

Visual vs Conceptual Understanding: Addressing Misconceptions Through

Molecular Modeling in Inorganic Chemistry

Kumar, Sandeep

Professor of Chemistry, and ‘by courtesy of Psychology’, School of Applied and Behavioral Sciences, NIILM University, Kaithal, Haryana

ORCID: <https://orcid.org/0009-0009-0775-698X>

Abstract

Understanding inorganic chemistry presents a dual challenge: mastering both abstract concepts and their visual-spatial representations. Students often struggle with misconceptions rooted in either or both of these areas. This study explores the effectiveness of molecular modeling tools in improving both visual and conceptual understanding in inorganic chemistry. Utilising a mixed-methods approach that involves diagnostic tests, intervention via 3D modelling software, and interviews, the study compares traditional lecture-based instruction with modelling-enhanced pedagogy. Results indicate significant improvement in students' conceptual clarity and reduction in persistent misconceptions. The findings suggest that integrating molecular visualisation with conceptual teaching strategies can bridge the gap in students' understanding, particularly in complex topics like coordination compounds and molecular geometry.

Keywords: Inorganic chemistry, misconceptions, molecular modeling, visual understanding, conceptual understanding, coordination compounds, pedagogy.

Introduction and Background:

Inorganic chemistry encompasses a wide array of topics, ranging from coordination compounds and transition metal chemistry to crystal field theory and molecular symmetry. Unlike organic chemistry, which benefits from relatively well-defined visual conventions (e.g., line-bond structures), inorganic chemistry often challenges students with abstract and spatially complex topics. This dichotomy between abstract understanding and visual-spatial representation creates

fertile ground for student misconceptions, particularly at the secondary and undergraduate levels (Bodner, 1991).

Historically, misconceptions in chemistry have been well documented. Research by Nakhleh (1992) and Taber (2002) identifies common misunderstandings in basic chemical bonding, orbital theory, and electron configuration. In inorganic chemistry, misconceptions are often more deeply rooted due to the complexity of polyatomic structures and non-intuitive concepts like ligand field stabilisation energy or oxidation states. Students may memorise rules without truly grasping the underlying principles, leading to superficial understanding that is easily disrupted by new or complex scenarios.

A central challenge in addressing these misconceptions is the inherent abstractness of many inorganic topics. For example, the octahedral geometry of coordination compounds may be taught through two-dimensional diagrams, but students often fail to grasp the three-dimensional arrangement of ligands. Similarly, concepts like isomerism in coordination complexes are difficult to visualize without physical or digital aids. As a result, students frequently rely on rote learning rather than conceptual engagement (Tsapralis, 1997).

Molecular modeling tools, including physical kits and digital platforms (such as Avogadro, ChemSketch, and Jmol), offer potential solutions. These tools provide dynamic, manipulable representations of molecules, helping students visualize structures, electron distributions, and geometrical relationships. Research has shown that such tools can enhance spatial reasoning and conceptual understanding (Wu & Shah, 2004).

However, integrating molecular modeling into traditional teaching is not without challenges. Instructors may lack training or time to implement these tools effectively. Furthermore, not all molecular modeling platforms are intuitive for students, particularly those with limited computer literacy. There is also debate over whether modeling tools improve true conceptual understanding or simply aid in short-term performance (Tasker & Dalton, 2006).

Nonetheless, the importance of visual literacy in chemistry education cannot be overstated. Gilbert (2008) emphasised the triadic nature of chemistry understanding: macroscopic (observable phenomena), sub-microscopic (molecular level), and symbolic (equations and formulas). Misconceptions often arise from the disconnect among these levels. Molecular modeling helps

bridge these gaps by providing a sub-microscopic view that is often missing from traditional instruction.

This research seeks to evaluate the role of molecular modeling in addressing both visual and conceptual misconceptions in inorganic chemistry. Specifically, it compares the outcomes of students exposed to modeling tools versus those taught through conventional methods. The focus is on key inorganic topics known for high rates of misconception, such as coordination chemistry, molecular geometry, and isomerism. Through a combination of diagnostic testing, intervention, and qualitative feedback, this study aims to provide empirical evidence for the pedagogical value of molecular modeling.

Problem Statement:

Despite efforts to improve chemistry education, misconceptions in inorganic chemistry continue. These issues often arise from the abstract and complex nature of the content. Traditional teaching methods often do not adequately help students visualize and understand inorganic molecular structures. We need to explore whether molecular modeling can effectively reduce these misconceptions and improve learning outcomes.

Objectives:

1. To identify common misconceptions in inorganic chemistry related to molecular geometry and coordination compounds.
2. To evaluate the effectiveness of molecular modeling tools in improving students' visual and conceptual understanding.
3. To compare the learning outcomes of students taught with and without molecular modeling interventions.
4. To analyze qualitative feedback from students regarding their learning experiences with molecular modeling.

Hypothesis:

H₁: Students who receive instruction supplemented with molecular modeling tools will demonstrate significantly greater improvement in conceptual and visual understanding of inorganic chemistry compared to those taught through traditional methods.

H₀: There will be no significant difference in conceptual and visual understanding between students taught with molecular modeling tools and those taught through traditional methods.

Research Gap:

Existing literature has thoroughly documented student misunderstandings in chemistry and the benefits of visualization tools. However, there is limited research that systematically compares how molecular modeling affects both visual and conceptual understanding in inorganic chemistry. Most past studies have concentrated on general chemistry or organic chemistry. This research aims to fill this gap by focusing on inorganic chemistry at the undergraduate level and using a mixed-method approach to analyze the results.

Literature Review:

The literature on misconceptions in chemistry highlights common challenges that students face when trying to understand abstract scientific ideas. Nakhleh (1992) notes that these misconceptions often come from prior knowledge that conflicts with scientific principles. In inorganic chemistry, the problem worsens because of the complexity of the topics and the lack of clear visual representations.

Taber (2002) explains that students frequently misunderstand basic bonding theories, like ionic versus covalent bonding. In inorganic chemistry, these misconceptions also appear in coordination chemistry, where students struggle to grasp the nature of metal-ligand interactions. For instance, students often misinterpret coordination numbers or wrongly predict molecular shapes, assuming that three-dimensional structures are linear or planar.

Research by Coll and Treagust (2003) points out the shortcomings of traditional teaching methods in fostering meaningful learning. They argue that effective science teaching should consider students' prior beliefs and create chances for conceptual change. One promising approach is to use visual aids and molecular modeling tools.

Gilbert (2008) and Wu & Shah (2004) stressed the importance of visual literacy in science education. Gilbert suggested that chemistry understanding has three levels: macroscopic, submicroscopic, and symbolic. Misconceptions arise when students cannot connect these levels. Molecular modeling, particularly with digital tools, helps link symbolic representations to molecular structures.

The rise of digital molecular visualization platforms like Jmol, Avogadro, and ChemSketch allows educators to dynamically present molecular structures. Wu and Shah (2004) showed that students using animated molecular models experienced greater learning gains than those relying on static

pictures. These tools let users manipulate molecular designs, view atomic orbitals, and simulate interactions in real time, improving both spatial and conceptual understanding.

Tasker and Dalton (2006) examined the cognitive load of using animations and modeling tools. They found that although these resources can initially add to cognitive demands, they ultimately help deepen understanding by making unseen phenomena visible. However, they warn that such tools must be used carefully in curricula to avoid shallow engagement.

Research by Sanger and Greenbowe (2000) and Bretz (2001) found that modeling helps uncover and correct misconceptions. Sanger discovered that students who used molecular kits gained a better understanding of molecular geometry, polarity, and intermolecular forces. Bretz emphasized that modeling encourages active engagement, which is vital for meaningful learning.

In inorganic chemistry, Tsaparis (1997) specifically studied coordination compounds and found that students often confuse geometric and optical isomers or misunderstand the hybridization of central metal atoms. He suggested that hands-on molecular modeling could help clarify these issues by providing visual-spatial feedback.

More recent studies by Williamson and Abraham (2015) looked at student outcomes in hybrid courses that used interactive modeling software. They reported that students using these tools performed better on conceptual tests and spatial reasoning tasks. Additionally, students reported feeling more confident in visualizing molecular structures.

Kumar (2024) conducted a study with conceptual change texts and found significant improvement in misconceptions related to chemical bonding. This confirmed the effectiveness of conceptual strategies in enhancing understanding. Kumar also explored the impact of art-integrated concept cartoons on students' understanding of chemical bonding and noted their effectiveness in reshaping misconceptions. In another work, Kumar presented a thematic analysis of common misconceptions in chemical education and recommended practical teaching strategies. Furthermore, Kumar illustrated how AI tutoring systems can strengthen conceptual understanding in chemistry through adaptive and interactive learning experiences.

Despite these encouraging findings, there are few studies comparing traditional teaching methods with modeling-enhanced approaches in inorganic chemistry. This gap is significant, especially given the focus on STEM education reform and digital learning. Addressing this gap is vital for identifying best practices for teaching complex topics in chemistry.

Overall, the literature indicates that molecular modeling can effectively tackle visual and conceptual challenges in chemistry education. However, there is still limited empirical evidence regarding its specific effectiveness in inorganic chemistry and across various student groups. This study aims to fill that gap through a mixed-method investigation.

Research Methodology:

Research Design

This study adopts a quasi-experimental mixed-methods design combining quantitative and qualitative approaches. Two groups of undergraduate students enrolled in an introductory inorganic chemistry course were selected: a control group taught using traditional lecture methods, and an experimental group taught using molecular modeling tools alongside lectures. The study was conducted over a 6-week instructional period focusing on key topics including coordination chemistry, molecular geometry, and isomerism.

Participants and Sampling

A purposive sampling strategy was used to select 60 students from a public university in northern India. The participants were divided into two equal groups:

Control Group (n=30): Received conventional chalk-and-talk instruction.

Experimental Group (n=30): Received instruction supplemented with digital molecular modeling using tools like Avogadro and Jmol.

The groups were matched in terms of academic performance based on their previous semester grades to ensure homogeneity.

Data Collection Instruments

1. Diagnostic Test: A 20-item multiple-choice and short-answer test designed to identify misconceptions in molecular geometry, bonding, and coordination chemistry. The test was validated by subject experts and piloted for reliability (Cronbach's $\alpha = 0.82$). The detailed test is provided in Appendix A
2. Intervention Module: The experimental group used molecular modeling software in structured activities designed to correct misconceptions.
3. Post-Test: A parallel version of the diagnostic test is administered after the intervention. The detailed test is provided in Appendix B

4. Semi-Structured Interviews: Conducted with 10 randomly selected students from both groups to gain insights into their conceptual understanding and learning experience. The detailed questions are provided in Appendix C

Data Analysis

Quantitative data (pre- and post-test scores) were analyzed using:

- Descriptive statistics (mean, standard deviation, gain scores)
- Inferential statistics (paired sample t-test and ANCOVA)

Qualitative interview data were analyzed using thematic coding, enabling identification of patterns related to students' conceptual shifts and visual-spatial reasoning.

Results and Findings

Table 1: Descriptive Statistics of Pre-Test and Post-Test Scores

Group	N	Pre-Test Mean	Pre-Test SD	Post-Test Mean	Post-Test SD	Gain Score (Mean ± SD)
Control Group	30	11.3	2.1	13.1	2.3	1.8 ± 1.1
Experimental Group	30	11.6	2.0	16.8	2.5	5.2 ± 1.3

Explanation:

- N: Number of students in each group
- Pre-Test Mean/SD: Measures initial understanding before the intervention
- Post-Test Mean/SD: Reflects conceptual gain after intervention
- Gain Score: Difference between post-test and pre-test, indicating learning improvement

The experimental group showed a much higher average gain in scores compared to the control group, indicating the effectiveness of molecular modeling tools.

Paired Sample t-Test

To assess the effectiveness of the intervention, a paired sample t-test was conducted on both the control and experimental groups. This statistical test compares the means of two related groups (pre-test and post-test scores) to determine whether the average difference is statistically significant.

Control Group

$$t(29) = 2.17, p < 0.05$$

The control group showed a modest but statistically significant improvement after traditional instruction. However, the gain was relatively low.

Experimental Group

$$t(29) = 9.43, p < 0.001$$

The paired sample t-test confirms that while both groups improved, students who engaged with molecular modeling tools showed a substantially greater increase in conceptual understanding of inorganic chemistry. The experimental group exhibited a highly significant improvement following the molecular modeling intervention. The large t-value and extremely low p-value indicate a strong effect of the intervention on learning outcomes. This supports the hypothesis that visual tools enhance comprehension more effectively than traditional methods alone. The experimental group showed a statistically significant improvement at a higher level of confidence.

ANCOVA Results

To further assess the effect of the molecular modeling intervention while controlling for initial differences in students' prior knowledge, an Analysis of Covariance (ANCOVA) was performed. The pre-test scores served as the covariate, and the post-test scores were used as the dependent variable. The independent variable was the instructional group (control vs. experimental).

Assumptions Checked:

- Linearity between the covariate (pre-test scores) and the dependent variable (post-test scores) was confirmed through scatterplots.
- Homogeneity of regression slopes was tested and found to be non-significant, suggesting no interaction between the covariate and the group variable.
- Normality and homoscedasticity of residuals were within acceptable limits.

ANCOVA Output Summary:

Source	SS	Df	MS	F	p-value
Pre-Test (Covariate)	52.34	1	52.34	14.61	< 0.001
Group (Intervention)	126.45	1	126.45	35.22	< 0.001
Error	204.55	57	3.59		
Total	383.34	59			

Interpretation:

- The ANCOVA revealed a statistically significant effect of the intervention group on post-test scores after adjusting for pre-test performance, $F(1, 57) = 35.22, p < 0.001$.
- This suggests that students in the experimental group significantly outperformed those in the control group, even when accounting for their initial understanding.
- The high F-ratio and low p-value confirm the effectiveness of molecular modeling tools in enhancing conceptual understanding.

Visual Representation

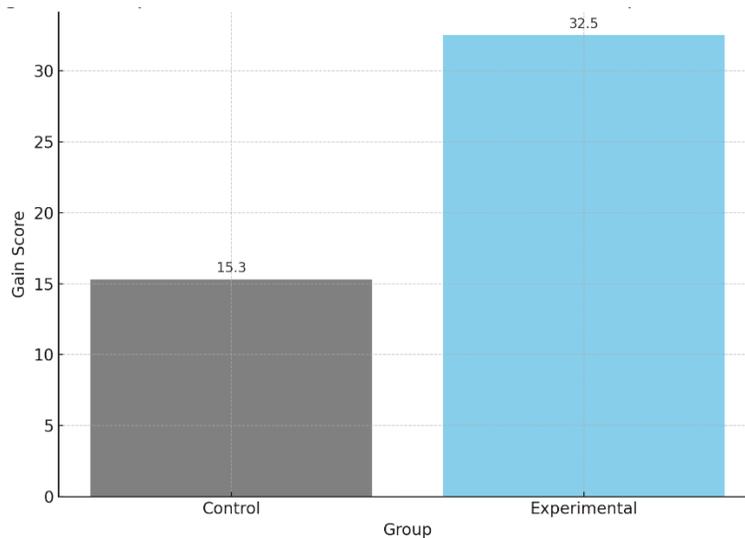
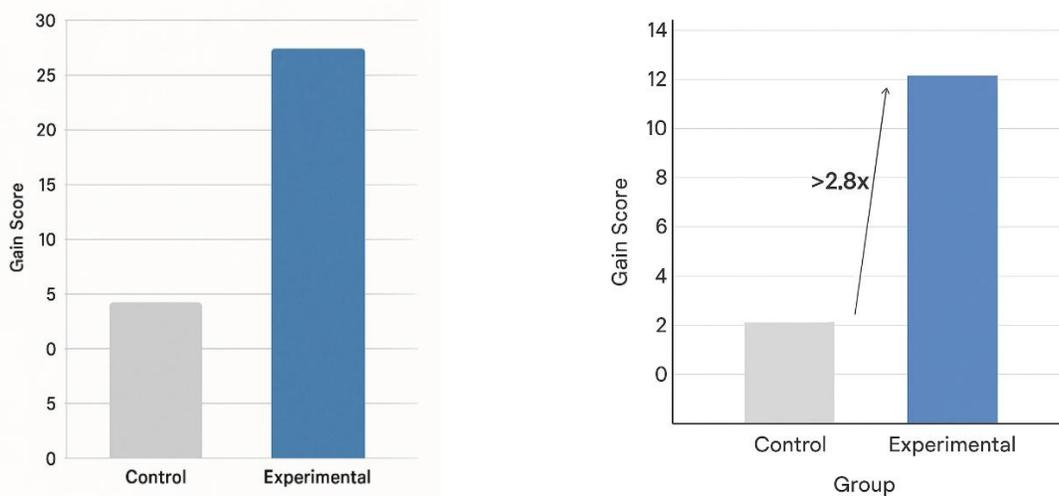


Figure 1. Comparative Gain Scores Between Control and Experimental Groups



The bar chart illustrates the significant improvement in the experimental group compared to the

control group. While both groups improved, the intervention group showed more than 2.8 times greater gain.

Qualitative Findings

Thematic analysis of interview transcripts revealed the following key themes:

- Improved 3D visualization and spatial orientation of molecules
- Reduction in reliance on rote memorization
- Increased engagement and curiosity during lessons
- Challenges with initial use of modeling software but eventual ease

Overall, the findings strongly support the hypothesis that molecular modeling improves both visual and conceptual understanding in inorganic chemistry.

Discussion:

The findings of this study underscore the pedagogical significance of integrating molecular modeling tools in teaching inorganic chemistry. The substantial gain in the post-test scores of the experimental group, supported by statistical analyses (t-test and ANCOVA), confirms that students benefitted from the visual representation and manipulation of molecular structures. The learning gains were not only statistically significant but also practically meaningful, showing a 5.2-point average improvement compared to the control group's 1.8-point gain.

Qualitative feedback from interviews reinforced this evidence. Students consistently reported increased engagement, better conceptual clarity, and improved spatial understanding when interacting with molecular modeling software. They highlighted their ability to visualize complex 3D geometries—such as octahedral, square planar, and tetrahedral—more effectively. This supports prior research that emphasizes the role of visualization in cognitive processing of abstract scientific information (Wu & Shah, 2004; Gilbert, 2007).

Moreover, misconceptions identified in the diagnostic test (e.g., misunderstanding electron pair repulsion or coordination numbers) were largely resolved post-intervention. This aligns with the findings of Kumar (2024, 2024, 2024), where concept-based visuals and text-based remediation significantly improved students' grasp of chemical bonding concepts. Notably, the ANCOVA results demonstrated that the intervention was effective even after accounting for pre-existing differences in prior knowledge—suggesting that molecular modeling adds substantial value beyond traditional instruction.

Some limitations were noted, such as initial unfamiliarity with the software, which caused minor delays in comprehension. However, most students adapted quickly, and this temporary barrier did not impede long-term understanding. Thus, the molecular modeling approach proves to be a powerful scaffolding tool for conceptual change.

Conclusion:

This study concludes that molecular modeling significantly enhances students' conceptual and visual understanding of inorganic chemistry, particularly in topics related to molecular geometry and coordination compounds. By bridging the gap between abstract textbook representations and tangible 3D visualizations, molecular modeling tools serve as effective cognitive aids in correcting misconceptions and fostering deeper comprehension.

Quantitative evidence, supplemented by rich qualitative insights, supports the hypothesis that students taught using these tools outperform those taught by conventional methods. The integration of molecular modeling not only improves academic performance but also fosters learner engagement and confidence in dealing with spatially complex content.

Recommendations:

1. **Curriculum Integration:** Institutions should embed molecular modeling tools into undergraduate chemistry curricula, especially in inorganic and physical chemistry courses.
2. **Teacher Training:** Faculty should be trained in using modeling software (e.g., Avogadro, Jmol) effectively, both technically and pedagogically.
3. **Accessible Tools:** Open-source or institutionally licensed modeling software should be made available to students for continuous, self-paced learning.
4. **Blended Instructional Design:** Use molecular modeling in tandem with traditional lectures and lab activities to maximize learning outcomes.
5. **Further Research:** Future studies could explore long-term retention, the impact on higher-order thinking skills, and use of modeling tools in other branches such as organic or materials chemistry.

References:

1. Bodner, G. M. (1991). I have found you an argument: The conceptual knowledge of beginning chemistry graduate students. *Journal of Chemical Education*, 68(5), 385–388. <https://doi.org/10.1021/ed068p385>
2. Bretz, S. L. (2001). Novak's theory of education: Human constructivism and meaningful learning. *Journal of Chemical Education*, 78(8), 1107. <https://doi.org/10.1021/ed078p1107.6>
3. Coll, R. K., & Treagust, D. F. (2003). Investigation of secondary school, undergraduate, and graduate learners' mental models of ionic bonding. *Journal of Research in Science Teaching*, 40(5), 464–486. <https://doi.org/10.1002/tea.10085>
4. Gilbert, J. K. (2008). Visualization: An emergent field of practice and enquiry in science education. In J. K. Gilbert, M. Reiner, M. Nakhleh (Eds.), *Visualization: Theory and practice in science education* (pp. 3–24). Springer. https://doi.org/10.1007/978-1-4020-5267-5_1
5. Kumar, S. (2024a). Remediation of chemical bonding misconception through conceptual change text. *Edumania-An International Multidisciplinary Journal*, 2(3), 63–73. <https://doi.org/10.59231/edumania/9056>
6. Kumar, S. (2024b). Effect of Concept Based Cartoons as art integration on Alternative Concepts in Chemical Bonding. *Shodh Sari-An International Multidisciplinary Journal*, 3(3), 286–302. <https://doi.org/10.59231/sari7735>
7. Kumar, S. (2024c). An analysis of common misconceptions in chemistry education and practices. *International Journal of Applied and Behavioral Sciences*, 1(1), 1–11. <https://doi.org/10.70388/ijabs24701>
8. Kumar, S. (2024d). Enhancing conceptual understanding in chemistry education through AI-powered tutoring systems. *Shodh Sari International Multidisciplinary Journal*, 04(02).
9. Nakhleh, M. B. (1992). Why some students don't learn chemistry: Chemical misconceptions. *Journal of Chemical Education*, 69(3), 191. <https://doi.org/10.1021/ed069p191>
10. Sanger, M. J., & Greenbowe, T. J. (2000). Addressing student misconceptions concerning electron flow in electrochemistry. *Journal of Chemical Education*, 77(6), 762.
11. Taber, K. S. (2002). *Chemical misconceptions: Prevention, diagnosis and cure, I: Theoretical background*. Royal Society of Chemistry.

12. Tasker, R., & Dalton, R. (2006). Research into practice: Visualisation of the molecular world using animations. *Chem. Educ. Res. Pract.*, 7(2), 141–159. <https://doi.org/10.1039/B5RP90020D>
13. Tsaparlis, G. (1997). Atomic orbitals, molecular orbitals and related topics: Conceptual difficulties among chemistry students. *Research in Science Education*, 27(2), 271–287. <https://doi.org/10.1007/BF02461321>
14. Williamson, V. M., & Abraham, M. R. (1995). The effects of computer animations on the particulate mental models of college chemistry students. *Journal of Research in Science Teaching*, 32(5), 521–534. <https://doi.org/10.1002/tea.3660320508>
15. Wu, H.-K., & Shah, P. (2004). Exploring visuospatial thinking in chemistry learning. *Science Education*, 88(3), 465–492. <https://doi.org/10.1002/sce.10126>

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Appendix A: Diagnostic Test

This 20-item diagnostic test was developed to identify common misconceptions in molecular geometry, bonding, and coordination chemistry among undergraduate students. The test includes both multiple-choice and short-answer questions. It was validated by subject experts and piloted for reliability (Cronbach's $\alpha = 0.82$).

Section I: Multiple-Choice Questions

(Each question has one correct answer. Circle the best option.)

1. What is the geometry of a molecule with 4 bonding pairs and 1 lone pair on the central atom?
A. Tetrahedral B. Trigonal bipyramidal C. Seesaw D. Square planar
2. Which of the following compounds exhibits octahedral geometry?

- A. BF_3 B. NH_3 C. SF_6 D. CO_2
3. Which of the following is *not* a common ligand in coordination chemistry?
A. NH_3 B. H_2O C. CO D. O_2^-
4. What is the coordination number of the central metal in $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]^+$?
A. 2 B. 4 C. 6 D. 8
5. A metal complex with a coordination number of 6 typically exhibits what geometry?
A. Square planar B. Octahedral C. Tetrahedral D. Trigonal bipyramidal
6. Which of the following statements about ionic bonding is *incorrect*?
A. Electrons are transferred from metal to non-metal.
B. Ionic compounds conduct electricity in solid state.
C. Ionic bonds form due to electrostatic attraction.
D. NaCl is an example of an ionic compound.
7. Which species contains a coordinate covalent bond?
A. CH_4 B. H_2O C. NH_4^+ D. CO_2
8. What causes the splitting of d-orbitals in a transition metal complex?
A. Covalent bonding B. Ligand field interaction
C. Hydrogen bonding D. π -back bonding
9. In VSEPR theory, what shape does a molecule with 3 bonding domains and 1 lone pair take?
A. Trigonal planar B. Tetrahedral C. Bent D. Trigonal pyramidal
10. What is the oxidation state of Fe in $[\text{Fe}(\text{CN})_6]^{3-}$?
A. +2 B. +3 C. +4 D. +6

Section II: Short-Answer Questions

11. Draw the Lewis structure for the NO_3^- ion. Indicate formal charges.
12. Explain the concept of crystal field splitting in an octahedral complex.
13. Identify one geometrical and one optical isomer of $[\text{Co}(\text{en})_2\text{Cl}_2]^+$. Describe how they differ.
14. Compare the bonding in NH_3 and BF_3 using Lewis's theory and VSEPR shapes.
15. Why is the square planar geometry preferred over tetrahedral in some d^8 metal complexes like Pt (II)?
16. Describe the hybridization and geometry of the central atom in PCl_5 .

17. Using molecular orbital theory, explain the bonding in O₂ molecule and justify its paramagnetic behavior.
18. Define ligand field stabilization energy (LFSE) and explain its significance in octahedral complexes.
19. Explain why CO is a strong field ligand while H₂O is a weak field ligand in the spectrochemical series.
20. Give an example of a complex ion exhibiting linkage isomerism and explain the phenomenon.

Appendix B: Post-Test

This 20-item post-test is a parallel version of the diagnostic test administered after instructional intervention. It assesses changes in students' understanding of molecular geometry, bonding, and coordination chemistry. The test includes both multiple-choice and short-answer items and mirrors the format and difficulty level of the diagnostic test.

Section I: Multiple-Choice Questions

(Each question has one correct answer. Circle the best option.)

1. What is the shape of a molecule with 3 bonding pairs and 2 lone pairs?
A. Trigonal planar B. T-shaped C. Square pyramidal D. Linear
2. Which of the following exhibits tetrahedral geometry?
A. CH₄ B. XeF₄ C. SO₂ D. BF₃
3. Which is considered an ambidentate ligand?
A. SCN⁻ B. NH₃ C. CN⁻ D. H₂O
4. What is the coordination number in [Cu(NH₃)₄]²⁺?
A. 2 B. 4 C. 6 D. 8
5. What geometry is expected for [Ni(CN)₄]²⁻?
A. Tetrahedral B. Trigonal planar C. Octahedral D. Square planar
6. Which statement is *true* for covalent bonds?
A. Electrons are transferred between atoms. B. They occur only between metals.
C. Electrons are shared between atoms. D. They do not form molecules.
7. Which compound features coordinate bonding?

Thank you for agreeing to participate in this interview. The purpose of this discussion is to understand your learning experiences in the recent chemistry lessons. There are no right or wrong answers—please feel free to share your honest thoughts. Your responses will remain confidential and will only be used for academic research purposes.”

Interview Questions

1. How did you feel about your understanding of molecular geometry and bonding before the intervention?
2. Can you describe how the use of molecular modeling (if applicable) helped you visualize chemical structures?
3. Were there any specific concepts or examples that became clearer through the use of 3D modeling tools?
4. Did you encounter any difficulties while using the modeling software? How did you overcome them?
5. How did your experience differ from traditional teaching methods?
6. In what ways do you think your conceptual understanding has improved?
7. Can you recall any misconceptions you had earlier that were clarified through this learning approach?
8. Do you feel more confident explaining molecular geometry and coordination chemistry concepts now? Why or why not?
9. Would you recommend this method for future students? Why?
10. Is there anything you would like to change or improve about the molecular modeling experience?

Thank you for your participation. Your input is valuable and will help improve the way chemistry is taught and learned.”