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# Challenges Faced by Teachers and Students in Teaching-Learning Reaction Mechanism

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**Abstract**

*This study explores teachers' and students' difficulties while teaching and learning chemical reaction mechanisms. It included a sample of forty students and four teachers. It was carried out across two of the constituent campuses of TU. Likert scale statements were used in the quantitative methodology employed for the study to measure the difficulties teaching and learning reaction mechanisms. In-depth interviews and Focus Group Discussions (FGDs) with ten students and two purposefully chosen teachers also provided qualitative insights. The results show that students have difficulty in learning inductance, polar covalent bonds, $SN_1$ and $SN_2$ reactions, and homolytic and heterolytic bond fission. Similarly, educators face difficulties restricting pupils' insufficient basic comprehension in modulation and visualization. The use of 3D simulation and modulation can improve understanding of reaction processes. The highlighted areas of this study need intervention to enhance teaching and learning of chemical reaction mechanisms.*

**Keywords:** Challenges, Constructivism, reaction mechanism, 3D modulation, simulation.

## Introduction

Chemistry education deals with teaching and learning chemistry, a branch of science involving matter's properties, composition, structure, and reactions. It can be formal or informal in schools, colleges, universities, various programs, and online

resources (Affeldt et al., 2015). Chemistry education aims to help students understand fundamental chemical concepts, laboratory skills, problem-solving abilities, and critical thinking skills. It covers many topics, including atomic structure, chemical bonding, chemical reactions, stoichiometry, thermodynamics, and kinetics. In addition to theoretical discussions, chemistry education involves practical or hands-on laboratory experiments, demonstrations, and multimedia resources to facilitate protocols, environmental awareness, and ethical considerations in scientific research and practices (Ali et al., 2022). Ultimately, chemistry education is vital in preparing students for learning, safety for careers in various scientific fields, promoting scientific literacy, and fostering curiosity about the natural world.

Mammino (2021) expresses that chemistry education involves teaching students about reaction mechanisms, which are detailed explanations of how chemical reactions occur at the molecular level. Understanding reaction mechanisms is key to understanding the behavior of chemical substances and predicting their reactions. In chemistry classes, students learn various reaction mechanisms: substitution, elimination, addition, and oxidation-reduction reactions. They also study the role of catalysts, reaction intermediates, and rate-determining steps in these mechanisms. Students develop the skills to analyze and propose reaction mechanisms based on experimental evidence and chemical principles by engaging in theoretical discussions, problem-solving exercises, and laboratory experiments. Studying reaction mechanisms in chemistry education helps students gain insights into the underlying processes that drive chemical transformations, facilitating their understanding of chemistry as a discipline.

Recently, the way reaction mechanisms are taught in classrooms has been considered quite traditional, combining lectures and discussions (Broman & Johnels, 2019). However, hands-on activities are lacking to engage and enhance students' understanding. Also, visual aids, such as animations, simulations, and molecular modeling software, are not used to show how the reaction mechanisms and molecular interactions work dynamically and visually. Active learning strategies can encourage student participation and collaboration in analyzing reaction mechanisms.

These strategies include think-pair-share, group discussions, and concept mapping. Additionally, inquiry-based learning approaches are necessary, where students design experiments and engage in case studies to explore reaction mechanisms, propose hypotheses, and draw conclusions through guided inquiry. Real-world applications of reaction mechanisms from current research and industrial processes are emphasized to demonstrate the relevance and practical implications of studying chemistry

(Mutlu et al., 2019). However, formative assessment techniques, such as quizzes and concept inventories, are not used to assess students' understanding and do not provide timely feedback for improvement. Technology integration is given less priority, with educators using digital platforms, online resources, and educational apps to deliver instructional materials, facilitate discussions, and provide supplementary learning materials for studying reaction mechanisms. These recent classroom practices promote active engagement, critical thinking, and a deeper understanding of reaction mechanisms among students in the classroom, fostering a more dynamic and effective learning experience. However, classroom practices of teaching reaction mechanisms are mainly dominated by lectures.

In the Bachelor of Science (B.Sc.) program, practical components are crucial for students to gain hands-on experience, reinforce theoretical concepts, and develop critical skills relevant to their field of study. The experiment was designed to enhance the learning experience of B.Sc. students, preparing them for careers in academia, research, industry, and further education at the graduate level (Hjelmas & Wolthusen, 2006). However, the laboratory sessions are not adequate for students. These may be the challenges for teaching and learning. Reaction mechanisms in chemistry are often complicated; and involve multiple steps and intermediates. These teaching and learning mechanisms can be challenging due to the abstract nature of the concepts involved. Investigating the challenges teachers and students face can provide insights into where the difficulties lie and how they can be addressed. Understanding reaction mechanisms is fundamental to many branches of chemistry, including organic, inorganic, and biochemistry.

Learning reaction mechanisms is essential for students tracking chemistry-related careers. Teachers and researchers must identify challenges in teaching and learning mechanisms to improve instruction. Effective pedagogical strategies, new teaching materials, and innovative methods can address these challenges. Educators can improve student success by understanding student difficulties and implementing strategies to overcome them. Curriculum development can be informed by research on these challenges, leading to better preparation for chemistry-related fields.

## Research Problem

Teaching and learning reaction mechanisms can be challenging for teachers and students (Iyamuremye et al., 2022). Teachers and students may struggle with understanding and explaining the complex concepts involved in reaction mechanisms.

Lack of hands-on experience, time limits, pressure to cover all aspects of the syllabus, and lack of resources also add to the challenges in learning and teaching this subject. These challenges must be addressed to ensure that students develop a deep understanding of the subject and are adequately prepared for higher education and future careers in chemistry-related fields. Teaching and learning reaction mechanisms can be difficult for teachers and students alike (Iyamuremye et al., 2022). The concepts involved in this subject are often complex and require a deep understanding of chemistry principles to explain them briefly. However, students and teachers may struggle with this for various reasons, such as lack of practical experience, limited time to cover all aspects of the syllabus, and inadequate resources for learning and teaching reaction mechanisms.

The lack of hands-on experience can often make it difficult for students to visualize and understand the abstract concepts involved in reaction mechanisms. Additionally, the pressure to cover all aspects of the syllabus within a limited time frame can make it challenging for teachers to delve into the intricacies of this subject and provide detailed explanations. Moreover, the lack of resources such as laboratory equipment, textbooks, and reference materials can further add to the difficulty in learning this subject. It is essential to address these challenges to ensure that students develop a solid foundation in chemistry and are adequately prepared for their higher education and possible future career paths in chemistry-related fields. Therefore, teachers must adopt effective teaching strategies and provide students with sufficient opportunities to practice and apply their knowledge. Similarly, educational institutions must provide adequate resources to support teachers and students in learning and teaching reaction mechanisms.

## Objectives

The study was undertaken with objectives as follows:

- To explore the perceptions of students and teachers toward teaching and learning reaction mechanism in chemistry
- To find out the challenges faced by students in learning reaction mechanisms in chemistry
- To investigate challenges faced by teachers in teaching reaction mechanisms in chemistry

## Research Questions

The following research questions were made for the study.

- How do students and teachers perceive reaction mechanisms in chemistry learning?
- What are the challenges faced by students in learning reaction mechanisms in chemistry?
- What are the challenges faced by teachers in teaching reaction mechanisms in chemistry?

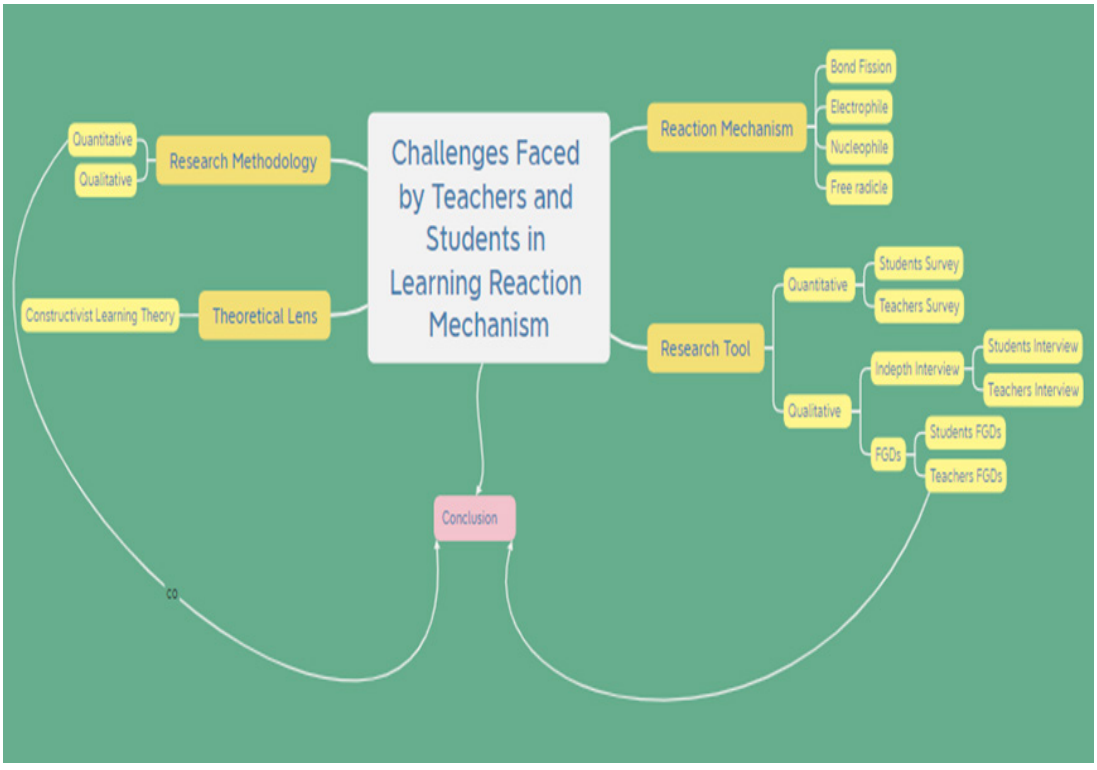
## Significance of the Study

Understanding reaction mechanisms is essential for predicting and explaining chemical reactions and further research. However, students often face challenges in understanding the complex concepts involved. It can negatively affect their academic performance, leading to lower grades, reduced confidence, and a lack of interest in the subject. A deep understanding of reaction mechanisms is required for pursuing advanced studies and careers in chemistry-related fields. Understanding chemical reaction mechanisms is essential for scientific research in pharmaceuticals, materials science, and environmental chemistry. A lack of understanding in this area can limit career predictions and future opportunities for students and hinder scientific progress and innovation. Chemistry has significant implications for society in areas such as healthcare, energy, and the environment, and addressing the challenges in learning and teaching reaction mechanisms is essential for ensuring that students receive a high-quality education and are equipped with the necessary skills for advanced studies and careers in the field.

## Theoretical/ Conceptual Framework

Ibrahim et al. (2014) recommended using the constructivist approach and inquiry strategy during classroom experiments. Akani (2015) found that labs help students build scientific attitudes and problem-solving skills. Tanner (1990) showed the benefits of teaching quantum chemistry using a computer-based method to integrate the Schrodinger equation. A mixed-method research design was used to investigate the challenges teachers and students face in teaching and understanding reaction mechanisms. Surveys, interviews, and Focused Group Discussions (FGDs) were employed to gather data. A conceptual framework was developed to provide an in-depth analysis of the issues.

**Figure 1.** *Theoretical/ Conceptual Framework*




## Methods and Methodology

This study used the concurrent mixed-method research design to investigate bachelor-level students' challenges in chemical reaction mechanisms. Data were collected from 40 students and four teachers using surveys, in-depth interviews, and FGDs. The study was conducted at Dhawalagiri Multiple Campus, Baglung, and Prithivi Narayan Campus, Pokhara. Quantitative tools were validated statistically, while qualitative tools were validated through expert suggestions. Questionnaires were administered via Google Docs for the survey data, while interviews were conducted in person for the qualitative part. The data was analyzed through survey questionnaires, in-depth interviews, and FGDs. The information collected from the field was analyzed, transcribed, coded, and interpreted to solve the research questions. The data analysis involved both quantitative and qualitative methods. Google Docs was used to process Likert scale responses. Descriptive and inferential analyses were performed on mean, frequency, and percentage data. Transcripts were created from interviews and FGDs. Coding was done in content analysis using inductive reasoning. Similar codes were

grouped under a single category and evaluated for similarities and differences before classification. Themes were created by integrating meaningful and comprehensive categories. Finally, the themes were listed under various subheadings.

### Ethical Consideration

This study engaged the research participants with due respect to their right to privacy. Before the study began, each patient gave their complete agreement for it to be carried out. Both participant information and research data were kept private. The study takes an unbiased approach by including whatever inaccuracies it may detect together with the results of the original data.

## Results and Findings

The following results and findings were reported using quantitative and qualitative data analysis.

## Quantitative Analysis

Researchers used a Google Docs form with a Likert scale to measure science students' opinions on classroom challenges. Data was collected and analyzed based on frequency and percentage. The following table shows the students' responses regarding learning chemical reaction mechanisms.

**Table 1.** *Student's Responses Towards Learning Chemical Reaction*

| SN | Questions | SA | A | N | D | SD |
|---|---|---|---|---|---|---|
| 1 | I feel difficulty understanding the reaction mechanism. | 62.5 | 7.5 | 30 | 0 | 0 |
| 2 | I find it challenging to write reaction mechanisms taught in class. | 37.5 | 10 | 35 | 15 | 2.5 |
| 3. | I agree that the definitions of valence electrons, electron density, and polarity are easy to learn. | 52. 5 | 27.5 | 12.5 | 5 | 2.5 |

*Note:* SA = Strongly Agree; A = Agree; N = Neutral; D = Disagree; SD = Strongly Agree; SA = Strongly Disagree

Table 1 shows that 70% of the students find it challenging to learn chemical reactions. However, 80% of students find learning definitions related to valence electrons, electron density, and polarity easy. It indicates a potential difference in students'

comfort levels with various aspects of the subject matter, emphasizing the need for specialized support and teaching methods.

**Table 2.** *Students' Response Towards Learning Chemical Reaction*

| SN | Questions | SA | A | N | D | SD |
|---|---|---|---|---|---|---|
| 1 | The complexity of reaction mechanism concepts hinders my learning progress. | 25 | 75 | 0 | 0 | 0 |
| 2 | The concept of SN1 and SN2 reaction mechanisms is difficult for me. | 50 | 25 | 0 | 25 | 0 |

*Note:* SA = Strongly Agree; A = Agree; N = Neutral; D = Disagree; SD = Strongly Agree; SA = Strongly Disagree

Table 2 shows that 75% of students find the complexity of reaction mechanism concepts hindering their progress, while 50% find $SN_1$ and $SN_2$ reaction mechanisms difficult to understand. These challenges suggest a need for instructional support to improve students' comprehension and confidence.

**Table 3.** *Teachers' Response to Teaching Chemical Reaction*

| | Statements | Responses | | | | |
|---|---|---|---|---|---|---|
| SN. | | SA% | A% | N% | D% | SD% |
| 1 | Teachers should have command of the elementary reaction and mechanism for students' learning | 75 | 25 | 0 | 0 | 0 |
| 2 | Students themselves can define reaction intermediates easily | 25 | 50 | 0 | 25 | 0 |
| 3 | Students can tell the definition of electrophiles and nucleophiles before studying the reaction mechanism. | 75 | 0 | 0 | 25 | 0 |
| 4 | Teachers have obstacles in teaching learning reaction mechanism | 50 | 50 | 0 | 0 | 0 |

*Note:* SA = Strongly Agree; A = Agree; N = Neutral; D = Disagree; SD = Strongly Agree; SA = Strongly Disagree

Table 3 presents teachers' responses to teaching reaction mechanisms, categorized into five levels of agreement. Seventy-five percent strongly agree, and 25% disagree, that students can easily understand reaction intermediates. Similarly, seventy-five percent strongly agree, and 25% disagree, that students can define electrophiles and

nucleophiles before studying reaction mechanisms. Half of the teachers agree that they face obstacles in teaching and learning reaction mechanisms.

**Table 4.** *Teachers' Response to Teaching Chemical Reaction*

| SN | Statement | Response | | | | |
|---|---|---|---|---|---|---|
| | | SA% | A% | N% | D% | SD% |
| 1 | Students cannot tell the definition of electrophiles and nucleophiles before studying the reaction mechanism | 25 | 25 | 0 | 25 | 25 |
| 2 | Teachers have no obstacles in teaching learning reaction mechanism | 0 | 25 | 0 | 75 | 0 |
| 3 | Teachers should have less command of elementary reactions for teaching learning reaction mechanisms. | 0 | 0 | 0 | 100 | 0 |

*Note:* SA = Strongly Agree; A = Agree; N = Neutral; D = Disagree; SD = Strongly Agree; SA = Strongly Disagree

Table 4 shows students' responses regarding teaching reaction mechanisms and their understanding of electrophiles and nucleophiles. Responses were categorized into Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. 25% of students strongly agree that they understand reaction mechanisms. 75% disagree that teachers have no obstacles in teaching reaction mechanisms. 100% disagree that teachers should not have a command of elementary reactions for teaching.

**Table 5.** *Challenges Faced by Students in Learning Reaction Mechanism*

| SN | Statements | Frequency | | | | | |
|---|---|---|---|---|---|---|---|
| | | SA% | A% | N% | D% | SD% | Total |
| 1 | I am having difficulties understanding the reaction mechanism. | 7.5 | 62.5 | 30 | 0 | 0 | 100 |
| 2 | I have difficulties in writing reaction mechanisms. | 10 | 37.5 | 35 | 15 | 2.5 | 100 |
| 3 | I have less difficulty defining valence electrons, electron density, and polarity. | 27.5 | 52.5 | 12.5 | 5 | 2.5 | 100 |

*Note:* SA = Strongly Agree; A = Agree; N = Neutral; D = Disagree; SD = Strongly Agree; SA = Strongly Disagree

Table 5 shows that students struggle with understanding reaction mechanisms (62.5%), writing them (37.5%), and defining key concepts (52.5%). Based on the study's results,

there is a clear requirement for additional instructional support if students are to improve their learning. Therefore, teachers should explore and implement alternative approaches to teaching to help students achieve a greater level of understanding.

**Table 6.** *Challenges Faced by Teachers in Learning Reaction Mechanism*

| SN | Statement | Frequency % | | | | | |
|---|---|---|---|---|---|---|---|
| | | SA | A | N | D | SD | Total |
| 1 | Teachers have problems faced with teaching elementary reactions and mechanisms for students learning. | 75 | 25 | 0 | 0 | 0 | 100 |
| 2 | Students have problems defining reaction intermediates. | 25 | 50 | 0 | 25 | 0 | 100 |
| 3 | Students are confused in identifying electrophiles and nucleophiles before studying reaction mechanism. | 75 | 0 | 0 | 25 | 0 | 100 |
| 4 | Teachers have obstacles in teaching learning reaction mechanisms. | 50 | 50 | 0 | 0 | 0 | 100 |

Table 6 shows the challenges faced by teachers in teaching reaction mechanisms. Most teachers (75%) find teaching elementary reactions and mechanisms challenging. 50% of teachers say they have obstacles teaching learning reaction mechanisms. Half of the teachers also report obstacles in teaching and learning reaction mechanisms. These findings highlight the complexities teachers face in delivering effective instruction on reaction mechanisms and suggest a need for additional support.

## Qualitative Analysis

Reaction mechanisms are significant for learning chemistry and personal development. A qualitative response discussed the challenges associated with learning them.

### Reaction Mechanism and Its Challenges Area

A reaction mechanism is a step-by-step description of the changes involved in a chemical reaction. It includes basic concepts like bond fission, electrophile, nucleophile, and free radicles. The mechanisms in organic chemistry include substitution, addition, elimination, rearrangement, and free radical reaction. However, some of the contents can be challenging for students to learn. As a participant, one of the students $S_{10}$ says, "I can describe the arrangement of electrophiles, nucleophiles, and free radicals to

write the steps of reactions proceeds. The condition of bond fission and the formation of attacking reagents identification confuses me" (interview recorded, July 2023).

The above views of participants point out that the concept of bond fission and the formation of electrophile, nucleophile, and free radicles are challenges for learning reaction mechanisms. Similarly, the participants, such as teacher T3, also support this area of reaction mechanism, which is challenging for the students to teach in classroom practices. Likewise, another participant, student S7, pinpointed the problematic areas of the reaction mechanism as "The factors that affect the reaction rate, like inductive, mesomeric, and electrometric effects of the reaction mechanism, are challenging to learn. Similarly, writing the reaction mechanism stepwise is also complicated for me" (interview recorded, July 2023)

The above view indicated that factors affecting the reaction rate, like the reaction mechanism's inductive, mesomeric, and electrometric effects, are challenging.

**Challenges Faced by Students in Learning Mechanisms**

Students face various challenges in learning reaction mechanisms. Learning is difficult for students, so reaction mechanisms are challenging and exciting. In this context, one of the students' $S_{1s}$ told me, "When I entered my science class, the teacher used the traditional lecture method, so we learned passively within the classroom. Still, the teacher only teaches us but does not assess how we understand" (interview recorded, July 2023).

The above information of participants indicated that the science classes' practices are based on traditional teaching, which leads to challenges in learning reaction mechanisms. The research conducted by Berrett (2012) also matches the above view of participants. Similarly, participant $S_5$ expressed, "The traditional teaching method is not fruitful for the teaching-learning reaction mechanism. Memorization and recall do not foster creative and critical thinking on reaction mechanisms. It is not conceptualized due to rote memorization" (interview recorded, July 2023).

The above view of participants explores that the teaching methods also affect the learning reaction mechanism. Most of the participant's views support this statement. The traditional teaching method does not foster creative and critical thinking for students learning. Therefore, conventional teaching methods present challenges for students in learning reaction mechanisms.

## Challenges Faced by Teachers in Reaction Mechanism

Chemistry is an essential subject in our daily lives, and it has many potential benefits for our future. Many academics regard Organic Chemistry as a challenging course. Understanding reaction mechanisms is one of the problematic aspects of Organic Chemistry for students. However, according to various research reports, Organic Chemistry is a complex subject for students who follow a career in this field (Bhattacharyya & Bodner, 2005; Childs & Sheehan, 2009; Ferguson & Bodner, 2008; Johnstone, 1991; O'Dwyer & Childs, 2011; Sirhan G., 2007). According to Johnston (1991), the nature of Chemistry concepts and how they are represented (macroscopic, microscopic, or symbolic) are essential. The methods used to teach pupils may conflict with the nature of science or the methods used by teachers in the past (Johnstone, 1997; Li & McCormick, 2006; Simsek, 2009). Regarding challenges faced by the teacher in the teaching reaction mechanism, one of the teachers, $T_4$, says as follows:

> Teachers have fewer ideas on identifying the students' prior knowledge, misconceptions, and cognitive development level. The teaching reaction mechanism is complex and challenging due to the lack of knowledge to classify the content into macroscopic, microscopic, or representational levels. The content of the reaction mechanism is also abstract. It is not easily visualized. (interview recorded, July 2023)

The above views of the participants point out that most teachers have no idea how to identify the prior knowledge of students, their misconceptions, and different levels of cognitive development. Similarly, they do not categorize the contents of chemistry into Johnston's macroscopic, microscopic, or representational levels. Therefore, teaching reaction mechanisms is challenging.

Teaching Methods and Complexity in Learning Mechanisms. Students' poor scores in understanding different teaching styles may be due to their lack of exposure. This is especially true for science majors, mostly taught through traditional lectures. Students face difficulties in learning reaction mechanisms, and teachers need to be trained in using student-centered teaching approaches and updated on the latest ICT techniques. The views of teacher and student on teaching and learning are as follows:

> Some teaching methods like discussion, interactive demonstration, experimental, individualized instruction, collaborative, cooperative, etc. are effective for teaching and learning, making it easy to learn. The traditional

> method of teaching is not fruitful for the teaching-learning reaction mechanism. Memorization and recall do not foster creative and critical thinking in the reaction mechanism. It is not conceptualized due to rote memorization. (FGD recorded, July 2023)

The above view of participants indicates that teaching does not contextualize an effective learning process like the pedagogy of science. Students are believed to learn more from their experiences. Therefore, the teaching method impacts meaningful learning in the reaction mechanism. The reaction mechanism has many symbols of atoms and molecules, notation of chemical reactions, cations, and anion charge carriers, which are complex for students learning the reaction mechanism.

### Impact of ICT on Learning Reaction Mechanism

ICT can enhance the quality of chemistry education by solving problems related to traditional classroom teaching methods. ICT tools and techniques can help students understand the subject matter in-depth, particularly in teaching reaction mechanisms. Instructional provisions concern to a significant extent, as a participant said:

> We have only limited knowledge and skills in ICT. This is rooted in the absence of relevant training on learning. Organic chemistry courses cover a wide range of topics that require conceptual understanding and knowledge, which might be related to students' perceptions that the course is challenging. Organic chemistry is considered a complex subject within the branch of chemistry, preventing learners from continuing to study the subject matter. (FGDs recorded, July 2023)

The views of learners and teachers find it challenging to fascinate ICT services, and some educational materials are lacking. This has made learning reaction mechanisms increasingly complex over time, and the need to address this problem rests on the bears of the learners and their teachers.

## Visualization of Reaction

Molecular modeling packages utilize animated reaction mechanisms, which aid in organic chemistry. 3D visualization provides a better understanding of these reactions. These resources are helpful for first-year college students taking chemistry courses and improving their learning abilities. The views of teacher $T_1$ express the poor foundation

of students about modulation and visualization, and $T_2$ expresses that visualization of reaction is too difficult and complex.

The above views of teachers show that students' poor foundations in modulation and visualization make teaching reaction mechanisms challenging.

### Ways of Minimizing Challenges in Learning Reaction Mechanism

The teacher expressed that identifying prior knowledge, understanding the abstract nature of chemistry content, and complex areas of reaction mechanisms are all challenges to teaching and learning. Their goal is to find ways to minimize these challenges. For ways to minimize learning difficulties and challenges, most of the participants say, "Training in student-centered teaching methods leading to meaningful learning should be provided to teachers in professional development programs to facilitate teaching and learning of reaction mechanisms. They should also be aware of the recent exclusion of knowledge-based ICT techniques."

This narrative of respondents indicates that the teacher needs in-service training for professional development. We need to use the student-centered approach in classroom practices, and teachers should have ideas about integrating ICT knowledge into classroom teaching, Johnston's triangle of three levels of chemical representation, and innovative teaching materials to visualize the abstract concept of chemistry content.

## Discussion

This study has attempted to investigate students' and teachers' challenges in learning and teaching chemical reaction mechanisms. Results show that while most students can understand the concepts of molecular geometry, hybridization, acids, and bases, a significant portion struggle with bonding, intermediate stability, resonance, and inductive effects. These concepts resonate with the study of Kilpatrick (2020). Furthermore, Lewis structures, electrophiles, and nucleophiles were identified as crucial concepts, yet a quarter of students were unsure of their definitions. Many students struggle to understand and write reaction mechanisms despite being able to explain bonding, intermediate stability, resonance, and inductive effects. Lewis structures, electrophiles, and nucleophiles are crucial concepts in organic reaction mechanisms, but many students have trouble defining them. Teachers agree that students must understand electrophiles and nucleophiles before learning about reaction mechanisms. Students find abstract concepts like reaction mechanisms challenging

but can easily understand electronegativity and polar covalent bonds. These findings match Boateng's study (2024).

Students struggle to understand the differences between homolytic and heterolytic bond fission, curly arrows, and the experimental rate rule about reaction mechanisms. Teachers find it challenging to teach reaction mechanisms due to weak foundations in modulation and visualization. The visualization and simulation concepts are highlighted in the study of Meltzoff et al. (2009) foundations for a new science of learning. Simulations and knowledge of electronegativity, polarity, valency electron, and electron density are essential for understanding organic reaction mechanisms. Understanding Lewis structures, electrophiles, and nucleophiles is also significant for students.

## Conclusion

For many students who study chemistry, electronegativity may come quickly to them. However, they may face challenges regarding more complex topics such as reaction mechanisms, polar covalent bonds, inductive effects, SN1 and SN2 reactions, and hemolytic and heterolytic bond fission. One of the students' most significant difficulties is linking reaction mechanisms with experiments. It can be particularly challenging without a concrete experimental basis. Furthermore, another challenge that students often face is understanding the less prior concept of the direction of attack and the stability of the products, which can be problematic for teachers trying to teach reaction mechanisms. In addition, students may also struggle with the foundations of modulation and visualization, which can present difficulties for teachers. However, students can better understand reaction mechanisms using the latest technology, 3D modulation, and simulation. These tools provide a visual and interactive representation of chemical reactions, enabling students to better understand the concepts and their applications.

## Implications

Policies should focus on improving infrastructure, teacher training, and curriculum design to improve the teaching and learning of reaction mechanisms. Teachers should use various teaching strategies, create a supportive learning environment, and use technology to make concepts more accessible. Research can help identify the challenges and effective interventions. Constructivist learning theory and Dewey's pragmatism can enhance understanding of complex subjects like reaction mechanisms.

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