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Strengthening the Conceptual Understanding of Molecular Structures among First-Year Geodetic Engineering Students through an Interactive Workshop

Ma. Ashly Fate S. Castillo[1], Ken Cedric M. Ambay[2], Samantha Nichole S. De Chavez[3], Princess Rawyah E. Dumayre[4], Christian Gerwin V. Eduardo[5], Abegail M. Palmes[6], John Keesler R. Pilar[7], Neishel Clize T. Quilala[8], Bryle A. Armeza[9]
Bachelor of Sciences in Geodetic Engineering, Batangas State University, The National Engineering University, Batangas City, Philippines

Abstract: This study examined how the interactive workshop enhanced students' conceptual understanding of the molecular structure, highlighting the importance of tangible learning in terms of strengthening students' grasp of complex concepts. It delves into the knowledge of the students regarding molecular structure before and after the integration of the interactive workshop, along with their perception of the workshop. To comply with the objectives, the study employed a quasi-experimental research design where a non-randomized intact group was assigned into control and experimental group, with a sample of 36 first year Geodetic Engineering of Batangas State University. Data collection was carried out through pre- and post-tests, along with surveys administered during and after the interactive workshop.The findings revealed identical pretest scores for both groups, but there are slight but notable differences between the post-test results of control group and the experimental group. Students reported positive learning experience highlighting enjoyment and participation, learning effectiveness, and overall satisfaction with the integration of 3D molecular model to the interactive workshop.
Keywords: molecular structure, chemistry learning, interactive workshop, 3D molecular models

I. INTRODUCTION

Chemistry is a branch of science that explores both the macroscopic and microscopic aspects of matter, including the creation, properties, and interactions of substances. According to Moving beyond the language–Visualizing chemical concepts through one's own creative expression (Adbo & Åkesson-Nilsson, 2022), university students used their creative, tactile modelling (e.g., play-dough atomic nuclei) to represent invisible atomic structures, thus engaging their senses, visualization and imagination in order to understand abstract chemical concepts. Consequently, students' cognition can be stimulated to reason logically, visualize internally, and imagine the unseen, thereby enhancing comprehension of complex chemistry ideas.

Recent studies find that many tertiary students prefer learning through visual learning modalities. For instance, Lu & Yang (2018) discovered that students who learn best visually showed a stronger link between their ability to concentrate and their academic success. Supporting, a 2025 study of Turkish medical students using eye-tracking technology also found strong preference for visual learning, which was even more common among female students.

Although visualizations enhance students' comprehension of invisible chemical phenomena, not properly designed or scaffolded (Sanger & Phelps, 2020; Ryoo & Linn, 2022). However, research shows that visual aids can sometimes be ineffective or have the opposite effect of the intended goal. If animations or simulations are too complicated or fast, they can overwhelm a students' working memory. This makes it hard for them to connect different types of scientific representation (Makransky & Mayer, 2019). Additionally, students can be misled by visuals, thinking they understand a concept just because they remember what it looked like, when in reality they have not truly grasped the fundamental concept.

Static visualizations, such as diagrams, drawings, or images, remain unchanged over time, whereas dynamic visualizations—like animations or videos—alter their content to depict processes or transformations. The debate of whether dynamic or static visuals are better for teaching is still not settled, with studies showing conflicting outcomes (Berney & Bétrancourt, 2016; Castro-Alonso et al., 2019; Makransky et al., 2021). Some studies support dynamic visuals because they are good at showing how things change over time and can help students who have trouble imagining movement (Höffler & Leutner, 2007; Lin & Wu, 2021).

On the other hand, static visuals can sometimes be more effective as they are less complex, simpler, and lower mental strain. Moreover, recent studies suggest that factors like learning objectives, type of content, and personal or individual learner characteristics greatly affect the effectiveness of static versus dynamic formats.

There has been less research on the value of physical, hands-on tools like 3D molecular models, as most studies focus on digital or flat images. Unlike 2D pictures, 3D models let students physically change structures and explore how molecules fit together in space, turning abstract ideas into real objects. This direct experience, which connects theory to tangible form, can help students learn and remember molecular concepts more effectively.

For first-year geodetic engineering students, understanding molecular structures is a fundamental part of their field, as it is essential for topics like material science and geochemistry. Since chemistry is often seen as abstract and difficult, using hands-on learning methods can make the subject more interesting and easier to appreciate.

Studies in the Philippines have demonstrated how well digital media and visualization may improve students' conceptual understanding of chemistry. The use of visual aids is supported by several studies. Tibudan and Fajardo (2021) discovered that students' comprehension and attitudes regarding chemistry were improved by both moving and still visual aids. Similarly, Galvez (2022) found that teaching chemical bonding through animations produced better scores than traditional approaches. In another study, Montalbo (2021) demonstrated how incorporating Augmented Reality (AR) into lessons enhanced students' spatial skills and interest. Asedillas and Quimbo (2019) discovered that computer-based simulations improved students' retention and maintained interest in chemistry.

Despite these encouraging findings, local studies have primarily focused on digital and screen-based visualization tools. Research on the use of interactive workshops using real 3D molecular models as a tool for tertiary conceptual learning, specifically among engineering students, is currently lacking. This gap offers a chance to look at how interactive workshops and hands-on methods like these can help students learn effectively about molecular structure.

Aligned with SDG 4 (Quality Education) this study examines the effectiveness of interactive teaching approaches to bridge the gap in understanding and strengthening molecular structure among students. It investigates how this method can improve student engagement and academic performance in a challenging subject. It specifically aims to promote accessible and effective learning by addressing diverse student preferences. The ultimate goal is to contribute to good quality education by ensuring all students have the opportunity to succeed.

This study's potential to enhance student engagement, teaching method, and learning outcomes makes it significant. For students, the practical and group activities, it seeks to increase the significance of students' learning by making abstract chemical concepts simpler for them to visualize and understand. For teachers, it provides an innovative method of teaching that goes beyond memorization and encourages better understanding and active participation in the classroom. This technique helps to produce capable students with the strong scientific foundation required for their field.

II. OBJECTIVES

This study aims to strengthen the conceptual understanding of molecular structures among first-year Geodetic Engineering students through the implementation of an interactive workshop utilizing 3D molecular models. Specifically, it seeks to achieve the following objectives:

1) Prepare the workshop plan integrating 3D molecular models in the conceptual understanding of molecular structures
2) Determine the level of conceptual understanding of molecular structures of the students before and after the implementation of the interactive workshop with 3D models.
3) Evaluate students' experience of the interactive workshop in terms of:

- Enjoyment and participation
- Learning effectiveness
- Overall satisfaction

III. MATERIALS AND METHODS

A. Research Design

This study utilized quasi-experimental design, integrating pre-test and posttest to determine the effectiveness of the interactive workshop utilizing molding of 3D molecular structure activity in strengthening first-year Geodetic Engineering students' conceptual understanding of molecular geometry. This design is appropriate since the participants were selected from an existing class, without random assignment to groups (Sreekumar, 2025). Through this design, the class participant is divided into a control group, which integrates the traditional teaching method, and the treatment group, for introducing the new method of learning.

In addition, a descriptive approach was used to systematically describe the treatment group's experiences of enjoyment, participation, learning effectiveness, and overall satisfaction.

B. Subjects of the Study

The participants in this study include first-year Geodetic Engineering students at Batangas State University-Alangilan who are enrolled in a Chemistry course, introducing concepts of understanding molecular geometry. The class with 36 students who were intentionally selected from block 1102 is divided into two equal groups, having both 18 members. The control group sticks with the traditional method of teaching which includes lectures and textual materials. The experimental group joins the workshop utilizing 3D molecular structure in addition to peer collaboration and discussions. Both groups completed a pre-test and posttest to assess their level of understanding. Through their participation, they represent the effectiveness of a workshop with 3D molecular models in comparison with the traditional lecture-based learning.

The integration of the interactive workshop was conducted inside the school's student lounge where it was easy to gather the respondents without compromising their comfort of learning.

Table 1. Distribution of Respondents

GEODENG 1102	Population of Students
Control Group	18
Experimental Group	18
Total	36

C. Data Gathering Instrument

To achieve the objective of the study, a pre-test and posttest were used to evaluate the performance of the participants before and after having the workshop session utilizing 3D molecular models.

In various educational researches, pre-test and posttest are instruments used to measure and highlight the level of understanding and improvement participants possess before and after an intervention, which helps determine if the course of action is an effective learning strategy (Williams, 2024).

In this study, questions for the quiz that are adapted from ChemQuiz.net were altered, aligning with the problem under investigation. These questions served as the bases for providing the measurable data gained from the workshop session.

Ensuring validity and reliability, these instruments went through validation from experts and professionals with relevant experiences in Chemistry courses. This certifies that these instruments are accurate for data gathering and will provide necessary points to satisfy the objectives and desired learning outcomes at the end of this study.

Option	Scale Range	Adjectival Rating
4	3.50 – 4.00	Strongly Agree
3	2.50 – 3.49	Agree
2	1.50 – 2.49	Disagree
1	1.00 – 1.49	Strongly Disagree

D. Data Gathering Procedure

The data gathering procedure began with determining the course of action with regard to the specific problem under investigation and obtaining approval from the Chemistry instructor to conduct the study among first-year Geodetic Engineering students, specifically block 1102. Upon approval, the participants' initial understanding and first-hand knowledge about molecular structures was assessed through a pre-test.

The experimental group then participated in the interactive workshop which incorporates molding 3D molecular models with the use of clays and sticks to help them visualize the structure better. The workshop also involves brief discussion and presents handouts as guides for the session. Through this, participants are encouraged to build teamwork and be active throughout the workshop. To ensure that both groups receive similar content exposure, the control group participated in a lecture having only the handouts and discussions as a means for learning the concepts.

When both sessions are done, a posttest, which has the similar content of the pre-test, was used to assess their understanding and improvement. A survey questionnaire was also distributed among the participants of the experimental group to evaluate their enjoyment, participation, learning effectiveness, and overall satisfaction of the interactive workshop. The data collected from pre-test, posttest, and survey questionnaires are then recorded and interpreted to establish a result and conclusion regarding the effectiveness of the interactive workshop in first-year Geodetic Engineering students' conceptual understanding of molecular structure.

IV. RESULTS AND DISCUSSION

A. *Analysis of Students' Pretest and Post-test Scores Regarding Molecular Geometry.*

The pretest and post-test scores obtained from the molecular structure exercise were analyzed to evaluate students' performance using the appropriate statistical method.

1) *Students' Pretest and Post-test Result*

Table 2. Analysis of Pretest and Post-test Scores Obtained by Students Regarding Molecular Geometry

Control Group					
Test	N	Min.	Max.	x̄	SD
Pretest	18	0	15	6.89	4.84
Post-test	18	27	40	33.67	3.16
Experimental Group					
Test	N	Min.	Max.	x̄	SD
Pre-test	18	0	15	8	5.57
Post-test	18	34	40	38	2.22

The table shows that both the control and experimental groups improved their scores from the pre-test to the post-test. In the control group, the mean increased from 6.89 to 33.67, with the standard deviation decreasing from 4.84 to 3.16. Meanwhile, the experimental group obtained a mean of 8 in the pre-test and 38 in the post-test, with the standard deviation decreasing from 5.57 to 2.22. For both groups, the highest percentage of students obtained a score of 37.5%.

As seen in the table, the experimental group achieved a higher post-test mean score of 38, with a perfect percentage of 100%, which indicates that students who participated in the experiment greatly benefited from the activity. On the other hand, the control group obtained a post-test mean score of 33.67 with a percentage of 95%, showing that there was still improvement.

Overall, the results of the experimental group show that the interactive workshop improved students' comprehension of molecular geometry. This demonstrates how effectively the interactive workshop enhanced the students' understanding of molecular geometry.

According to Erlina et al. (2021), they conducted a study that analyzed the effect of using simple molecular models in hands-on learning activities on students.

Pre-test and post-test results, along with an SPSS t-test, were used to assess their study. Students who participated in the workshop showed a significant improvement, according to their analysis. This suggests that basic molecular models can improve students' comprehension of molecular geometry.

2) Paired t-test sample of Pretest and Post-test

Table 3. Paired t-test sample of Pretest and Post-test of the Obtained Scores by Students on Molecular Geometry

Control Group			
Comparison	t	df	p
Pretest vs Posttest	-20.78	17	.000
Experimental Group			
Comparison	t	df	p
Pretest vs Posttest	-29.44	17	.000

Table 3 shows the result of paired t-test samples of pre-test and posttest that determine the effectiveness of interactive workshops in strengthening the conceptual understanding of molecular structures. For the control group, the t-value is -20.78 with df = 17 and a p-value of .000, which revealed that even without interactive workshops the students get a higher score most likely due to familiarity with the topic. However, for the experimental group, the t-value is -29.44 with df = 17 and a p-value of .000, which revealed that the use of 3D molecular models has significantly improved the students' understanding of molecular geometry than the traditional learning.

The results revealed that both groups showed improvement from pre-test to post test, but the experimental group exposed in interactive 3D molecular workshop shows a better improvement in students' understanding. This aligned with the study of Alharbi (2025), which indicated that the students who used 3D models scored higher and showed a better understanding of molecular structure than the traditional learning. Therefore, the use of 3D interactive workshops is more effective in enhancing students' understanding in molecular geometry.

B. Evaluation of students' experience of the interactive workshop

This section presents the evaluation of the perceived experience of the student from the interactive workshop in terms of enjoyment and participation, learning effectiveness, and overall satisfaction.

1) Enjoyment and Participation

Table 4. Students' enjoyment and participation of the Interactive Workshop

Enjoyment and Participation	WM	VI	AR
1. I feel confident to analyze and evaluate problems related to molecular geometry.	3.42	Agree	Agree
2. I followed most of the teaching activity with interest.	3.44	Agree	Agree
3. I was able to participate and share my thoughts during the workshop.	3.44	Agree	Agree
4. I was relaxed and not stress.	3.06	Agree	Agree
5. The activities and exercises were engaging and interactive.	3.58	Strongly Agree	Strongly Agree
6. The workshop encouraged participation and discussion.	3.63	Strongly Agree	Strongly Agree
7. I enjoyed during the interactive workshop.	3.56	Strongly Agree	Strongly Agree
Composite Mean	3.45	Agree	Agree

The students overwhelmingly gave positive feedback about the Molecular Structure Interactive Workshop, which is also supported by the data in Table 4. These findings strongly suggest that the employment of interactive tools dramatically improved the learning process of chemistry concepts. Among the surveyed items, the statement "The workshop encouraged participation and discussion" was the most prominent one, as students demonstrated through their weighted mean response that they strongly agreed that participation was evident throughout the integration of the interactive workshop (WM = 3.63), further demonstrates the workshop's ability to sustain engagement, consistent with Newman et al. (2018), who noted that physical and interactive molecular models increase participation and interest in challenging chemistry topics, as well as Elyasova (2024), who found that molecular simulations improve cognitive immersion and participation in science learning environments. The statement "The activities and exercises were engaging and interactive." was also highly rated by the students (WM = 3.58, Strongly Agree). The high level of engagement is in line with the conclusion of Freeman et al. in their meta-analysis (2014) that the degree of students' participation and engagement when they are exposed to active learning methods are noticeably higher than when they are taught using Traditional Lecture Methods. The statement "I enjoyed during the interactive workshop." with a (WM = 3.56) indicates that students strongly agreed that there was enjoyment in participating in this workshop other than just learning molecular structures. The findings from this research provide evidence in support of the publication by Slavin (2015) that the participation and collaboration of peers in a group project such as in the interactive workshop is a powerful way to engage household elements of critical thinking and social skills in addition to content knowledge. The statement, "I followed most of the teaching activity with interest." with a (WM = 3.44) suggests that students agreed that they show interest with this manner of learning. This finding is in line with the results of Hoai et al. (2023) who found that students' levels of satisfaction are greatly increased through active learning techniques. Students gave the statement " I was able to participate and share my thoughts during the workshop." a (WM = 3.44), which indicates that they agreed with it, reflecting active engagement and involvement in the learning process. Cuello and Muñoz (2025) similarly demonstrated that interactive workshops enhanced emotional engagement and positive attitudes towards science. Verangel and Prudente (2021) also provided evidence that interactive tools significantly improve conceptual understanding and confidence in chemical concepts. Meanwhile, the statement " I was relaxed and not stress" got the lowest weighted mean (WM = 3.06), although it is still under the "Agree" verbal interpretation, suggesting that the workshop fostered a positive cognitive and emotional disposition toward chemistry learning, supported by Iyamuremye et al. (2025), who observed that accessible model kits reduce anxiety and build confidence, and by Assaf (2025), who reported that interactive simulations help learners feel more capable when dealing with complex concepts.

The Composite Mean of (3.45, Agree) for all the items reveals students' strong and consistent belief that the interactive molecular structure workshop is an effective instructional strategy in chemistry education that effectively fosters active participation and enjoyment.

2) Learning Efficacy

Table 5. Learning Efficacy of the Interactive Workshop

Learning Efficacy	WM	VI	AR
1. I will be able to retain the knowledge I gained from this interactive workshop over the long term.	3.61	Strongly Agree	Strongly Agree
2. I was fully engaged throughout this interactive workshop.	3.50	Strongly Agree	Strongly Agree
3. This workshop helped me develop new skills related to chemistry learning.	3.61	Strongly Agree	Strongly Agree
4. The interactive workshop was effective in building my confidence in studying molecular structures.	3.58	Strong Agree	Strongly Agree
5. I have a stronger understanding of molecular structure concepts after participating in this interactive workshop.	3.64	Strongly Agree	Strongly Agree
Composite Mean	3.59	Strongly Agree	Strongly Agree

The results in Table 5 revealed that the item where participants rated their satisfaction with the workshop outcomes received the highest score (WM = 3.64, Strongly Agree). This finding aligns with the outcomes of Adbo and Åkesson-Nilsson (2022), where the authors advocated the benefits of the 'hands-on and artistic modeling' method in assisting students to grasp abstract ideas in chemistry. This is further supported by Tibudan and Fajardo (2021), who found that both moving and static visual aids enhanced students' comprehension and attitudes in chemistry, reinforcing why participants strongly agreed with the workshop's effectiveness. Suffice to say, the high score on the statement "This workshop helped me develop new skills related to chemistry learning" (WM = 3.61, Strongly Agree), suggest that the workshop was successfully conducted and the topic regarding molecular structure, along with the desired goal of the learning outcome was meet through the interactive workshop. Similar to this, Galvez (2022) demonstrated that well-designed visual approaches, such as animations in chemical bonding, improve students' scores and engagement, mirroring the participants' strong agreement on content relevance. The item "I will be able to retain the knowledge I gained from this interactive workshop over the long term." also performed well (WM = 3.61, Strongly Agree), which shows that the workshop allows possible long-term memory retention of the topic discussed about molecular structures. The finding is connected with the study of Miller (2021), who emphasized that visual literacy strengthens students' ability to recall and internalize scientific information. The participants attested with the item "The interactive workshop was effective in building my confidence in studying molecular structures." (WM = 3.58, Strongly Agree). This further affirms the results of Lu and Yang (2018) which states that there are marked differences in the participation and the outcomes of learning of the students who are visualizers when the mode of presentation is congruent to their learning style. Likewise, Montalbo (2021) found that integrating interactive tools such as Augmented Reality boosted students' spatial skills and interest, showing how effective facilitation paired with visual tools enhances learning. Finally, the item that performed the lowest, "I was fully engaged throughout this interactive workshop." also performed positively and strongly (WM = 3.50, Strongly Agree), which implies that although it is the least favourable evaluation, the integration of the interactive workshop is effective in learning molecular structures. While Ryoo and Linn, (2022), state that participants may not visually understand the concept, the results suggest that participants were actually able to master the concept.

According to the findings outlined in Table 5, the interactive workshop was received well with an average of 3.59 (Strongly Agree). This demonstrates that the workshop improved participants' knowledge of the molecular structure. Overall, the results suggest that the audience received the instruction successfully and were engaged in the interactive workshop.

3) Overall Satisfaction

Table 6. Students' Overall Satisfaction of the Interactive Workshop

Overall Satisfaction	WM	VI	AR
1. The workshop content was relevant to improving my understanding of molecular geometry.	3.69	Strongly Agree	Strongly Agree
2. The use of visuals and example enhanced my learning experience.	3.61	Strongly Agree	Strongly Agree
3. The facilitator/s were knowledgeable and communicated the concepts clearly and effectively.	3.64	Strongly Agree	Strongly Agree
4. The depth of the content was appropriate for my level of understanding.	3.58	Strongly Agree	Strongly Agree
5. I am satisfied with the skills I gained during the interactive workshop.	3.72	Strongly Agree	Strongly Agree
6. I feel confident to apply the information I learned in this activity.	3.53	Strongly Agree	Strongly Agree
7. The workshop met my expectations in terms of learning outcomes.	3.50	Strongly Agree	Strongly Agree
Composite Mean	3.61	Strongly Agree	Strongly Agree

Table 6 presents the students' overall Table 6 presents the students' overall satisfaction regarding their experience with the molecular structure interactive workshop. The composite mean of 3.61, interpreted as Strongly Agree, indicates that students consistently perceived the workshop as highly beneficial to their learning of molecular structures, suggesting that the integration of interactive tools such as 3D models effectively supported their conceptual understanding and engagement throughout the activity. Among the indicators, the item, "I am satisfied with the skills I gained during the interactive workshop." (WM = 3.72), recorded the highest weighted mean, indicating that the workshop increased students' appreciation for experiential, interactive learning strategy, consistent with Smiar et al. (2016) and the JoVE Science Education Database (2020), both of which highlighted increased enthusiasm resulting from the use of interactive and 3D-printed models across different learning contexts. The item, "The workshop content was relevant to improving my understanding of molecular geometry." (WM = 3.69), reflects a strong belief in the impact of the workshop on students' understanding of chemistry concepts, aligning with Bobek and Tversky (2016), who reported that visual and interactive explanations promote deeper cognitive processing and enhance long-term memory. The third item, "The facilitator/s were knowledgeable and communicated the concepts clearly and effectively." (WM = 3.64), shows that facilitators performed effectively in improving students' skill-building beyond content acquisition, resonating with Lansangan et al. (2020), who emphasized the role of representational competence in understanding chemical principles. The item, "The use of visuals and example enhanced my learning experience." (WM = 3.61) reflects students' positive engagement and satisfaction with the use of visual aids and 3D model in understanding chemistry concepts. This is similar to Timilsena and Devkota (2022), stating that interactive demonstration of the lessons results in better student performance rather than just the traditional lecture-based learning methods. The item, "The depth of the content was appropriate for my level of understanding" (WM = 3.58) revealed that students felt the material covered in the workshop matched their current knowledge and cognitive abilities, suggesting that the content allows the student to engage meaningfully without being overwhelmed or under-challenged. Kuit and Osman (2021) supported this finding, revealing that significant improvements in knowledge and spatial skills using 3D visualization modules enhance understanding of chemical bonding in an accessible way. The item, "I feel confident to apply the information I learned in this activity." (WM = 3.53), affirms the value of hands-on and multimodal learning tools, supporting Phankingthongkum et al. (2021), who demonstrated that virtual modeling applications significantly improve conceptual understanding, and Kusumaningdyah et al. (2024), who stressed that combining multimedia with hands-on models deepens comprehension among learners with varied reasoning skills. Meanwhile, the seventh item, "The workshop met my expectations in terms of learning outcomes." (WM = 3.50), reflected the lowest weighted mean, though it still indicates a strong positive impact on students' conceptual understanding, aligning with findings from Cañete and Mutya (2025), who argued that improvised molecular kits improve academic performance.

Overall, the consistently high ratings across all items demonstrate that the molecular structure interactive workshop substantially contributed to students' cognitive, motivational, and affective learning outcomes, aligning with extensive literature supporting interactive, model-based, and simulation-supported instructional approaches, and providing strong evidence that integrating 3D molecular models with interactive activities enhances engagement, builds confidence, and improves students' understanding of molecular structure concepts.

V. CONCLUSIONS

The following conclusion are drawn based from the findings and results of the current study.

1) This research successfully conducted the interactive workshop to enhance students' conceptual understanding of molecular structures.
2) The students' conceptual understanding of molecular geometry significantly improved after participating to the interactive workshop.
3) Students agreed that they enjoy and that they actively participated in the interactive workshopn, strongly agreeing that it was effective in terms of learning molecular structure and expressing satisfaction with its integration into the session.

VI. RECOMMENDATIONS

The findings of this study point to several actionable recommendations:

1) Chemistry Instructors could use the workshop during lessons on molecular shapes, offering clear support so learners understand tough topics without losing interest or missing core points.
2) Engineering Departments could use the interactive 3D molecular model workshop as supplemental support for students struggling with spatial reasoning in molecular structures. Pairing advanced students with beginners through guided mentorship programs may strengthen understanding gradually over time.

3) Academic Institutions may provide training for instructors on active techniques rather than one-way classroom talks. Science classes tied together through cross-topic sessions may help students think more widely.
4) Future researchers may repeat this work with bigger or broader groups, test tech aids like virtual models or augmented reality, then follow how well students remember and apply what they learned - helping interactive approaches grow through real feedback.

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