Research Article

**Nuraga: Journal of Education and Learning Insights**
Volume 1, Number 1, 2026
Open Access: http://journal.nuragascientific.com/jeli

# Exploring the Implementation of Online Chemistry Learning During the COVID-19 Pandemic: A Case Study of a Public High School in Kendari City

**Arsyil Salido[1*], La Harimu[2], Dahlan Dahlan[2]**
[1] Department of Master of Science Education, Universitas Halu Oleo, Indonesia
[2] Department of Chemical Education, Universitas Halu Oleo, Indonesia

Received March 27th, 2026 | Revised Apr 3th, 2026 | Accepted June 20th, 2026

**Abstract**
The COVID-19 pandemic forced schools worldwide to transition from face-to-face instruction to online learning, creating particular challenges for chemistry education due to its emphasis on conceptual understanding, scientific inquiry, and laboratory activities. This study aimed to examine the implementation of online chemistry learning during the COVID-19 pandemic in public senior high schools in Kendari City, Indonesia. A descriptive qualitative design was employed involving 701 Grade XI science students from six public schools and six chemistry teachers. Data were collected through validated online questionnaires and semi-structured interviews and analyzed using thematic analysis. The findings revealed five major themes. First, online learning became the primary instructional approach, although schools provided alternative learning arrangements for students with limited access to technology. Second, teachers utilized various digital platforms, including Google Classroom, Microsoft Teams, Zoom, Google Meet, YouTube, and WhatsApp Group, to facilitate instruction, communication, and assessment. Third, most students actively participated in online learning and reported generally positive perceptions of the learning process despite experiencing difficulties in understanding chemistry concepts and completing assignments. Fourth, assessment practices continued to address cognitive, affective, and psychomotor domains through assignments, quizzes, projects, portfolios, and online examinations. Finally, major challenges included limited access to devices, unstable internet connectivity, insufficient data quotas, and difficulties in monitoring student engagement. These findings highlight the importance of inclusive digital learning strategies, adequate technological infrastructure, and adaptive chemistry teaching approaches to support effective learning during emergency situations and future digital education initiatives.

**Keywords:** COVID-19 pandemic, digital learning platforms, online chemistry learning, science education, secondary education.

**To cite this article**: Salido, A., Harimu, L., & Dahlan, D. (2026). Exploring the implementation of online chemistry learning during the covid-19 pandemic: A case study of a public high school in Kendari city. *Nuraga: Journal of Education and Learning Insights, 1*(1), 12-24.

## INTRODUCTION

The Coronavirus Disease 2019 (COVID-19) pandemic has transformed many aspects of human life, including education. To curb the spread of the virus, the Indonesian government implemented social restriction policies that forced schools to suspend face-to-face instruction and transition to distance learning. This shift prompted educational institutions to adopt online learning as the primary mode of instruction to ensure educational continuity. Online learning utilizes digital technologies and internet-based platforms to facilitate interactions between teachers and students regardless of time and location constraints (Dhawan, 2020; Hodges et al., 2020). While online learning offers flexibility and broader access to educational resources, its successful implementation depends on teachers' and students' readiness, the availability of technological infrastructure, and the use of instructional strategies aligned with the characteristics of specific subjects (Bao, 2020; Basilaia & Kvavadze, 2020).


***Corresponding author:** Arsyil Salido, arsyilalfatih@gmail.com

Among school subjects, chemistry presents unique challenges in online learning environments. Chemistry education requires not only the acquisition of scientific concepts and principles but also the development of scientific process skills, experimental competencies, and the ability to connect macroscopic, submicroscopic, and symbolic representations of chemical phenomena (Taber, 2019; Talanquer, 2018). These characteristics make chemistry highly dependent on interaction, demonstrations, and laboratory activities to support meaningful conceptual understanding. During the pandemic, restrictions on face-to-face laboratory work became a major obstacle to effective chemistry instruction (Accettone, 2022; Díez-Pascual & Jurado-Sánchez, 2022; Kelley, 2021). Consequently, the abrupt transition to online learning had the potential to influence instructional quality, student participation, assessment practices, and the achievement of chemistry learning outcomes (Qazi et al., 2023).

Previous studies have examined various aspects of chemistry learning during the COVID-19 pandemic. Farida et al. (2020) reported that chemistry education students were generally able to adapt to online learning through the use of various digital platforms. However, they continued to experience difficulties with topics involving chemical calculations, chemical reactions, and submicroscopic representations. Similarly, Al-Idrus et al. (2021) found that online chemistry learning among chemistry education students at FKIP UNRAM was implemented successfully, although challenges related to internet connectivity, health conditions, and home learning environments persisted. Rahman and Silaban (2021) demonstrated that Zoom was effective in supporting communication and student satisfaction in online chemistry learning. In addition, Saraswati and Mertayasa (2020) showed that online technologies could effectively facilitate chemistry laboratory activities through platforms such as Google Classroom, WhatsApp, and Google Meet. Collectively, these studies have provided valuable insights into the effectiveness of digital platforms, student perceptions, and the implementation of online chemistry laboratory activities during the pandemic.

Despite these contributions, several limitations remain in the existing literature. First, most previous studies have focused on higher education settings, particularly chemistry education students (Al-Idrus et al., 2021; Farida et al., 2020; Rahman & Silaban, 2021). Second, prior research has typically examined specific aspects of online chemistry learning separately, such as platform effectiveness, student perceptions, or virtual laboratory implementation. As a result, a comprehensive understanding of the overall online chemistry learning process remains limited. Third, relatively few studies have investigated online chemistry learning at the senior high school level, particularly those that simultaneously examine instructional approaches, student participation, learning media, student responses, assessment practices, and learning challenges. Furthermore, empirical evidence from Eastern Indonesia, including Kendari City, remains scarce, leaving the characteristics of online chemistry learning implementation in this context insufficiently documented.

This study addresses these gaps by providing a comprehensive analysis of online chemistry learning implementation at the senior high school level during the COVID-19 pandemic. Unlike previous studies that focused on a single aspect of learning or were conducted in higher education contexts, this study integrates multiple dimensions of online chemistry learning, including instructional approaches, student participation, learning media, student responses, assessment practices, and learning challenges within a unified analytical framework. In addition, the study involves 701 students from six public senior high schools in Kendari City, offering broader empirical evidence regarding the implementation of online chemistry learning in secondary education. The findings are expected to contribute to the development of more adaptive chemistry teaching strategies for emergency situations and future digital learning environments.

Based on these considerations, this study aims to analyze the implementation of online chemistry learning during the COVID-19 pandemic in public senior high schools in Kendari City. Specifically, the study seeks to address the following research questions:

1. How was online chemistry learning implemented in public senior high schools in Kendari City during the COVID-19 pandemic?
2. What learning media and digital platforms were used to support online chemistry learning?
3. How did students respond to online chemistry learning, and what was their level of participation?
4. How were assessment practices implemented during online chemistry learning?

5. What challenges did teachers and students encounter during the implementation of online chemistry learning?

## LITERATURE REVIEW

### Online Learning During the COVID-19 Pandemic

The COVID-19 pandemic triggered a major transformation in educational systems worldwide. Social restriction policies led to the suspension of face-to-face instruction and its replacement with technology-mediated distance learning (Dhawan, 2020; Hodges et al., 2020). In this context, online learning emerged as the primary alternative for ensuring educational continuity. Online learning utilizes internet-based technologies and digital tools to facilitate interactions between teachers and students without requiring physical presence (Dhawan, 2020). Its key characteristics include flexibility in time and location, broader access to learning resources, and the ability to support both synchronous and asynchronous communication according to learners' needs (Chen et al., 2021; Fernandes et al., 2023).

The implementation of online learning requires the readiness of multiple educational components, including teachers, students, curricula, and technological infrastructure. The effectiveness of online learning is influenced by instructional design quality, appropriate technology integration, meaningful interaction, and institutional support (Bao, 2020). Previous studies have shown that digital platforms played a crucial role in maintaining educational activities during the pandemic. However, challenges related to internet accessibility, digital literacy, and users' readiness to adapt to new learning environments remained prevalent (Basilaia & Kvavadze, 2020; Dhawan, 2020). Therefore, the success of online learning depends not only on technological availability but also on the ability of teachers and students to adapt to changing instructional practices (Chen et al., 2021; Xiao et al., 2024).

### Characteristics of Chemistry Learning in Online Environments

Chemistry is a branch of science that examines the structure, properties, composition, and transformations of matter and the energy associated with these changes. Chemistry education possesses distinctive characteristics because it requires not only conceptual and theoretical understanding but also scientific process skills, scientific reasoning, and laboratory experiences that support meaningful learning (Kelley, 2021; Taber, 2019). Furthermore, understanding chemical concepts requires learners to connect macroscopic, submicroscopic, and symbolic representations, commonly referred to as the chemistry triplet representation (Hamerská et al., 2024; Talanquer, 2018). The integration of these representations enables students to develop a comprehensive understanding of chemical phenomena through observation, experimentation, modeling, and scientific reasoning.

These characteristics make chemistry particularly challenging to teach and learn in online environments. Previous studies have reported that students often struggle with abstract concepts involving submicroscopic representations, conceptual relationships, and quantitative problem-solving when chemistry instruction is delivered online (Aroch et al., 2024; Fitria & Sebastian, 2024). In addition, restrictions on face-to-face laboratory activities became a significant barrier during the pandemic because laboratory experiences are essential for developing scientific process skills and conceptual understanding (Accettone, 2022; Díez-Pascual & Jurado-Sánchez, 2022; Kelley, 2021). Consequently, chemistry teachers are required to design instructional strategies that support conceptual learning, scientific inquiry, and chemical visualization through the use of digital technologies, virtual laboratories, simulations, and other interactive learning resources (Aroch et al., 2024; Hu-Au, 2024).

### Digital Media and Platforms in Chemistry Education

Instructional media play a critical role in supporting the effectiveness of online learning. They facilitate the delivery of information and help students understand complex concepts through visualization, interaction, and structured learning experiences (Aroch et al., 2024; Mayer & Fiorella, 2011). In online learning environments, instructional media encompass not only digital learning materials but also digital platforms that enable communication, collaboration, and interaction between teachers and students. The effective use of instructional media can enhance student

engagement, increase learning flexibility, and broaden access to educational resources (Bond et al., 2021; Dhawan, 2020).

Various digital platforms have been employed to support chemistry learning during the COVID-19 pandemic. Video-conferencing tools such as Zoom and Google Meet facilitate synchronous interaction, while learning management systems such as Google Classroom support content distribution, assignment submission, and learning management (Bond et al., 2021; Pokhrel & Chhetri, 2021). Moreover, virtual laboratories, interactive simulations, and technology-enhanced visualizations have been shown to support students' understanding of abstract chemical concepts, particularly those involving submicroscopic representations and phenomena that cannot be directly observed (Aroch et al., 2024; Hu-Au, 2024). These technologies enable teachers to deliver instruction, facilitate discussions, assign learning activities, and conduct assessments more flexibly. Nevertheless, their effectiveness depends on internet quality, users' digital competencies, and the alignment between instructional media, learning objectives, and content characteristics (Bond et al., 2021; Pokhrel & Chhetri, 2021).

**Student Participation, Assessment Practices, and Learning Challenges**

Student participation is a key indicator of successful online learning. It reflects students' involvement in learning activities, interactions with teachers and peers, and completion of assigned tasks. High levels of participation suggest that learning experiences are engaging and motivating, encouraging students to become actively involved in the learning process (Bond et al., 2021; Martin & Bolliger, 2018). In contrast, low participation may indicate barriers that reduce the quality of learning experiences and negatively affect learning outcomes (Bond et al., 2021; Qazi et al., 2023).

In addition to participation, assessment practices and learning challenges are critical components of online learning implementation. Previous studies have identified limited internet access, inadequate technological devices, unfavorable home learning environments, and low digital literacy as major challenges during the pandemic (Adedoyin & Soykan, 2023; Bond et al., 2021; Pokhrel & Chhetri, 2021). In chemistry education, these challenges become even more pronounced because students are expected not only to understand abstract concepts but also to engage in laboratory-related activities and solve complex problems that require intensive interaction with teachers and learning resources (Aroch et al., 2024; Kelley, 2021). Consequently, teachers need to adopt flexible and adaptive assessment strategies by utilizing digital quizzes, projects, portfolios, and performance-based tasks to ensure fair assessment and comprehensive evaluation of students' competencies (Adedoyin & Soykan, 2023).

**Conceptual Framework**

Online chemistry learning during the COVID-19 pandemic represents a complex educational phenomenon shaped by multiple interrelated factors. The unique characteristics of chemistry education, including conceptual understanding, scientific process skills, and laboratory activities, require substantial instructional adaptation when learning is conducted online. In this context, successful implementation depends not only on the use of digital technologies but also on student engagement, assessment strategies, and the ability of schools to address emerging challenges.

Drawing on the literature, this study conceptualizes online chemistry learning implementation as a system comprising six key components: instructional approaches, student participation, learning media, student responses, assessment practices, and learning challenges. Instructional approaches refer to the strategies employed by teachers to facilitate learning during the pandemic. Student participation reflects learners' engagement in instructional activities. Learning media encompass the digital platforms and educational resources used to support learning. Student responses represent learners' perceptions and experiences of online chemistry learning. Assessment practices refer to the procedures used to evaluate students' achievement of learning objectives. Finally, learning challenges include the barriers encountered by both teachers and students during the implementation of online learning.

These six components are analyzed holistically to provide a comprehensive understanding of online chemistry learning implementation during the COVID-19 pandemic in public senior high schools in Kendari City. The conceptual framework serves as the foundation for data collection, data analysis, and the interpretation of research findings.

## RESEARCH METHODS

### Research Design

This study employed a qualitative approach with a descriptive qualitative design. This design was selected because the study aimed to obtain a comprehensive understanding of online chemistry learning during the COVID-19 pandemic based on students' and teachers' experiences and perceptions. A descriptive qualitative approach allows researchers to explore educational phenomena in real-life contexts without manipulating the conditions being studied (Maria & Susilowati, 2026; Martins & Reis, 2026).

The study focused on identifying the key aspects that shaped the implementation of online chemistry learning. These aspects included instructional approaches, student participation, learning media, student responses, assessment practices, and learning challenges. Through this approach, the study not only described the learning practices implemented during the pandemic but also interpreted the experiences and challenges encountered in online chemistry learning.

### Research Sample or Participants

The study was conducted in six public senior high schools in Kendari City, Southeast Sulawesi, Indonesia. Data were collected during the even semester of the 2020/2021 academic year, from February to March 2021. During this period, distance learning policies were still being implemented in most schools.

The participants consisted of 701 Grade XI science students selected through purposive sampling. These students were selected because they had directly experienced online chemistry learning during the COVID-19 pandemic. In addition, six chemistry teachers from the participating schools were involved as informants. They provided more detailed information about instructional implementation, assessment strategies, and challenges encountered during the learning process.

### Instruments and Data Collection

This study used two main instruments: a questionnaire and a semi-structured interview guide. The questionnaire was developed based on the literature on online learning and chemistry learning during the COVID-19 pandemic (Al-Idrus et al., 2021; Farida et al., 2020; Rahman & Silaban, 2021). It covered six main dimensions: (1) instructional approaches, (2) student participation, (3) learning media, (4) student responses to learning, (5) assessment practices, and (6) learning challenges. Most questionnaire items used multiple-choice formats, while several open-ended questions were included to allow students to provide additional explanations about their learning experiences.

Before being used, the questionnaire and interview guide underwent content validation by three experts in chemistry education, educational assessment, and research methodology. The experts evaluated the alignment of each item with the research objectives, the clarity of wording, and the relevance of the measured indicators. Based on their feedback, several items were revised to improve clarity and contextual suitability for online learning. The validation results indicated that all indicators were relevant and appropriate for data collection.

Data were collected by distributing the questionnaire through Google Forms with the assistance of chemistry teachers at each school. This online platform was chosen to align with learning conditions during the pandemic and to facilitate participant access. After the questionnaire data had been collected, semi-structured interviews were conducted with chemistry teachers. These interviews aimed to obtain deeper explanations of the questionnaire results and strengthen data triangulation. The interview questions were open-ended, allowing informants to provide broader and more contextual accounts of their experiences.

### Ethical Considerations

This study followed ethical principles for research involving human participants. Before data collection, the researchers obtained permission from the participating schools. All participants received information about the study objectives, research procedures, data confidentiality, and their right to withdraw from participation at any time without any consequences. Participation in the study was voluntary. Informed consent was obtained electronically before respondents completed the online questionnaire. The identities of all participants were kept confidential, and all collected data were used solely for academic and research purposes.

### Data Analysis

Data were analyzed using thematic analysis based on the qualitative data analysis framework proposed by Miles et al. (2014). The analysis involved four interconnected stages: data collection, data condensation, data display, and conclusion drawing/verification. During the data collection stage, all questionnaire responses from students and interview data from teachers were compiled and prepared for analysis.

The second stage, data condensation, involved selecting, simplifying, coding, and organizing the data according to the research focus. Relevant information related to the implementation of online chemistry learning was identified and grouped into initial categories. Subsequently, the categorized data were displayed in tables, figures, and descriptive narratives to facilitate the identification of patterns, trends, and relationships across categories. This stage also enabled comparisons between students' and teachers' perspectives.

The final stage consisted of conclusion drawing and verification. The researchers identified the major themes emerging from the data and interpreted their meanings in relation to the research objectives. To enhance the credibility of the findings, source triangulation was conducted by comparing information obtained from student questionnaires and teacher interviews. Verification was performed continuously throughout the analysis process to ensure the consistency, trustworthiness, and accuracy of the interpretations.

## RESULTS

Data obtained from student questionnaires and teacher interviews were analyzed using thematic analysis. The analysis identified five major themes that characterized the implementation of online chemistry learning in public senior high schools in Kendari City during the COVID-19 pandemic. These themes included the implementation of online chemistry learning, the use of learning media and digital platforms, student participation and responses, assessment practices, and challenges encountered during the learning process.

### Implementation of Online Chemistry Learning

Questionnaire data indicated that most schools adopted online learning as the primary approach to chemistry instruction during the COVID-19 pandemic. As shown in Figure 1, all students from School A reported that chemistry learning was conducted online. Similarly, high percentages of students in other schools reported the use of online learning, reaching 97% in School B, 86% in School C, 89% in School D, and 95% in both School E and School F.

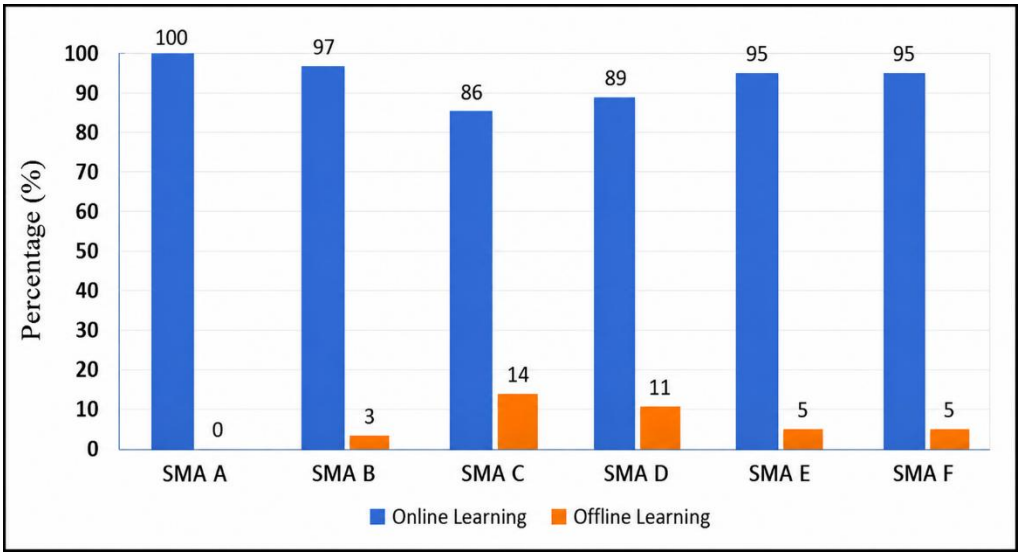


Figure 1. Overview of Chemistry Learning Approaches Implemented During the COVID-19 Pandemic

Despite the predominance of online learning, a small proportion of students reported that instruction was not conducted entirely online. The percentage ranged from 3% to 14% across schools. Interview findings revealed that teachers provided alternative learning arrangements for students

who were unable to participate in online learning due to limited access to devices, internet connectivity, or data quotas.

Interview data further indicated that instruction was not limited to conceptual content. Teachers continued to implement practical activities through various adaptations. Some schools used experiment videos shared through digital platforms, whereas others assigned simple home-based practical activities that students could perform independently using teacher-prepared guidelines.

### Learning Media and Digital Platforms

The findings showed that teachers utilized a variety of instructional media and digital platforms to support online chemistry learning. The most frequently used instructional materials included PowerPoint presentations, student worksheets, learning videos, and teacher-developed digital resources. In addition to these materials, several digital platforms were employed to facilitate content delivery, communication, discussion, and assignment submission, including Microsoft Teams, Google Classroom, Zoom, Google Meet, YouTube, and WhatsApp Groups.

Interview findings indicated that platform selection was largely influenced by ease of use, accessibility for students, and efficient internet data consumption. Teachers preferred platforms that could support both instructional and administrative functions while remaining accessible to students with varying technological resources. Consequently, these platforms were used not only for synchronous learning activities, such as virtual meetings and discussions, but also for asynchronous purposes, including content distribution, assignment submission, and ongoing communication between teachers and students.

### Student Participation and Responses

The findings indicated that most students participated in the online chemistry learning activities organized by their schools. However, participation was not consistent across all students. Some participants reported limited access to learning facilities, particularly the lack of smartphones and reliable internet connections. Teacher interviews further revealed that students living in areas with poor internet coverage experienced difficulties participating regularly in online learning activities. To address this issue, several schools provided alternative learning resources, such as printed worksheets and independent learning assignments that could be completed without stable internet access.

In terms of student responses, most participants expressed positive attitudes toward online chemistry learning. Students generally appreciated the flexibility offered by online instruction and their ability to access learning materials through various digital platforms. Nevertheless, many students reported difficulties understanding chemistry concepts delivered through online environments, particularly when explanations and interactions with teachers were limited.

The findings also revealed several challenges that affected students' learning experiences. Some students experienced difficulties completing assignments and participating in learning activities due to technical issues related to internet connectivity and access to learning resources. Similar challenges were reported during online examinations and assignment submission, where unstable internet connections and limitations in learning devices frequently disrupted students' participation and task completion.

### Assessment Practices in Online Chemistry Learning

The findings revealed that all participating schools continued to implement assessment activities throughout the COVID-19 pandemic. Assessment practices included assignments, quizzes, daily tests, midterm examinations, and final examinations. Questionnaire data indicated that students received assignments regularly, either during each learning session or at the end of a learning topic. Some students reported difficulties completing assignments due to the relatively high workload and closely scheduled deadlines.

Google Classroom and WhatsApp Groups were the primary platforms used for assignment submission and assessment management. These platforms facilitated task distribution, submission of student work, and the provision of feedback by teachers. Interview data further revealed that tests and examinations were conducted through two different approaches. The first approach involved

fully online assessment using digital platforms, while the second employed a semi-online format for students with limited internet access. Under this approach, assessment materials were distributed through peers who had more reliable internet connectivity.

Teachers also reported that assessment continued to address the three domains of learning. Cognitive assessment was conducted through assignments, quizzes, and examinations. Affective assessment focused on students' discipline, responsibility, and participation during the learning process. Meanwhile, psychomotor assessment was carried out through portfolios, projects, and student presentations completed as part of online chemistry learning activities.

### Challenges Encountered by Teachers and Students

The analysis revealed that students encountered several challenges during the implementation of online chemistry learning. The most frequently reported difficulties included limited access to learning devices, insufficient internet data quotas, inadequate device storage capacity, and unstable internet connectivity. In addition, some students reported that government-provided internet data assistance could not always be utilized effectively. These constraints affected their ability to participate in synchronous learning sessions, access instructional materials, complete assignments, and engage fully in online learning activities.

From the teachers' perspective, the main challenges included low participation among some students, delays in assignment submission, difficulties in monitoring students' learning activities, and unstable internet connections during instruction. Interview findings further indicated that teachers needed to adapt instructional and assessment strategies to accommodate students with limited access to technology and internet services. Consequently, teachers were required to provide alternative learning arrangements in addition to the online learning mechanisms formally implemented by schools.

## DISCUSSION

### Implementation of Online Chemistry Learning

The findings revealed that online learning became the dominant mode of chemistry instruction during the COVID-19 pandemic, although several schools continued to provide alternative learning arrangements for students with limited access to technology. This finding suggests that schools and teachers sought to maintain educational continuity by adopting flexible and adaptive instructional approaches that accommodated students' diverse circumstances. Such flexibility is essential because the effectiveness of online learning depends not only on institutional policies but also on students' access to technology, the availability of supportive learning environments, and their readiness to engage in distance learning (Bond et al., 2021; Dhawan, 2020; Pokhrel & Chhetri, 2021).

The findings further demonstrate that implementing online chemistry learning involved more than simply transferring face-to-face instruction to digital environments. Effective online learning requires teachers to redesign instructional strategies and learning experiences that align with both the characteristics of the subject matter and students' learning needs (Bao, 2020). In chemistry education, this challenge is particularly demanding because learning extends beyond conceptual understanding to include scientific process skills, chemical representations, and laboratory experiences that support meaningful conceptual development (Aroch et al., 2024; Kelley, 2021; Taber, 2019).

Another notable finding is that practical activities continued to be implemented despite substantial modifications to traditional laboratory instruction. This result indicates that teachers attempted to preserve one of the core features of chemistry education: students' engagement in scientific inquiry and experimentation. Previous studies have reported similar adaptations during the pandemic, including the use of experiment videos, virtual laboratories, interactive simulations, and home-based experiments to support practical learning objectives (Díez-Pascual & Jurado-Sánchez, 2022; Forster et al., 2020; Kelley, 2021). These adaptations demonstrate that chemistry learning can continue during emergency situations, although virtual and home-based laboratory experiences may not fully replicate the authenticity and richness of face-to-face laboratory practice (Accettone, 2022; Díez-Pascual & Jurado-Sánchez, 2022).

### Digital Platforms and Learning Media in Chemistry Learning

The findings indicate that teachers employed a variety of digital platforms to support online chemistry learning. The use of multiple platforms suggests that teachers adapted instructional media to address different pedagogical needs, including communication, content delivery, assignment management, and monitoring student participation. This practice reflects teachers' efforts to overcome the limitations of distance learning while ensuring that instructional activities remained accessible and effective (Bond et al., 2021; Pokhrel & Chhetri, 2021).

The diversity of learning media highlights the central role of technology in sustaining educational activities during the pandemic. Effective online learning environments require digital tools that facilitate interaction, collaboration, communication, and access to learning resources (Bond et al., 2021; Dhawan, 2020). In the present study, platforms such as Google Classroom, Microsoft Teams, WhatsApp Groups, Zoom, and Google Meet were used to support both synchronous and asynchronous learning activities. The simultaneous use of multiple platforms enabled teachers to capitalize on the strengths of each technology and align them with specific instructional objectives and learning tasks (Adedoyin & Soykan, 2023; Pokhrel & Chhetri, 2021).

These findings suggest that the effectiveness of online chemistry learning is not determined by the use of a particular platform but rather by teachers' ability to integrate various digital technologies into meaningful learning experiences. This conclusion is consistent with the findings of Bond et al. (2021), who reported that combining multiple digital platforms enhances learning flexibility and expands opportunities for interaction between teachers and students. In chemistry education, digital media also play a crucial role in supporting the visualization of abstract concepts and facilitating the integration of macroscopic, submicroscopic, and symbolic representations that are fundamental to chemistry learning (Aroch et al., 2024; Hu-Au, 2024). Therefore, the effectiveness of online chemistry learning depends more on the alignment between instructional media, learning objectives, and pedagogical strategies than on the specific platforms employed.

**Student Participation and Responses toward Online Chemistry Learning**

The findings revealed that most students continued to participate in online chemistry learning despite facing various constraints. This finding suggests that students were generally able to adapt to the abrupt changes in learning environments caused by the COVID-19 pandemic. Such adaptability was critical for sustaining learning activities during a period of significant educational disruption. Previous studies have similarly reported that successful adaptation to online learning is influenced by students' motivation, access to technology, and ability to adjust to new learning environments (Adedoyin & Soykan, 2023; Bond et al., 2021; Qazi et al., 2023).

However, high levels of participation did not necessarily translate into ease of understanding learning materials. This finding indicates that engagement in online learning does not automatically reflect the quality of students' learning experiences. Martin and Bolliger (2018) argued that participation primarily reflects students' involvement in learning activities rather than the depth of conceptual understanding achieved. In chemistry education, this issue is particularly relevant because students must simultaneously connect macroscopic, submicroscopic, and symbolic representations to develop meaningful understanding of chemical phenomena (Hamerská et al., 2024; Talanquer, 2018).

The present findings are consistent with previous studies reporting that students often experience difficulties understanding chemistry concepts involving submicroscopic representations, particle modeling, and quantitative problem-solving in online learning environments (Aroch et al., 2024; Fitria & Sebastian, 2024). Furthermore, limited interaction with teachers and reduced opportunities for laboratory activities may negatively affect both learning experiences and conceptual development (Díez-Pascual & Jurado-Sánchez, 2022; Kelley, 2021). Therefore, the effectiveness of online chemistry learning should be evaluated not only through participation rates but also through its capacity to foster meaningful conceptual understanding and support the development of scientific skills.

**Assessment Practices during Online Chemistry Learning**

The findings showed that teachers continued to assess students' cognitive, affective, and psychomotor competencies throughout the period of online learning. This practice reflects efforts to maintain comprehensive assessment principles despite the challenges associated with remote instruction. Rather than focusing exclusively on academic achievement, teachers also considered students' responsibility, engagement, and practical skills. Such an approach is consistent with the

principles of authentic assessment, which emphasize the evaluation of multiple dimensions of student competence through diverse learning activities (García-Peñalvo et al., 2020).

The use of multiple assessment methods also reflects the need to adapt evaluation practices to online learning conditions. In distance learning environments, teachers face limitations in directly observing students' learning processes. Consequently, assignments, projects, portfolios, presentations, and other performance-based assessments became valuable alternatives for obtaining a more comprehensive picture of students' progress (Adedoyin & Soykan, 2023; García-Peñalvo et al., 2020). These assessment approaches also provide students with opportunities to demonstrate their understanding and skills in authentic contexts beyond conventional written examinations (Pokhrel & Chhetri, 2021).

The findings further suggest a shift from test-centered assessment toward more diversified evaluation practices during the pandemic. This shift is particularly important in chemistry education because learning outcomes extend beyond conceptual knowledge to include scientific process skills, problem-solving abilities, and the application of knowledge in scientific contexts (Kelley, 2021; Taber, 2019). Moreover, alternative assessment methods allow teachers to evaluate higher-order thinking skills and scientific competencies that are difficult to capture through traditional testing alone (García-Peñalvo et al., 2020; Scharlott et al., 2024). As a result, diversified assessment practices can provide a more comprehensive representation of students' learning achievements while supporting broader educational goals in chemistry learning.

**Challenges in Online Chemistry Learning**

The findings indicate that limited access to technology and internet connectivity represented the most significant challenges in online chemistry learning. These barriers suggest that the rapid transition to digital learning environments was not fully accompanied by equitable access to supporting infrastructure. Consequently, some students experienced difficulties participating effectively in online learning despite the availability of various digital learning platforms. This situation reflects a persistent digital divide, which has been widely recognized as a major challenge during the COVID-19 pandemic, particularly for students with limited access to internet services, digital devices, and supportive learning environments (Adedoyin & Soykan, 2023; Bond et al., 2021; Pokhrel & Chhetri, 2021).

These findings reinforce previous research identifying internet accessibility and technological limitations as major obstacles to effective online learning. Studies have shown that poor internet connectivity, inadequate technological resources, and limited digital support can hinder learning interactions and reduce the effectiveness of educational activities (Adedoyin & Soykan, 2023; Bond et al., 2021). In addition, home learning conditions and students' readiness to use digital technologies contribute to variations in learning experiences and outcomes (Pokhrel & Chhetri, 2021; Qazi et al., 2023). Together, these findings highlight that successful online learning depends not only on the availability of digital platforms but also on broader social, economic, and technological factors that support student learning.

Beyond student-related challenges, teachers also faced difficulties in monitoring learning activities and maintaining student engagement. These findings demonstrate that online learning transformed not only how students learned but also how teachers managed instructional processes. Teachers were required to adopt more flexible instructional approaches, provide alternative learning arrangements for students with limited access, and use technology strategically to sustain communication and participation throughout the learning process (Adedoyin & Soykan, 2023; Bond et al., 2021). Such demands underscore the importance of teachers' pedagogical and digital competencies in ensuring successful online learning implementation (Aroch et al., 2024; Bao, 2020).

Overall, the findings suggest that online chemistry learning during the COVID-19 pandemic was sustained through the integration of digital technologies and the adaptive efforts of both teachers and students. However, its effectiveness remained influenced by technological infrastructure, access to digital resources, the inherent complexity of chemistry content, and the ability of teachers and students to adapt to new learning environments (Aroch et al., 2024; Bond et al., 2021; Kelley, 2021). Given that chemistry learning involves abstract concepts, multilevel representations, and laboratory experiences that are difficult to fully replicate online, strengthening digital infrastructure, enhancing teachers' technological competencies, and developing more adaptive chemistry learning models

remain essential for improving educational quality in both emergency situations and future digital learning contexts (Díez-Pascual & Jurado-Sánchez, 2022; Hu-Au, 2024; Kelley, 2021).

### Implications of the Study

This study offers important implications for the development of chemistry education in both emergency situations and emerging digital learning environments. The findings demonstrate that online chemistry learning is a complex process shaped by the interaction of instructional approaches, student participation, learning media, assessment practices, and learning challenges. Consequently, the effectiveness of online chemistry learning depends not only on the availability of technology but also on the ability of teachers and schools to integrate these components into a coherent learning system that supports meaningful student learning experiences.

From a practical perspective, the findings indicate that the use of multiple digital platforms and instructional media can help sustain chemistry learning when face-to-face instruction is not feasible. However, challenges related to internet access, learning devices, and uneven student participation highlight the need for more inclusive learning strategies. Teachers should therefore adopt adaptive instructional approaches, including the use of visual media, experiment videos, virtual simulations, and simple home-based practical activities to support students' understanding of abstract chemistry concepts and scientific processes.

The findings also have implications for educational policy. The successful implementation of digital learning requires adequate technological infrastructure, equitable internet access, and continuous enhancement of teachers' digital competencies. Therefore, educational policies should extend beyond the provision of learning platforms and focus on strengthening teacher capacity and expanding technological support for all students. Lessons learned from the COVID-19 pandemic can serve as a foundation for developing more flexible, inclusive, and sustainable models of chemistry education in future digital learning contexts.

## CONCLUSION

This study aimed to analyze the implementation of online chemistry learning during the COVID-19 pandemic in public senior high schools in Kendari City. The findings revealed that online learning became the dominant instructional approach across all participating schools, accompanied by various adaptations to accommodate students with limited access to technology. The learning process was supported by a range of digital platforms, including Google Classroom, Microsoft Teams, Zoom, Google Meet, YouTube, and WhatsApp Groups. These platforms were used not only for content delivery but also for communication, discussion, practical activities, assignment submission, and assessment.

The study further found that most students continued to participate in online chemistry learning and generally expressed positive perceptions of the learning experience. Nevertheless, many students experienced difficulties in understanding chemistry concepts and completing learning tasks effectively. Assessment practices continued to address cognitive, affective, and psychomotor domains through a variety of assessment methods adapted to distance learning conditions. These findings demonstrate teachers' efforts to maintain instructional quality and comprehensive assessment practices despite the constraints imposed by the pandemic.

The major challenges identified in this study were related to limited access to learning devices, internet connectivity, data quotas, and teachers' difficulties in monitoring students' learning activities. These findings suggest that improving the quality of digital chemistry education requires more equitable technological infrastructure, enhanced digital competencies among teachers, and the development of learning models that effectively integrate practical activities, learner interaction, and assessment. Overall, this study provides empirical evidence on the implementation of online chemistry learning at the secondary school level and offers insights that may inform educational policy and instructional innovation in both emergency situations and future digital learning environments.

## REFERENCES

Accettone, S. L. W. (2022). Student perceptions of remote chemistry laboratory delivery models. *Journal of Chemical Education, 99*(2), 654–668. https://doi.org/10.1021/acs.jchemed.1c00757

Adedoyin, O. B., & Soykan, E. (2023). Covid-19 pandemic and online learning: The challenges and opportunities. *Interactive Learning Environments, 31*(2), 863–875. https://doi.org/10.1080/10494820.2020.1813180

Al-Idrus, S. W., Muti'ah, M., & Rahmawati, R. (2021). Analisis proses pembelajaran daring selama pandemi Covid-19 pada mahasiswa program studi pendidikan kimia FKIP Unram. *PENSA: Jurnal Pendidikan Dan Ilmu Sosial, 3*(1), 139–148. https://ejournal.stitpn.ac.id/index.php/pensa

Aroch, I., Katchevich, D., & Blonder, R. (2024). Modes of technology integration in chemistry teaching: theory and practice. *Chem. Educ. Res. Pract., 25*(3), 843–861. https://doi.org/10.1039/D3RP00307H

Bao, W. (2020). COVID-19 and online teaching in higher education: A case study of Peking University. *Human Behavior and Emerging Technologies, 2*(2), 113–115. https://doi.org/10.1002/hbe2.191

Basilaia, G., & Kvavadze, D. (2020). Transition to online education in schools during a SARS-CoV-2 coronavirus (COVID-19) pandemic in Georgia. *Pedagogical Research, 5*(4). https://doi.org/10.29333/pr/7937

Bond, M., Bedenlier, S., Marín, V. I., & Händel, M. (2021). Emergency remote teaching in higher education: mapping the first global online semester. *International Journal of Educational Technology in Higher Education, 18*(1). https://doi.org/10.1186/s41239-021-00282-x

Chen, C., Landa, S., Padilla, A., & Yur-Austin, J. (2021). Learners' experience and needs in online environments: Adopting agility in teaching. Journal of Research in Innovative Teaching and Learning, 14(1), 18–31. https://doi.org/10.1108/JRIT-11-2020-0073

Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. Journal of Educational Technology Systems, 49(1), 5–22. https://doi.org/10.1177/0047239520934018

Díez-Pascual, A. M., & Jurado-Sánchez, B. (2022). Remote teaching of chemistry laboratory courses during COVID-19. *Journal of Chemical Education, 99*(5), 1913–1922. https://doi.org/10.1021/acs.jchemed.2c00022

Farida, I., Sunarya, R. R., Aisyah, R., & Helsy, I. (2020). Pembelajaran kimia sistem daring di masa pandemi Covid-19 bagi generasi Z. *In KTI UIN Sunan Gunung Djati*, (pp. 1–11). http://digilib.uinsgd.ac.id/30638/

Fernandes, S., Mahendiran, S., & Balasudarsun, N. L. (2023). Teachers' assessment of the challenges faced during COVID-19 outbreak and new-normal teaching: qualitative study. *Journal of Applied Research in Higher Education, 16*(5), 1642–1658. https://doi.org/10.1108/JARHE-04-2023-0142

Fitria, R., & Sebastian, R. (2024). Trends in research on representation in chemistry learning: A systematic review. *International Journal of Instruction, 9*(2), 65–78. https://doi.org/10.29333/aje.2024.926a

Forster, J., Nedungadi, S., & Mosher, M. (2020). Moving to remote instruction in organic chemistry II laboratories. *Journal of Chemical Education, 97*(9), 3251–3255. https://doi.org/10.1021/acs.jchemed.0c00852

García-Peñalvo, F. J., Corell, A., Abella-García, V., & Grande, M. (2020). Online assessment in higher education in the time of COVID-19. *Education in the Knowledge Society, 21*, 1–26. https://doi.org/10.14201/eks.23013

Hamerská, L., Matěcha, T., Tóthová, M., & Rusek, M. (2024). Between symbols and particles: Investigating the complexity of learning chemical equations. *Education Sciences, 14*(6). https://doi.org/10.3390/educsci14060570

Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020). The difference between emergency remote teaching and online learning. *Educause Review, 27*(1), 1–9.

Hu-Au, E. (2024). Learning abstract chemistry concepts with virtual reality: An experimental study using a VR chemistry lab and molecule simulation. *Electronics (Switzerland), 13*(16). https://doi.org/10.3390/electronics13163197

Kelley, E. W. (2021). LAB theory, HLAB pedagogy, and review of laboratory learning in chemistry during the COVID-19 pandemic. *Journal of Chemical Education, 98*(8), 2496–2517. https://doi.org/10.1021/acs.jchemed.1c00457

Maria, E., & Susilowati, E. (2026). Exploration of the application of the peer tutoring method to improve reading skills of fourth grade students: A case study at SDN Tanjung Waras. *Primary Education Insight, 1*(2), 92–103. https://doi.org/10.65779/pedi.v1i2.49

Martin, F., & Bolliger, D. U. (2018). Engagement matters: Student perceptions on the importance of engagement strategies in the online learning environment. *Online Learning Journal, 22*(1), 205–222. https://doi.org/10.24059/olj.v22i1.1092

Martins, A., & Reis, A. J. dos. (2026). Implementation of multicultural education in primary schools to build intercultural tolerance: A case study on Escola Primaria Timor-Leste. *Primary Education Insight, 1*(2), 132–143. https://doi.org/10.65779/pedi.v1i2.63

Mayer, R. E., & Fiorella, L. (2011). Introduction to multimedia. *In Cambridge handbook of multimedia learning, 2*(1). https://doi.org/10.1525/jsah.2011.70.4.532

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis a methods sourcebook (3rd ed.)*. SAGE Publications, Inc.

Pokhrel, S., & Chhetri, R. (2021). A literature review on impact of COVID-19 pandemic on teaching and learning. *Higher Education for the Future, 8*(1), 133–141. https://doi.org/10.1177/2347631120983481

Qazi, A., Hasan, N., Owusu-Ansah, C. M., Hardaker, G., Dey, S. K., & Haruna, K. (2023). SentiTAM: Sentiments centered integrated framework for mobile learning adaptability in higher education. *Heliyon, 9*(1), e12705. https://doi.org/10.1016/j.heliyon.2022.e12705

Rahman, L., & Silaban, R. (2021). Analysis of the effectiveness of using Zoom applications in online chemistry learning in the Covid-19 pandemic. *Prosiding Seminar Nasional Kimia 2021 Jurusan Kimia FMIPA UNMUL*, 99–102. https://www.academia.edu/download/101681221/1050-25-2709-1-10-20211003.pdf

Saraswati, N. L. P. A., & Mertayasa, I. N. E. (2020). Pembelajaran praktikum kimia pada masa pandemi Covid-19: Qualitative content analysis. Wahana Matematika Dan Sains: *Jurnal Matematika, Sains, Dan Pembelajarannya, 14*(2), 144–161. https://ejournal.undiksha.ac.id/index.php/JPM/article/view/28297

Scharlott, L. J., Rippey, D. W., Rosa, V., & Becker, N. M. (2024). Progression toward causal mechanistic reasoning through phenomenon-based learning in introductory chemistry. *Journal of Chemical Education, 101*(3), 777–788. https://doi.org/10.1021/acs.jchemed.3c00517

Taber, K. S. (2019). The nature of the chemical concept: Re-constructing chemical knowledge in teaching and learning. *In Royal Society of Chemistry*. https://doi.org/10.1590/S0103-50532008000200007

Talanquer, V. (2018). Progressions in reasoning about structure–property relationships. *Chem. Educ. Res. Pract., 19*(4), 998–1009. https://doi.org/10.1039/C7RP00187H

Xiao, H., Silva, S. D., & Keifert, D. T. (2024). "I gave it all, who gave it to me?" A qualitative study of challenges experienced by faculty during the COVID-19 pandemic. *Journal of University Teaching and Learning Practice, 21*(1). https://doi.org/10.53761/hn9nmd88