with data and counterexamples; for instance, following a lesson on neutralisation with an investigation into the pH of various salt solutions to challenge the assumption that all salts are neutral. Methodologically, this principle must be extended to high-stakes assessments. By innovating examination design to include items that probe reasoning and justification, signalling that conceptual understanding is valued over rote recall, educational systems can create a powerful feedback loop that incentivises teachers to employ these deeper, more critical teaching practices throughout the academic year.

7. CONCLUSION

This study demonstrates the profound efficacy of an integrated framework that strategically pairs alternative diagnostic assessments with the pedagogical power of the Socratic method. Moving beyond the limitations of conventional testing, the triangulation of two-tiered tests, concept maps, and interviews provided a distinct yet holistic map of student cognition, unmasking specific and persistent misconceptions in acid-base chemistry that would otherwise remain hidden. In addition to being a diagnostic tool, this multifaceted approach serves as a vital precursor to targeted interventions. The findings affirm that Socratic questioning, when informed by rich diagnostic data, acts as a powerful engine for conceptual change, actively engaging students in critical reflection and the reconstruction of their knowledge. The implications are significant for science educators, suggesting a necessary shift towards classroom practices that are not only inquiry-based but also diagnostically driven. Future research should explore the scalability of this framework across diverse educational contexts and its longitudinal impact on the retention and application of scientific concepts. Ultimately, this research underscores that the path to robust scientific literacy requires both a precise compass to diagnose misunderstandings and deliberate pedagogy to guide students toward more accurate and enduring understanding.

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10. AUTHOR'S CONTRIBUTION

Author1 supervised the entire study, wrote the write-up, and finalised the article. Author2 carried out the field work, prepared the literature review, and carried out the analysis as well as the interpretation of results.

11. CONFLICT OF INTEREST DECLARATION

We certify that the article is the author's and co-authors' original work. The article has not received prior publication and is not under consideration for publication elsewhere. This research/manuscript has not been submitted for publication, nor has it been published in whole or in part elsewhere. We attest that all authors have contributed significantly to the work, the validity and legitimacy of the data, and its interpretation for submission to IJELHE.

12. REFERENCES

- Alshenqeeti, H. (2014). Interviewing as a data collection method: A critical review. English Linguistics Research, 3(1), 39–45. <https://doi.org/10.5430/elr.v3n1p39>*
- Amdan, A.I. (2025). The Effects of Socratic Questioning on Form 4 Students' Conceptual Understanding of Acid, Base & Salt. Unpublished Academic Exercise. Faculty of Education: Universiti Teknologi MARA Malaysia.*
- Amin, T. G., Smith, C. L., & Wiser, M. (2014). Student Conceptions and Conceptual Change. Three overlapping phases of research were identified. In N. G. Lederman & S. K. Abell (Eds.), Handbook of research on science education. 2. 57–81. Routledge: London*
- Ariyani, A., & Rusilowati, A. (2023). Identification and remediation of misconceptions on thermodynamics law for students with interactive demonstrations. AIP Conference Proceedings, 2614(1). <https://doi.org/10.1063/5.0125922>*

- Caleon, I. S. & Subramaniam, R. (2010). *Development and application of a three-tier diagnostic test to assess secondary students' understanding of waves*. *International Journal of Science Education*, 32(7), 939–961. <https://doi.org/10.1080/09500690902890130>
- Chang, C. Y., Yeh, T. K., & Barufaldi, J. P. (2010). *The positive and negative effects of science concept tests on student conceptual understanding*. *International Journal of Science Education*, 32(2), 265–282. <https://doi.org/10.1080/09500690802650055>
- Chu, C. K. & Hong, K. Y., (2010). *Misconceptions In The Teaching Of Chemistry In Secondary Schools In Singapore & Malaysia*, CORE, Retrieved from https://core.ac.uk/display/148366362?utm_source=pdf&utm_medium=banner&utm_campaign=pdf-decoration-v1
- Clark, G. I., & Egan, S. J. (2018). *Clarifying the role of the Socratic method in CBT: a survey of expert opinion*. *International Journal of Cognitive Therapy*, 11(2), 184–199. <http://doi.org/10.1007/s41811-018-0016-y>
- Cyril, N. (2017). *Students' Alternative Conceptions in Acid-Base Chemistry*, ResearchGate, Retrieved from https://www.researchgate.net/publication/345544285_Students'_misconception_in_acid_base_chemistry
- Damanhuri, M. I. M., Treagust, D. F., Won, M., & Chandrasegaran, A. L. (2016). *High school students' understanding of acid-base concepts: an ongoing challenge for teachers*. *International Journal of Environmental and Science Education*, 11(1), 9–27. <https://doi.org/10.12973/ijese.2015.284a>
- Duran, M., & Dökmé, İ. (2016). *The effect of the inquiry-based learning approach on students' critical-thinking skills*. *Eurasia Journal of Mathematics, Science and Technology Education*, 12(12), 2887–2908. <https://doi.org/10.12973/eurasia.2016.02311a>
- Elham, H., Dilmaghani, K.A. & Hesar, A.P. (2019). *Students' Misconceptions on Acid-Base Chemistry*, *Iraqi Academic Scientific Journal*, Retrieved from <https://www.iasj.net/iasj/pdf/e6db28acaf8f8ec8>

- Femintasari, V., Effendy, E., & Munzil, M. (2015). *The effectiveness of a two-tier multiple-choice test and a multiple-choice test followed by an interview in identifying misconceptions of students with different scientific reasoning skills in reaction rate. Jurnal Ilmu Pendidikan Universitas Negeri Malang*, 21(2), 107151.
- Fikri, R. A., Suwono, H., & Susilo, H. (2022). *Online three-tier diagnostic test to identify misconception about virus and COVID-19. JPBI (Jurnal Pendidikan Biologi Indonesia)*, 8(2), 129-141. <https://doi.org/10.22219/jpbi.v8i2.18895>
- Gurel, D. K., Eryilmaz, A., & McDermott, L. C. (2015). *A review and comparison of diagnostic instruments to identify students' misconceptions in science. Eurasia Journal of Mathematics, Science and Technology Education*, 11(5), 989–1008. <https://doi.org/10.12973/eurasia.2015.1369a>
- Handley, M. A., Lyles, C. R., McCulloch, C., & Cattamanchi, A. (2018). *Selecting and Improving Quasi-Experimental Designs in Effectiveness and Implementation Research. Annual review of public health*, 39, 5–25. <https://doi.org/10.1146/annurev-publhealth-040617-014128>
- Hiebert, J., & Lefevre, P. (1987). *Conceptual and procedural knowledge in mathematics: An introductory analysis. In J Hiebert (Ed.), Conceptual and procedural knowledge: The case of mathematics. pp. 1–28. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc*
- Inthasiri, S., Junpeng, P., Tawarungruang, C., & Intharah, T. (2023). *Designing methods to diagnose scientific misconceptions by using automated feedback through machine learning. Journal of Educational Measurement, Mahasarakham University*, 29(1), 1–20.
- Ivanoska, K. & Stojanovska, M. (2021). *Addressing and Eliminating the Misconceptions About Acid and Bases Concepts In Primary School Chemistry Teaching, Macedonian Journal of Chemistry and Chemical Engineering*, 40(2). <https://doi.org/10.20450/mjccce.2021.2413>

- Kristianti, R., Muchyidin, A., & Manfaat, B. (2022). *Exploration of Vocational School Students' Misconceptions of Circle Material*. *Journal of General Education and Humanities*, 1(2), 95–106. <https://doi.org/10.58421/gehu.v1i2.19>
- Larotonda, J. D., Alves, M. A., Freire, T. N., & Bastos, H. L. (2022). *Implementation of inquiry-based science in the classroom and its repercussions on the motivation to learn chemistry*. *Journal of Chemical Education*, 99(2), 578–591. <https://doi.org/10.1021/acs.jchemed.1c00287>
- Li, Y., & Abrahams, I. (2022). *Advancing students' scientific inquiry performance in chemistry through reading and evaluative reflection*. *Chemistry Education Research and Practice*, 23(4), 917–931. <https://doi.org/10.1039/D1RP00246E>
- Liliasari, S., Albaiti, A. & Wahtudi, A. (2018). *Calcium contained tap water phenomena: students misconception patterns of acids-bases concept*, *Journal of Physics: Conference Series*, Retrieved from <https://iopscience.iop.org/article/10.1088/1742-6596/1013/1/012095>
- Maison, M., Purwaningsih, S., Pathoni, H., Falah, H. S., Putri, K. E., Fitriani, R., & Hidayati, H. (2025). *Reduction Of Student Misconceptions Using Nearpod Interactive Learning Platform Based On Posner's Conceptual Change Theory*. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, 9(2), 709–720. <https://doi.org/10.22437/jiituj.v9i2.41932>
- Markham, K. M., Mintzes, J. J., & Jones, M. G. (1994). *The concept map as a research and evaluation tool: Further evidence of validity*. *Journal of Research in Science Teaching*, 31(1), 91–101. <https://doi.org/10.1002/tea.3660310109>.
- Naeem Sarwar, M., Ullah, Z., Shrahili, M., Raza, S., Elbatal, I., Qaisar, S., Shahzad, A., Faizan Nazar, M., Kulsoom, S., & Wasti, S. H. (2024). *Concept mapping and conceptual change texts: a constructivist approach to address the misconceptions in nanoscale science and technology*. *Frontiers in Education*, 9. <https://doi.org/10.3389/feduc.2024.1339957>

Novak, J. D., & Gowin, D. B. (1984). *Learning How to Learn*. Cambridge University Press

Oyler, D.R. & Romanelli, F. (2014). *The Fact of Ignorance Revisiting the Socratic Method as a Tool for Teaching Critical Thinking*, *American Journal of Pharmaceutical Education*, 78 (7), <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4174386/pdf/ajpe787144.pdf>

Paul, R., & Elder, L. (2007). *Critical Thinking: The Art of Socratic Questioning*. *Journal of Developmental Education*, 31(1), 34–37.

Perna, J., & Wiedmer, S. (2019). *A systematic review of 3D printing in chemistry education – analysis of earlier research and educational use through technological pedagogical content knowledge framework*. *Chemistry Teacher International*, 2(2). <https://doi.org/10.1515/cti-2019-0005>

Prastyo, A., Fithriyah, H., Rahmawati, A. D., & Ekawati, E. Y. (2024). *Identification of Students' Misconceptions using Four-Tier Diagnostic Assessment in Physics Learning Phase F*. *Indonesian Journal of Science and Education*, 8(1), 16–25. <https://doi.org/10.31002/IJOSE.V8I1.569>

Suprpto, N. (2020). *Do We Experience Misconceptions?: An Ontological Review of Misconceptions in Science*. *Studies in Philosophy of Science and Education*, 1(2), 50–55. <https://doi.org/10.46627/sipose.v1i2.24>

Sands, D. (2014). *Concepts and conceptual understanding: what are we talking about?*, ResearchGate, Retrieved from https://www.researchgate.net/publication/328336862_Concepts_and_conceptual_understanding_What_are_we_talking_about

Schroeder, V., Nesbit, J. C., & Winne, P. H. (2022). *How the design and complexity of concept maps influence cognitive learning processes*. *Educational Technology Research and Development*, 70(1), 215–234. <https://doi.org/10.1007/s11423-022-10083-2>

- Susilaningsih, E., Nuswowati, M., & Natasukma, M.M. (2019). Profile of misconception in particulate level of acid-basic subjects, IOPSCIENCE, Retrieved from <https://iopscience.iop.org/article/10.1088/1757-899X/830/4/042082>.*
- Taber, K. S. (2013). Revisiting the chemistry triplet: drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. Chem. Educ. Res. Pract., 14(2), 156–168. <https://doi.org/10.1039/c3rp00012e>*
- Taber, K. S. (2018). Alternative conceptions and the learning of chemistry. Israel Journal of Chemistry, 59. <https://doi.org/10.1002/ijch.201800046>*
- Taşci, G. (2024). Development of a two-tier diagnostic test to assess misconceptions about biology concepts at primary school. Science Insights Education Frontiers, 25(2). Retrieved from ERIC (EJ1456849). <https://doi.org/10.15354/sief.24.or652>*
- Wang, X.-M., Wang, J.-L., Xu, S.-Y., et al. (2025). Concept mapping in STEM education: A meta-analysis of its impact on students' achievement (2004-2023).” International Journal of STEM Education, 12(30). <https://doi.org/10.1186/s40594-025-00554-2>*