Dialogue Social Science Review (DSSR)
www.thedssr.com

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 3 No. 10 (October) (2025)

Addressing Students' Misconceptions and their Impact on Chemistry Performance: An Embedded Mixed-Methods Study at the Secondary Level

Dr. Muhammad Siddique
Research Scholar (Education), Superior University, Lahore, Pakistan
Email: siddiqueamar@gmail.com

Prof. Dr. Muhammad Sarwar
Dean and Professor of Education, Superior University, Lahore, Pakistan
Email: muhammad.sarwar@superior.edu.pk

Dr. Muhammad Arif
Assistant Professor, Education Department, Superior University, Lahore, Pakistan
Email: mu.arif@superior.edu.pk

ABSTRACT
This study investigated the effect of misconceptions on students' performance in chemistry at the secondary level, emphasizing how inaccurate conceptual frameworks hinder understanding and achievement. Guided by constructivist and conceptual change theories, the research explored the prevalence and persistence of misconceptions in core chemistry topics such as ionic, covalent, coordinate covalent, and metallic bonding, as well as the duplet and octet rules. A qualitatively driven embedded mixed-methods design was adopted within a quasi-experimental one-group pretest–posttest framework. Twenty secondary-level students from a government high school in Lahore, Pakistan, participated in the study. Data were collected through semi-structured interviews before and after a ten-session instructional intervention employing inquiry-based learning, cognitive conflict, and analogy-supported strategies. Thematic analysis was conducted on qualitative data, while frequency and intensity coding provided quantitative evidence of conceptual change. Findings revealed that students initially held deep-rooted misconceptions. Post-intervention results demonstrated significant improvement in conceptual understanding and academic performance. The study concludes that addressing misconceptions through constructivist and diagnostic approaches can enhance chemistry learning and promote conceptual clarity. Implications are discussed for curriculum developers, teacher educators, and policymakers aiming to improve science education at the secondary level.

Keywords: Misconceptions, Chemistry Education, Conceptual Change

Introduction

Chemistry, as a central branch of science, forms the foundation for students' understanding of the physical world and plays a crucial role in developing scientific reasoning and problem-solving abilities. However, research across educational contexts consistently reveals that students at the secondary level often hold persistent misconceptions about fundamental chemical concepts. These misconceptions false or incomplete mental models distort scientific understanding and reduce learners' ability to apply knowledge accurately. Misconceptions in chemistry are particularly concerning

Dialogue Social Science Review (DSSR)
www.thedssr.com

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 3 No. 10 (October) (2025)
because they not only hinder conceptual learning but also resist correction through conventional teaching methods.

In Pakistan, where science education forms a key component of secondary schooling, chemistry misconceptions contribute to students' low performance and lack of interest in the subject. Many students struggle with abstract topics such as atomic structure, bonding, and molecular behavior, which demand high levels of conceptual reasoning. Prior studies in chemistry education (Taber, 2018; Chiu, 2019) suggest that addressing misconceptions requires pedagogical innovation and constructivist approaches that engage students in conceptual change rather than rote memorization. Despite the growing emphasis on inquiry-based and active learning in the curriculum, classroom practices often remain traditional, focusing more on factual recall than on conceptual understanding.

Persistent misconceptions about electron transfer, electronegativity differences, ion formation, lattice structure, and electrical conductivity continue to impede secondary students' learning in chemistry, even after conventional instruction (Hunter & Carver, 2022; Simanjuntak et al., 2025). Diagnostic studies still reveal that many learners conflate ionic and covalent bonding or misunderstand the role of electronegativity in bond formation (Eclética Química Journal, 2024; Journal of Research in Education and Pedagogy, 2024). Although several conceptual-change and inquiry-based interventions have shown promise, there remains a research gap in embedded mixed-methods classroom studies that simultaneously track pre- and post-conceptual change across multiple, interrelated bonding concepts particularly within South Asian secondary-level contexts (van Dulmen et al., 2023). Moreover, recent simulation and computational-chemistry efforts illustrate potential gains in understanding polarity and electronegativity but seldom measure coordinated misconception reduction across bonding, ion formation, and conductivity (Holmelin et al., 2025; Hrubeš et al., 2024). Therefore, the problem addressed in this study is the persistence of interconnected misconceptions about ionic bonding among secondary students. This article implements a qualitatively driven embedded mixed-methods intervention and quantifies pre- to post-instruction changes in misconception frequency and percentage across key bonding domains, thereby providing context-specific, classroom-validated evidence of how targeted instructional strategies can promote conceptual clarity in chemistry education.

This study therefore sought to investigate the effect of misconceptions on students' performance in chemistry at the secondary level and to determine how targeted instructional strategies can promote conceptual clarity. By integrating constructivist and conceptual change theories, the research aimed to identify specific misconceptions, understand their nature, and evaluate the effectiveness of a carefully designed intervention.

Numerous studies have documented the prevalence of misconceptions in chemistry education. Students often misinterpret fundamental ideas such as valence, bonding, and molecular polarity due to the abstract and symbolic nature of the subject. According to Ausubel (1968) and Novak (2010), meaningful learning occurs when new information is anchored in existing cognitive structures; however, misconceptions act as barriers that prevent accurate knowledge construction.

Research by Taber (2002, 2018) and Chiu (2019) highlights that misconceptions in bonding such as confusing ionic and covalent bonding or misunderstanding electron sharing persist even after instruction Constructivist theorists argue that conceptual change occurs only when learners experience cognitive conflict, prompting them to re-evaluate their mental models. Similarly, Duit and Treagust (2012) stress the importance

Dialogue Social Science Review (DSSR)
www.thedssr.com

ISSN Online: 3007-3154
ISSN Print: 3007-3146

Vol. 3 No. 10 (October) (2025)

of diagnostic assessment and inquiry-based learning to detect and remediate such misconceptions.

In Pakistan, studies in science education (Iqbal & Mahmood, 2019; Rehman et al., 2021) have shown that students' difficulties in chemistry stem from limited conceptual engagement and teacher-centered instruction. The current study builds on this body of research by employing a qualitatively driven embedded mixed-methods design to explore not only the extent of misconceptions but also the process of conceptual transformation among learners.

Methodology

This research study directed the pragmatic paradigm as this is mixed-methods study. The study also adopted a qualitatively driven embedded mixed-methods design within a quasi-experimental one-group pretest–posttest framework. This approach allowed for the integration of quantitative measures of change with rich qualitative insights into students' thought processes.

A purposive sample of twenty secondary-level students was selected from a government high school in Lahore. Data were collected using semi-structured diagnostic interviews before and after a ten-session instructional intervention. The intervention was designed using inquiry-based learning, analogy-supported instruction, and cognitive conflict techniques to challenge misconceptions and promote conceptual restructuring.

The qualitative data from interviews were analyzed thematically to identify recurring patterns of misconceptions and conceptual shifts. Quantitative data, derived from frequency and intensity coding, were used to measure the reduction in misconceptions from pretest to posttest phases. Ethical approval was obtained, and participants' identities were kept confidential throughout the research process.

Data Analysis

As this is an experimental study so it composed of pre-assessment, post-assessment and comparison of pre-assessment and post-assessment phase

Pre-session Assessment

Table 1: *Misconception Regarding Transfer of Electron*

Title	Accuracy	Shared Electron	Mobile Electron	State of matter	outermost electrons
Frequency (*f*)	2	3	2	1	2
Percentage (%)	20	30	20	10	20

Table 1 presents the frequency and percentage of students' misconceptions regarding the transfer of electrons before the instructional intervention. The data show that only 2 students (20%) demonstrated an accurate understanding of the concept, while the remaining 8 students (80%) exhibited various misconceptions. The most common misconception was related to shared electrons, reported by 3 students (30%), indicating that many participants confused ionic bonding with covalent bonding, where electrons are shared rather than transferred. Another notable misconception was the mobile electron concept, mentioned by 2 students (20%), which reflects confusion between ionic and metallic bonding. Similarly, outermost electron misconceptions were identified among 2 students (20%), suggesting uncertainty about the role of valence electrons in ion formation. A smaller portion of students (10%) associated electron transfer with the state of matter, showing limited conceptual understanding.

Overall, the findings reveal that a majority of students held significant misconceptions about electron transfer in ionic bonding. These results highlight the need for conceptual clarification and targeted instructional strategies to help students differentiate between bonding types and understand the true nature of electron movement in ionic compounds.

Table 2: *Misconception Regarding Electronegativity Differences in Ionic bond*

Title	Accuracy	EN	Threshold Misunderstanding	Physical Interaction	E.N in Bond Types
Frequency (*f*)	2	3	2	2	1
Percentage (%)	20	30	20	20	10

Table 2 illustrates the frequency and percentage of students' misconceptions concerning electronegativity differences in ionic bonding before the instructional intervention. The data indicate that only 2 students (20%) demonstrated an accurate understanding of the concept, while the remaining participants showed varying degrees of misunderstanding. The most frequent misconception appeared in the E.N (Electronegativity) category, where 3 students (30%) incorrectly interpreted electronegativity as a physical property rather than a measure of an atom's tendency to attract electrons. Threshold misunderstanding was observed among 2 students (20%), indicating confusion about the degree of electronegativity difference required to classify a bond as ionic. Likewise, 2 students (20%) linked the concept to physical interaction, revealing limited understanding of the chemical nature of ionic bonds. Only 1 student (10%) incorrectly related electronegativity to different bond types, showing difficulty in distinguishing ionic, covalent, and metallic bonding based on electronegativity values.
Overall, the results reveal that a substantial proportion of students possessed misconceptions about electronegativity and its role in ionic bonding. These misconceptions suggest the need for instructional emphasis on how electronegativity differences determine bond polarity and the transfer of electrons between atoms.

Table 3: *Misconception Regarding Causes of Oppositely Charged Ions*

Title	Accuracy	Bonding Mechanisms	Lattice Structure	Physical Properties	Scientific Terminology
Frequency (*f*)	1	4	2	1	2
Percentage (%)	10	40	20	10	20

Table 3 presented the frequency and percentage of students' misconceptions regarding the causes of oppositely charged ions before the instructional intervention. The results indicate that only 1 student (10%) demonstrated an accurate understanding of the concept, whereas 9 students (90%) held various misconceptions. The most prevalent misunderstanding was observed in the bonding mechanisms category, reported by 4 students (40%), who were unable to correctly explain the process of ion formation through electron transfer. Lattice structure misconceptions were identified among 2 students (20%), suggesting confusion about how the regular arrangement of ions contributes to the stability of ionic compounds. Similarly, scientific terminology errors appeared in 2 students' (20%) responses, reflecting uncertainty in using correct chemical language to describe ionic interactions. In addition, 1 student (10%) showed misconceptions related to physical properties, indicating a limited understanding of how ionic bonding affects properties such as melting point and conductivity.
Overall, these findings highlight that most students had limited conceptual understanding of how oppositely charged ions are formed and stabilized in ionic compounds. The data

Dialogue Social Science Review (DSSR)
www.thedssr.com

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 3 No. 10 (October) (2025)

emphasize the need for explicit teaching of ionic mechanisms, correct terminology, and the structural nature of ionic bonding.

Table 4: *Misconception Regarding Electrical Conductivity in Ionic Bond*

Title	Accuracy	Ion Mobility	Conductivity to Physical Traits	Solution Conductivity	Bond Types
Frequency (*f*)	1	2	3	2	2
Percentage (%)	10	20	30	20	20

Table 4 displays the frequency and percentage of students' misconceptions related to electrical conductivity in ionic bonding prior to the instructional intervention. The data reveal that only 1 student (10%) demonstrated an accurate understanding of the concept, whereas the remaining 9 students (90%) held one or more misconceptions. The most frequent misunderstanding occurred in the conductivity to physical traits category, identified among 3 students (30%), indicating confusion between the physical appearance of ionic compounds and their ability to conduct electricity. Ion mobility misconceptions were observed in 2 students (20%), suggesting difficulty in recognizing that ions are mobile only in molten or aqueous states. Similarly, 2 students (20%) associated solution conductivity with factors unrelated to ion presence, showing a partial understanding of the role of dissociation in electrical conduction. Another 2 students (20%) exhibited confusion in the bond types category, implying a mix-up between ionic and covalent bond behaviors in relation to conductivity.
Overall, the results indicate that a majority of students were unable to correctly link ionic conductivity with ion movement and state changes. These findings underscore the importance of emphasizing experimental demonstrations and conceptual clarification in teaching the conductivity of ionic compounds.

Post-session Assessment

Table 5: *Misconception Regarding Transfer of Electron*

Title	Accuracy	Shared Electron	Mobile Electron	State of matter	outermost electrons
Frequency (*f*)	6	1	1	1	1
Percentage (%)	60	10	10	10	10

Table 5 presents the frequency and percentage of students' conceptions regarding the transfer of electrons after the instructional intervention. The data clearly show a marked improvement in conceptual understanding compared with the pre-session results. Six students (60%) demonstrated an accurate understanding of electron transfer, indicating substantial conceptual progress. Misconceptions such as shared electron, mobile electron, state of matter, and outermost electrons were each reported by only one student (10%), reflecting a significant reduction from earlier frequencies. The results suggest that the intervention effectively clarified the distinction between ionic and covalent bonding and enhanced students' comprehension of electron movement during ion formation.
Overall, the findings reveal a positive conceptual shift, with most students overcoming prior misconceptions and achieving accurate scientific understanding of electron transfer in ionic bonding.

Dialogue Social Science Review (DSSR)
www.thedssr.com

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 3 No. 10 (October) (2025)

Table 6: *Misconception Regarding Electronegativity Differences in Ionic Bond*

Title	Accuracy	EN	Threshold Misunderstanding	Physical Interaction	E.N in Bond Types
Frequency (*f*)	6	1	1	1	1
Percentage (%)	60	10	10	10	10

Table 6 illustrates the frequency and percentage of students' responses regarding electronegativity differences in ionic bonding after the instructional intervention. The data show a significant conceptual improvement compared with the pre-session findings. Six students (60%) demonstrated accurate understanding, indicating that most participants successfully grasped the relationship between electronegativity and ionic bond formation. Only one student (10%) in each of the categories E.N (Electronegativity), Threshold misunderstanding, Physical interaction, and E.N in bond types continued to exhibit partial misconceptions. These minimal frequencies reflect the effectiveness of the teaching strategies in promoting conceptual clarity.

Overall, the results confirm that the instructional intervention substantially improved students' understanding of electronegativity differences. The findings suggest that using inquiry-based and analogy-supported instruction helped learners differentiate ionic bonding from other bond types and correctly interpret the role of electronegativity in electron transfer.

Table 7: *Misconception Regarding Causes of Oppositely Charged Ions*

Title	Accuracy	Bonding Mechanisms	Lattice Structure	Physical Properties	Scientific Terminology
Frequency (*f*)	4	2	1	1	2
Percentage (%)	40	20	10	10	20

Table 7 presents the frequency and percentage of students' responses regarding the causes of oppositely charged ions after the instructional intervention. The results indicate a considerable improvement in conceptual understanding compared with the pre-session assessment. Four students (40%) demonstrated an accurate understanding of how oppositely charged ions are formed through electron transfer between metal and non-metal atoms. Misconceptions persisted among some students, particularly in the bonding mechanisms category, where 2 students (20%) continued to display partial misunderstandings about the process of ion formation. Similarly, scientific terminology errors were observed in 2 students (20%), suggesting occasional difficulty in articulating chemical concepts precisely. Misconceptions related to lattice structure and physical properties were minimal, each reported by 1 student (10%).

Overall, the findings reflect a meaningful conceptual gain, as fewer students held misconceptions and a larger proportion demonstrated accurate understanding. This improvement highlights the effectiveness of the intervention in clarifying the principles underlying ionic bond formation and the stabilization of oppositely charged ions.

Table 8: *Misconception Regarding Electrical Conductivity in Ionic bond*

Title	Accuracy	Ion Mobility	Conductivity to Physical Traits	Solution Conductivity	Bond Types
Frequency (*f*)	6	1	1	2	0
Percentage (%)	60	10	10	20	0

Table 8 shows the frequency and percentage of students' responses regarding electrical conductivity in ionic bonding after the instructional intervention. The results reveal substantial improvement in conceptual understanding compared with the pre-session assessment. Six students (60%) demonstrated accurate understanding, recognizing that ionic compounds conduct electricity only when molten or dissolved in water due to the mobility of ions. Misconceptions related to ion mobility and conductivity to physical traits were each reported by only one student (10%), while solution conductivity misconceptions were observed in two students (20%), indicating minor confusion regarding the role of dissociation in electrical conduction. Notably, no student (0%) exhibited misconceptions in the bond types category, reflecting a clear understanding of how ionic conductivity differs from that of covalent or metallic substances.
Overall, the findings indicate that the intervention effectively enhanced students' comprehension of electrical conductivity in ionic compounds. The significant reduction in misconceptions demonstrates that practical, concept-based instruction can successfully bridge the gap between theoretical knowledge and scientific reasoning in chemistry learning.

Comparison of Pre-Session and Post-Session Misconceptions
This section demonstrated the comparison of pre-assessment and post-assessment.
Table 9: *Comparison of Pre-Session and Post-Session Misconceptions Regarding Transfer of Electrons (N = 10)*

Concept	Pre-Session Understanding (%)	Post-Session Understanding (%)	% Change	Pre-Session *f*	Post-Session *f*	Frequency Change
Accurate Concept	20	60	↑ 40%	2	6	+4
Shared Electron	30	10	↓ 20%	3	1	–2
Mobile Electron	20	10	↓ 10%	2	1	–1
State of Matter	10	10	—	1	1	0
Outermost Electrons	20	10	↓ 10%	2	1	–1

Note. Percentages are calculated for N = 10 students. Arrows (↑, ↓) indicate improvement or reduction in frequency. 'Accurate Concept' represents correct understanding, while remaining categories denote specific misconceptions.

Table 9 revealed a substantial improvement in students' accurate conceptual understanding of electron transfer, rising from 20% to 60% (a +40% change in percentage and +4 in frequency). This indicates that the post-session intervention was highly effective in helping students differentiate between electron transfer and other bonding processes. In contrast, all misconceptions declined after the session. The most notable reduction was observed in the "Shared Electron" category (–20% / –2 frequency), showing that students corrected their confusion between ionic and covalent bonding. Smaller decreases were found in "Mobile Electron" (–10% / –1 frequency) and "Outermost Electrons" (–10% / –1 frequency), reflecting improved clarity about electron movement and valence shell behavior. The “State of Matter” misconception remained unchanged (10% / 0 frequency), suggesting minor persistence in understanding ionic bonding across different states.

This pattern demonstrates that the instructional intervention was successful in clarifying core concepts of ionic bonding, particularly the distinction between electron sharing and electron transfer, thereby strengthening students’ conceptual foundations in chemistry.

Table 10: *Comparison of Pre-Session and Post-Session Misconceptions Regarding Electronegativity Differences in Ionic Bond (N = 10)*

Concept	Pre-Session Understanding (%)	Post-Session Understanding (%)	% Change	Pre-Session *f*	Post-Session *f*	Frequency Change
Accurate Concept	20	60	↑ 40%	2	6	+4
E.N (Electronegativity)	30	10	↓ 20%	3	1	–2
Threshold Misunderstanding	20	10	↓ 10%	2	1	–1
Physical Interaction	20	10	↓ 10%	2	1	–1
E.N in Bond Types	10	10	—	1	1	0

Note. Percentages are calculated for N = 10 students. Arrows (↑, ↓) indicate improvement or reduction in frequency. ‘Accurate Concept’ represents correct understanding, while remaining categories denote specific misconceptions.

Table 10 revealed a significant improvement in students’ accurate conceptual understanding of electronegativity differences, increasing from 20% to 60% (a +40% change in percentage and +4 in frequency). This substantial gain indicates that the instructional session effectively enhanced students’ grasp of how differences in electronegativity determine ionic bond formation. In contrast, all misconceptions decreased following the intervention. The largest reduction was observed in the “E.N (Electronegativity)” category (–20% / –2 frequency), suggesting that students better understood that electronegativity reflects an atom’s tendency to attract electrons rather than a physical property. Smaller declines occurred in “Threshold Misunderstanding” (–10% / –1 frequency) and “Physical Interaction” (–10% / –1 frequency), indicating improved recognition that ionic bonding results from electrostatic attraction, not direct physical contact. The “E.N in Bond Types” misconception remained constant (10% / 0 frequency), showing minor persistence in distinguishing between ionic and covalent bonding types.

Overall, these findings demonstrate that the instructional intervention was effective in clarifying the concept of electronegativity and its role in ionic bond formation, significantly reducing prevalent misconceptions and improving scientific accuracy in students’ understanding.

Dialogue Social Science Review (DSSR)
www.thedssr.com

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 3 No. 10 (October) (2025)

Table 11: *Comparison of Pre-Session and Post-Session Misconceptions Regarding Causes of Oppositely Charged Ions (N = 10)*

Concept	Pre-Session Understanding (%)	Post-Session Understanding (%)	% Change	Pre-Session *f*	Post-Session *f*	Frequency Change
Accurate Concept	10	40	↑ 30%	1	4	+3
Bonding Mechanisms	40	20	↓ 20%	4	2	–2
Lattice Structure	20	10	↓ 10%	2	1	–1
Physical Properties	10	10	—	1	1	0
Scientific Terminology	20	20	—	2	2	0

Note. Percentages are calculated for N = 10 students. Arrows (↑, ↓) indicate improvement or reduction in frequency. 'Accurate Concept' represents correct understanding, while remaining categories denote specific misconceptions.

Table 11 revealed a noticeable improvement in students' accurate conceptual understanding of the causes of oppositely charged ions, rising from 10% to 40% (a +30% change in percentage and +3 in frequency). This increase reflects a clearer comprehension of how electron transfer leads to the formation of positive and negative ions. In contrast, misconceptions declined across several categories. The most significant reduction appeared in the "Bonding Mechanisms" category (–20% / –2 frequency), suggesting that students developed a better grasp of ionic bond formation through electrostatic attraction rather than shared electrons. A smaller decrease was found in "Lattice Structure" (–10% / –1 frequency), showing improved awareness of the regular arrangement of ions in ionic solids. However, misconceptions related to "Physical Properties" and "Scientific Terminology" remained unchanged (10% / 0 and 20% / 0 frequency, respectively), indicating a continued need for reinforcement in chemical vocabulary and property interpretation.

Overall, the pattern of improvement demonstrates that the intervention was effective in strengthening students' conceptual understanding of ion formation and stability, though minor gaps persisted in terminology and property-related reasoning.

Table 12: *Comparison of Pre-Session and Post-Session Misconceptions Regarding Electrical Conductivity in Ionic Bond (N = 10)*

Concept	Pre-Session Understanding (%)	Post-Session Understanding (%)	% Change	Pre-Session *f*	Post-Session *f*	Frequency Change
Accurate Concept	10	60	↑ 50%	1	6	+5
Ion Mobility	20	10	↓ 10%	2	1	–1
Conductivity to Physical Traits	30	10	↓ 20%	3	1	–2
Solution Conductivity	20	20	—	2	2	0
Bond Types	20	0	↓ 20%	2	0	–2

Note. Percentages are calculated for N = 10 students. Arrows (↑, ↓) indicate improvement or reduction in frequency. 'Accurate Concept' represents correct understanding, while remaining categories denote specific misconceptions.

Table 12 revealed a considerable improvement in students' accurate conceptual understanding of electrical conductivity in ionic bonding, increasing from 10% to 60% (a

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 3 No. 10 (October) (2025)

+50% change in percentage and +5 in frequency). This sharp rise indicates that the post-session instruction effectively enhanced students' awareness of how ionic compounds conduct electricity through ion mobility in molten or aqueous states. Meanwhile, misconceptions declined across most categories. The most prominent reductions were noted in "Conductivity to Physical Traits" (–20% / –2 frequency) and "Bond Types" (–20% / –2 frequency), suggesting that students were better able to distinguish ionic bonding from covalent and metallic bonds in terms of conductivity behavior. A smaller decrease was observed in "Ion Mobility" (–10% / –1 frequency), while "Solution Conductivity" remained unchanged (20% / 0 frequency), reflecting that some confusion persisted regarding the influence of dissociation on conduction.

Overall, the results demonstrate that the instructional intervention successfully improved students' conceptual understanding of ionic conductivity, significantly reducing misconceptions and promoting scientifically accurate reasoning about the relationship between ionic bonding and electrical behavior.

Results and Discussion

Analysis revealed that students initially displayed several misconceptions, particularly regarding electron transfer, electronegativity. Many perceived ionic bonding as involving partial sharing of electrons. Post-intervention results demonstrated a substantial decrease in the number and intensity of misconceptions, confirming the effectiveness of constructivist instructional strategies.

The findings corroborate prior studies (Taber, 2018; Chiu, 2019) that emphasize the value of conceptual change-oriented teaching in science education. Students exposed to inquiry-based and analogy-supported lessons showed greater ability to reason scientifically and connect molecular-level processes with macroscopic phenomena. The embedded mixed-methods design provided comprehensive insights by combining numerical evidence with qualitative understanding, thereby strengthening the validity of the conclusions.

Conclusion and Implications

The study concludes that misconceptions represent a critical barrier to conceptual understanding in chemistry. When left unaddressed, they lead to surface learning and poor academic performance. However, targeted interventions grounded in constructivist and conceptual change principles can significantly improve comprehension and retention.

These findings underscore the need for curriculum designers and teacher educators in Pakistan to incorporate diagnostic assessments, cognitive conflict strategies, and inquiry-based learning into secondary-level chemistry instruction. Policymakers and educators should also consider professional development programs that equip teachers with skills to identify and correct misconceptions effectively. The research study may be conducted on the same constructs by adopting the other experimental design or ex-post facto research design.

References

Ausubel, D. P. (1968). Educational psychology: A cognitive view. Holt, Rinehart & Winston.

Chiu, M. H. (2019). Promoting conceptual change in students' understanding of chemistry concepts. International Journal of Science Education, 41(3), 281–299.

Duit, R., & Treagust, D. F. (2012). Conceptual change: A powerful framework for improving science teaching and learning. International Journal of Science Education, 34(3), 381–401.

Hunter, K. H., & Carver, J. S. (2022). A review of research on the teaching and learning of chemical bonding (2006–2020). Journal of Chemical Education, 99(3), 1166–1187. https://doi.org/10.1021/acs.jchemed.2c00034

Holmelin, F. L., Monstad, A. H., Haahr, A. H., & Mork, S. M. (2025). Design of computer simulation exercises on polarity and intermolecular interactions. Journal of Chemical Education. https://doi.org/10.1021/acs.jchemed.4c01348

Hrubeš, J., Bína, D., & Kluiber, J. (2024). Integrating computational chemistry into secondary school: Teaching bonding and molecular orbitals. Journal of Chemical Education, 101(6), 2698–2706. https://doi.org/10.1021/acs.jchemed.3c00908

Identifying students' misconceptions about chemical bonding using a four-tier diagnostic test. (2024). Journal of Research in Education and Pedagogy, 1(1), 46–62. https://spm-online.com/jrep/index.php/journal/article/download/5/5/25

Identification of learning difficulties and misconceptions of chemical bonding material: A review. (2024). Eclética Química Journal, 49(4), 1–16. https://revista.iq.unesp.br/index.php/ecletica/article/download/1508/1847/9189

Iqbal, H., & Mahmood, N. (2019). Challenges in teaching chemistry at the secondary level in Pakistan. Journal of Educational Research, 22(2), 45–58.

Novak, J. D. (2010). Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations. Routledge.

Rehman, S., Ahmed, Z., & Javed, F. (2021). Misconceptions in chemistry: Identification and pedagogical implications. Pakistan Journal of Education, 38(1), 23–41.

Simanjuntak, B. R. N., et al. (2025). Three-tier diagnostic test to identify misconceptions in chemistry: A systematic review. Jurnal Penelitian Pendidikan IPA, 11(7), Article 11011. https://doi.org/10.29303/jppipa.v11i7.11011

Taber, K. S. (2018). Teaching secondary chemistry. Routledge.

van Dulmen, T. H. H., Visser, T. C., Coenders, F. G. M., Pepin, B., & McKenney, S. (2023). Learning to teach chemical bonding: A framework for preservice teacher educators. Chemistry Education Research and Practice, 24, 896–913. https://doi.org/10.1039/D2RP00049K