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High School Students' Performance Indicators in Distance Learning in Chemistry during the COVID-19 Pandemic

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Abstract: All private and public schools in the UAE had to run online classes as they closed their face-to-face classes due to the COVID-19 pandemic in the spring of 2021. In this context, the purpose of this study was to investigate the indicators of high school students' performance in online chemistry classes in a private school in Al Ain, UAE. A quantitative study with an online survey questionnaire was carried out with 101 participants. The data were analyzed using One-Sample Wilcoxon Signed Ranked Test, Independent Sample Mann Whitney U, Independent Sample Kruskal Wallis H, and Spearman's Rank Correlation in the Statistical Package for Social Sciences (IBM SPSS 26). The findings revealed that there was a statistically significant positive impact on critical thinking, collaborative skills, creativity and innovation, technology application, class participation, and overall achievement during online and distance learning of chemistry. There was a statistically significant difference in students' critical thinking, collaborative skills, creativity and innovation, class participation, and achievement by gender and nationality. These skills were not statistically significantly different across students of grades 10, 11, and 12, except for creativity and innovation, which were significantly different between students of grades 11 and 12. All the six indicators of students' performance had a significant correlation between each other, with the highest correlation between collaborative skills and participation level. These findings indicated that students' performance in online chemistry classes during the COVID-19 pandemic provided opportunities to develop creativity and collaborative skills, together with better learning achievement as perceived by the students.

Keywords: online chemistry classes; student performance; 21st-century skills

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1. Introduction

Online learning and instructions have emerged as popular methods and potential supplements to conventional face-to-face teaching and learning with the rapid development and integration of technology into education. Technology can be used as an effective tool to stimulate attention, interest, thought, and feeling of learners in learning activities to achieve learning goals [1]. Over the past few years, an increasing number of research studies have explored the perspectives of students and educators who are using various technologies for online learning and pedagogies for online teaching [2–5]. Online education is often associated with virtual education, internet education, cyber-learning, and asynchronous learning. Kearsley [6] stated that collaboration, connectivity, student-centeredness, unboundedness, community, exploration, shared knowledge, multisensory experience, and authenticity are the main themes that shape online education.

Many studies have suggested that education develops curiosity, imagination, creativity, diversity, efficiency, learning, and communication skills in students. Nonetheless, many reports [7] have indicated an increasing need to improve science, mathematics, and technology education, especially at the high school level. When talking about science, chemistry is at the center of producing the resources necessary for socio-economic, scientific, and technological advancement needed for any nation. Teaching and learning chemistry by using the World Wide Web (www) as an interactive mode is a topic of interest "to master chemical concepts while developing the wide spectrum of critical skills essential for future career development" [8] p. 445.

Chemistry is regarded as the central science for its contribution to other sciences such as Biology, Physics, Nutrition, and Health [9]. However, chemistry is mainly viewed as one of the most challenging subjects to understand among the science subjects, and as a result, it attracts fewer students to enroll in it [10]. Despite the vital role and importance of chemistry, the failure rate has remained very high. Various factors may contribute to students' poor achievement in chemistry, such as students' background, lack of interest and qualified teachers, and traditional teaching strategies with inadequate instructional materials [11]. Hussain [12] considered three levels of barriers to using ICT in chemistry classes. These levels are—teacher, school, and system levels that may affect the attitudes of students to learning, opportunities for professional development of science teachers that affect teaching in the classroom, and students' performance in chemistry.

In the UAE, chemistry is taught as a separate subject in grade 10. Then, in grade 11, students who choose a science track major in science study mathematics, chemistry, physics, biology, and geology [13]. One of the significant problems that education in the UAE suffers from is students' low achievement and poor performance in chemistry in high schools [14]. Studies show that the demographic, home environment, prior knowledge, scholastic ability, attitudes, and perceptions related to chemistry and science, and student perception of instructional practices are the variables correlated with student chemistry achievement and performance in the UAE [15]. The major chemistry resources in the selected school where this study was conducted included Next Generation Science Standards (NGSS), textbooks and other resources as per the NGSS, and a school science laboratory. There were three chemistry classes each week in grades 9–12. The teachers and students used Zoom meetings to conduct online synchronous classes. The school used the learning management system for students to access learning materials and upload their tasks and assignments. The Ministry of Education of the United Arab Emirates provided necessary support and training to all teachers and school administrators to conduct online classes smoothly during the COVID-19 pandemic [16]. The government also provided Internet connectivity to the needy students [16].

The recent coronavirus (COVID-19) pandemic has caused a paradigm shift in the way educators deliver quality education through various online platforms used in schools in the UAE [17]. Online or distance learning has become a solution for this unprecedented global pandemic, despite the challenges posed to both educators and the learners [18]. Simultaneously, the pandemic has uncovered various opportunities for new and innovative ways of learning and digitization in education systems worldwide and enabling them to "learn lessons from the COVID-19 pandemic that could make education policies more evidence based, inclusive, responsive, and transparent" [19]. However, this transition from traditional face-to-face chemistry learning to online chemistry learning can be an entirely different experience for learners and educators, in which they must adapt to with little or no other alternatives available with respect to changes in lessons, homework, and learning practices [20]. Teaching and learning of chemistry that requires some practical activities, such as lab demonstrations and hands-on modeling have been more challenging due to the virtual mode of classes with online and distance education [21].

The factors affecting students' performance in chemistry have continued to be a main concern for educational authorities and other education stakeholders in the UAE [14]. Academic achievement has led to low mean grades for most candidates and thus endangered their chances for upward social mobility, and it raises challenges for Emirati students to keep up with their international counterparts in science and mathematics-related subjects [22]. At the higher level, the academic achievement has led to low uptake of careers in science, especially chemistry, due to the declining interest of students in this field [23]. Various measures have been adopted targeting students, teachers, and the overall teaching and learning environment in the schools and classrooms in the UAE [15]. Despite these measures, the academic performance and achievement in chemistry has suffered, with lower mean national averages being recorded year after year [15]. The continued poor achievement in chemistry has been attributed to several factors, such as students' attitude towards chemistry, their motivation level, students' resources for learning, students' interpersonal relationships, students' collaboration, and students' irregularity in their classes [24]. However, there is limited information about factors affecting students' performance in chemistry during online and distance learning due to the COVID-19 pandemic. Therefore, it was crucial to examine some indicators of students' performance in online and distance chemistry classes during the COVID-19 pandemic in the UAE.

Numerous studies have been conducted on students' performance and different factors affecting their performance in science subjects in high school [25–28]. However, there are limited studies in this area in the United Arab Emirates (UAE). To the best of our knowledge, this study about students' performance and factors influencing those performances in online chemistry classes is the first to be carried out at the high school level in the UAE. Furthermore, this study argues that the online learning experience in chemistry could be better, and an effective method relative to the traditional methods of teaching and learning once it provides equal learning experiences to all the students. The study of students' achievement or performance in the online and distance learning of chemistry during COVID-19 may provide an insight to developing new pedagogical approaches and policies to deal with the crises in education in the future [29].

2. Literature Review

This review presented an argument related to factors affecting students' performance in online chemistry and non-chemistry classes using a thematic review approach. The review further expounded on some of the 21st century skills (e.g., collaborative skills) that potentially affect students' achievement in online learning.

2.1. Factors Affecting Students' Success in Online Courses

A comprehensive review of the literature sheds light on factors affecting student success in online courses. In this regard, Lee and Recker [30] investigated which system of instruction best engaged students in basic online math or statistics courses and how this method influenced students' participation and achievement. The results found four distinct variables—detailed feedback, problem-centered discussion setting, open-ended prompts, and grading—all of which have positive effects on students' performance. Additionally, the final average scores of students who attend classes where the lecturers marked the students' posts and induced open-ended conversations were relatively better. Another relevant study by Zheng et al. [31] examined the effect of course-level, students-level, and lecturers-level factors on the distance learning achievement of secondary school students registered in literature and English language subjects. The course-level findings revealed that students gain more in courses that incorporate project-based tasks and deep-learning activities. Moreover, results from the student level perspective showed that students perform better in education when they sign in more often and remain there longer and avoid taking courses only to recover credit [31]. Findings at the teacher level suggested that students taught by bachelor's degree holders had higher final scores compared to students taught by a master's degree holder [31].

A previous empirical study in Malaysia by Al-Rahmi et al. [32] related to similar findings as discussed above. The researchers assessed how social media could catalyze collaborative learning and how it would affect research students' performances. Their findings showed an improvement in the learning outcomes of both male and female students. This improvement resulted from the contentment they sensed while using social media (SM) for collective learning and discussion [32]. However, female students demonstrated a bit of dissatisfaction regarding the usefulness and perceived ease-of-use of SM. This finding suggests that using SM and having a positive, *easy to use* perception of

SM and its *usefulness* enhance students' online education activities [32]. Similarly, Cao and Hong [33] found a positive relationship between student educational achievement and the use of SM interaction. The abovementioned findings recommended that higher learning institutions encourage technological application in their educational practices because it elevates students' performance.

2.2. Collaborative Learning (CL) and Students' Performance in Online Learning

As stated by social constructivism and activity theory, working collectively to achieve a specific goal creates an influential learning atmosphere that helps in agile knowledge construction [34]. The pedagogical argument that students grasp and formulate ideas through collective education further supports the theory and is the basis for online collaborative learning [35]. Several researchers have identified CL as a means of improving student success in online learning as it enhances participation, builds students' confidence, and facilitates better understanding of course contents. For example, the article by Olakanmi [36] quoted student D's remarks regarding the efficacy of online CL as follows: "We were able to help each other in figuring out the online teacher's explanation of the rate of chemical reaction in our group, which in a way contributed to our understanding of the content." This remark supports the study by Zhu [37], who stated that online group learning goes beyond improving individual performance, meaning it may also enhance the entire group performance by raising the quality of their productivity. While Kanuka [38] recommended the blending of threaded discussion and collective online teamwork with case studies to enable students to comprehend complicated problems. Jung et al. [39] observed that undergraduate students who participated in online collaborative lessons felt more satisfied with their learning compared to those who did not. In the light of these findings in the literature, one may hypothetically state that collaborative online learning positively affects student performance.

2.3. Critical Thinking (CT) and Students' Achievement in Online Learning

Critical thinking is a recommended 21st century learning skill that education and political leaders across countries have identified as something imperative with which to equip their youths. While some findings in the literature present effective means to improve students' critical thinking skills, and the effects of critical thinking on students' academic achievement in online learning, other studies reveal that mere online teaching does not surely raise students' critical thinking. For example, Klemm and Snell [40] believe that applying online collaborative teamwork is one of the best ways to boost learners' critical thinking, interactivity, and creativity. Contrarily, other studies have found that students rarely demonstrate high critical thinking and participation levels in online discussions, which is evident in a colloquy that is uncollaborative and superficial [41–43]. However, a study by Driscoll and Carliner [44] reported that using a strategic online instruction approach, such as applying real-life simulations, can propel learners into deep thinking, promote engagement, and help generate new ideas. Analysis of the above findings from the literature shows that some findings identify the elements that affect the students' critical thinking skills, while others indicate that critical thinking affects student achievement in online chemistry classes.

2.4. Creativity and Innovation and Student Engagement in Online Learning

The online learning environment may provide students with opportunities to explore new ideas in the subject matter, as well as develop social presence and presentation skills. Teachers can use various platforms or media applications for students to work in groups and share ideas among each other, which otherwise would not happen in face-to-face classes [30]. Creativity and innovation as a part of students' learning and development is a major concern in higher education [45]. Students use computers, iPads, phones, or tablets to access online resources and explore new meanings, ideas, designs, applications, and innovations through virtual labs and manipulatives. Innovation and creativity should be, in fact, a most fundamental part of any education [46], and online teaching and learning is no exception [47]. Online instructional and learning tools can contribute to the development of a deep understanding of concepts in subject matters provided that the tools are integrated appropriately into the learning system [48,49].

2.5. Technology Application in Online Learning

Online teaching and learning may include the use of different technological tools, for example, digital devices (computers and phones), the Internet, online application tools, videos, and different software packages [50]. Integration of different technological tools into online learning provides students with opportunities to engage in collaboration, construction, and multiple learning options or choices [51]. Technology has played a major role in the implementation of online learning all over the world during the COVID-19 pandemic [52]. Technology-supported online learning systems not only help in collaboration through interaction and communication, but they also help students retain more information than in traditional face-to-face classes [52]. Technology applications in online learning provide greater flexibility for students to learn, share, and process information in a variety of ways [53]. Effective use of communication technology during online classes enhances student-teacher interaction and collaboration. However, it depends on teachers' ability to integrate such tools into virtual classes [54].

2.6. Level of Student Participation in Online Learning

Student participation level determines the effectiveness of online learning [30]. Despite the challenges, there was a significant increase in student participation in interaction and collaboration in online learning through Moodle and other learning management systems during the COVID-19 pandemic [55]. The mode of discussion in online classes may increase the level of participation due to its provision of a safe environment to share ideas and enable flexibility of time [54]. When students attend classes from their home in the online system, there is a greater chance of regularity (lack of absence), as parents can monitor their children's progress and class participation. For effective participation of students in online classes, there should be direct synchronous video conferencing so that students and teachers have the opportunity to participate in questioning, debating, and sharing information at a greater level of student participation than in regular face-to-face classrooms [54]. However, if there is less participation and isolation of students in the online classes, there is a risk of drop outs [56].

2.7. Students' Achievements in Online Chemistry Classes

Olakanmi [36], in a study of 66 first-year high school students, found that the flipped classroom teaching style substantially increased students' theoretical understanding of chemical reaction assessments compared with the traditional control method of teaching. Generally, he noticed that flipped classroom learners did far better on all evaluations with a positive difference [36]. These findings showed the advantage flipped classroom students have in reading the online materials first and discussing them with the teacher and peers in the classroom. Olakanmi's [36] findings are in line with Lamb and Annetta's [57] results, who used a series of tests to gauge 351 secondary school students' content knowledge in chemistry using online laboratory simulations. Their findings showed that using online replications can catalyze students to understand chemistry contents and increase their outlook towards science [57]. A similar study in the US by Arasasingham et al. [58] examined the impact the online homework method has on student performance in areas that students mostly have difficulties. The results revealed a positive effect of the online homework system on students' exam performance, indicating that higher students' performance is sustainable when different lectures teach multiple modules of similar courses using the online homework methods [58].

Briefly, the key takeaways of this review centered on the advantage online homework and flipped classroom methods have on students' performance. In addition, the literature review highlights the importance of technological application (e.g., using social media interaction) in online classes, especially in higher learning institutions [31,33]. The review also showed that almost all studies related to CL and TA confirm that both positively influence students' performance in online classes [36–39]. However, for CT, there is inconsistency in the literature regarding its effect on students' online academic success [40–43].

Given the limited research carried out in this context, the objective of this study was to investigate performance indicators of grade 10, 11, and 12 students in online chemistry classes. The study focused on students' performance in following four domains of 21st century skills, such as: critical thinking, communication skills, creativity and innovation, and technological applications, together with participation and overall achievement. Therefore, the purpose of the study was to examine the high school students' performance indicators in chemistry classes within these domains of 21st century skills. In order to achieve the purpose, the research questions used in this study were as follows: How does online and distance learning affect students' performance in chemistry classes? How do students perceive their overall performance in online chemistry classes? These research questions were significant because the indicators of students' performance in online chemistry classes have not so far been investigated in the UAE. The study findings can be used for increasing teachers' awareness and understanding of the indicators associated with students' performance in online chemistry classes. The results of the study may facilitate policies and programs to curtail the problems and improve the online learning experiences of high school students in chemistry (and other subjects).

3. Theoretical Framework

We applied social constructivism, activity theory, and interaction theory as guiding principles to the study. An effective integration of the propositions of these three theories into online classes could enhance the learning outcomes. These theories are associated with six performance indicators of students' online and distance learning of chemistry. These indicators were devised as critical thinking (CT), collaborative skills (CS), creativity and innovation (CI), technology application (TA), participation level (PL), and overall achievement (OA) of students during online chemistry learning. Similarly, creating an online learning environment that provides an equivalent learning experience relative to the face-to-face mode [59] may improve all six indicators of students' performance (Figure 1).

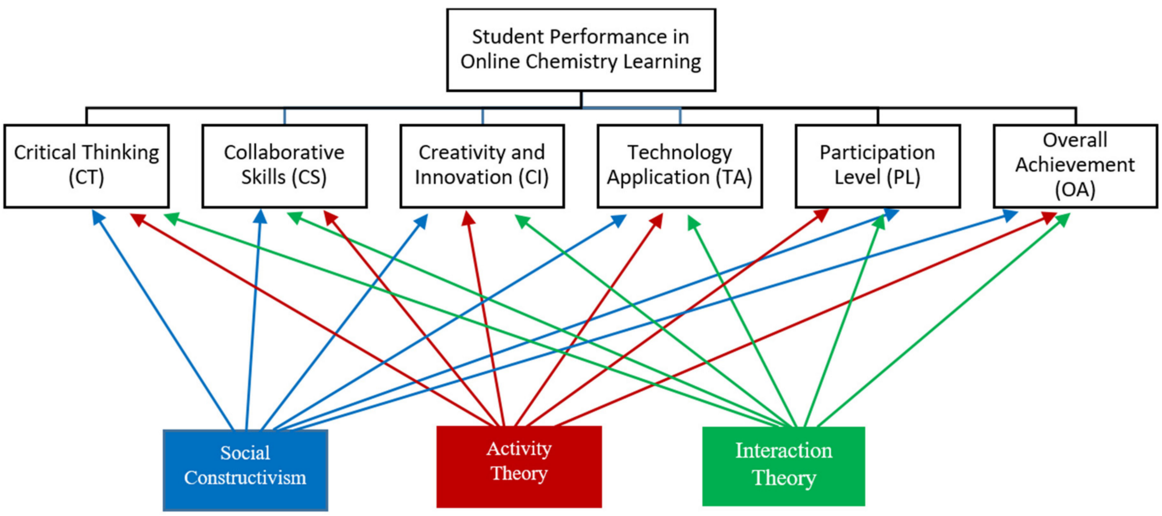

Figure 1. Theoretical framework of factors affecting students' performance in online classes.

Social constructivism is a theory of knowledge construction as a social reality with interaction of social members that continues forever without any time and space bounds [60]. The process of teaching and learning chemistry and the construction of knowledge, skills, and dispositions are based on social negotiation of concepts, methods, and processes in the social environment (e.g., classrooms, schools, and communities) [61] by transforming subjective meanings and actions into an objective social reality of teaching and learning (chemistry or any other discipline) in an online and distance-education context [62].

Activity theory focuses on three elements in human action—the actor (subject), the object on which the subject acts, and the method/tool to perform the action in a context [63]. These three elements are further interconnected to the community where the action takes place with some rules or norms based on the division of responsibilities and the potential outcomes to be shared by the members [64]. The online teaching-learning of chemistry can be interpreted with this framework in terms of role of teachers and students (subjects), the process of teaching-learning (actions), the methods and tools, such as technological devices and means of communication (artifacts) within the school community with a set of guidelines by the school and the government by dividing their roles and responsibilities for a better learning outcome [65].

Online and distance learning of chemistry has been influenced by how students and teachers interact with technological tools, such as computers and other hardware, and online web-based tools such as learning management systems, applications, and different learning and teaching tools [66]. Biundo and Wendemuth [66] introduced companion technology as a means of technology-human interaction as a cognitive technical system that focuses on user competence, adaptation, access, safety, cooperation, trust, and flexibility. In this context, we applied Norros et al.'s [67] human-technology interaction (HTI) as a means to understand students' performance in using technological tools to access chemistry class and resources for their learning in both live virtual classrooms and off-line asynchronous activities [44].

We applied these three broad theoretical constructs to understand students' performance in CT, CS, CI, TA, PL, and OA in online chemistry classes. Critical thinking (CT) is an essential skill that has been recommended by governments and educational institutions globally to enhance performance in education, especially among the younger generation. Another essential component in the theoretical structure is collaborative skill (CS), which is also one of the recommended 21st century skills in education, particularly in online classes [68]. The positive impact of CS on students' success in online learning could be explained by the social constructivism and activities theory, which states that working collectively to achieve a specific goal creates an influential learning atmosphere that helps in agile knowledge construction [34,35]. The CS helps students formulate ideas through collective learning, improves individual performance and raises the quality of students' productivity, and facilitates better understanding of course contents in online classes, which in turn improves students' performance [36,37]. The other components of the framework are creativity and innovation (CI) and technological applications (TA). Student participation is a critical factor for the success of online and distance learning in chemistry classes. In this regard, we studied students' participation level (PL) in terms of the impact of online and distance classes on their attendance, regularity, motivation, and engagement in chemistry learning. Finally, we associated students' perceptions of overall achievement (OA) in terms of effect on their grades and overall performance in chemistry learning.

4. Research Methodology

4.1. Research Design

This study employed a quantitative method. A quantitative research method emphasizes collecting information that is quantifiable and analyzable by using statistical tools to examine hypothesis or research questions to support or refute the knowledge claims [69]. In a quantitative research method, a researcher deals with quantifying and analyzing variables to achieve results. It involves the utilization and analysis of numerical data using specific statistical techniques to answer the research questions [70].

4.2. Instrument

To address the research questions, the study was conducted with an online survey using a questionnaire constructed by the researchers. According to Roopa and Rani [71], a well-designed and structured questionnaire is administered to the participants to collect information such as their age, gender, occupation, education, and income, together with other variables of interest. The questionnaire used in the study contained demographic information (e.g., gender, nationality, and grade levels) and 24 items were divided into six domains as variables to be studied. Based on the literature review and focus on 21st century skills, six key variables were identified for the examination of students' performance indicators during online learning. These variables were critical thinking (CT), collaborative skills (CS), creativity and innovation (CI), technology application (TA), participation level (PL), and overall achievement (OA). The items within each variable were scaled with a five-point Likert scale, where 5 signified strongly agree and 1 signified strongly disagree. These domains included six, six, three, four, three and two items, respectively (see Appendix A).

4.3. Sampling

A purposive sampling technique was used to select participants (N = 112) from a private school in Al Alin to participate in this study. In purposive sampling, the researcher makes a decision of what needs to be known and he or she also sets out to find people who can and are willing to provide the information with the best of their knowledge or experience [72,73]. All the 112 participants of the study who were studying chemistry were selected to collect the quantitative data. Chemistry was one of the core subjects of the selected participants. Students with different grade levels (10, 11, and 12) responded using an online questionnaire. Out of 112 students as the potential participants, only 101 (50 males and 51 females) of them responded to the questionnaire (see Table 1). Therefore, there could be sampling error due to non-participants who would affect the survey results if they had participated in the study. This sampling error was minimal, as 90.2% of the participants took part in the study and 9.8% did not. The statistical value of sampling error can be calculated by $SE = z\frac{\sigma}{\sqrt{n}}$, where z is the standard score (1.96 for 5% level of significance), σ is the population standard deviation, and n is the sample size. The sampling error for six categorical variables ranged from 0.12 to 0.22. The margin of error was high due to the small sample size of 101. However, it is acceptable on the condition that it represents almost 90% of the potential number of participants (population) (Table 2).

Table 1. Demographic statistics.

Measure	Category	Number	Percentage (%)
Gender	Male	50	49.5
	Female	51	50.5
Grade	10	5	5
	11	47	46.5
	12	49	48.5
Age (Years)	16–17	71	70.3
	18–19	13	12.9
	Below 16	17	16.8
Nationality	Emirati	68	67.3
	Non-Emirati	33	32.7

Table 2. Outputs of Descriptive Statistics Mean, Standard Deviation, Standard Error of Mean, Skewness and Kurtosis.

Variables	CT	CS	CI	TA	PL	OA
Mean	3.17	3.31	3.31	3.53	3.72	3.69
Std. Deviation	0.56	1.07	0.77	1.12	1.07	1.11
Std. Error	0.06	0.11	0.08	0.11	0.11	0.11
Skewness	0.19	−0.04	−0.10	−0.26	−0.69	−0.56
Kurtosis	0.55	−0.75	0.79	−0.61	0.14	−0.22
Sample Size (N)	101	101	101	101	101	101
Sampling Error (Zx Std. Error)	0.12	0.22	0.12	0.22	0.22	0.22

Z = 1.96 for 95% confidence interval.

4.4. Data Collection Procedure

The study plan and the questionnaire were approved by the Research Ethics Review Board of a higher education institution in the UAE. After receiving the official approval from the Research Ethics Review Board, an informed consent was sent to the parents of the potential participants through emails. The questionnaire links were shared with them to share it with their children if they consented the children to participate in the study. Prior to the collection of data, all participants in the study were informed of the purpose of the study and that they had the choice to participate in the study or not. Regarding confidentiality and anonymity, parents and the participants were ensured that their anonymity was guaranteed and protected. In addition, the respondents were not subjected to any abuse or harm nor the violation of their rights regarding the study. The identification of the participants was removed from the data before analyses and interpretations were carried out. The participants were given a one-week period to respond to the questionnaire.

4.5. Distribution of the Sample

The demographic information included students' grades, gender, age, nationality, and number of years in the same school. Out of 112 students as the potential participants, only 101 were able to complete the questionnaire because the rest of the others could not acquire parental consent to participate in the study. As shown in Table 1, about 50.5% were female students and 49.5% were male students. Approximately 5% were from Grade 10, 46.5% were from Grade 11, and 48.5% were from Grade 12. About 67.3% of Emirati and 32.7% of the non-Emirati students responded to the online questionnaire. Among the participants, 70.3% were between the ages 16–17 years, 12.9% were 18–19, and 16.8% were under 16 (Table 1).

4.6. Validity and Reliability

The questionnaire used in this study was validated by three experts with their feedback and comments on the instrument's relevancy, consistency, and easiness to read and understand. To maintain the content validity of the instrument, a piloting study was carried out by distributing the questionnaire among randomly selected participants (N = 20) from grades 10–12. Students' feedback on some items during the piloting was taken into account while finalizing the questionnaire. Gudmundsdottir and Brock-Utne [74] describe pilot study as a crucial part of a research design that is important in enhancing reliability and validity in research. The pilot study allowed us to enhance the quality of our questionnaire by focusing on correctness and clarity of instructions and statements, the length and order of the questions or items, and the range of answers on multiple-choice questions. A final pilot could be conducted to test the research process, e.g., the different ways of distributing and collecting questionnaires. The initial reliability coefficient for the 24 items in the piloting was 0.87 and was considered acceptable. The questionnaire was distributed to three research experts for construct and content validity. Their inputs were helpful to restructure some items for clarity and conciseness. The experts' views also helped in determining the items for each domain of study. According to Cousineau and Chartier [75], a few outliers are, sometimes, enough to mislead the group results, for example, altering the average performance and increasing variability. Therefore, the data of this study were examined for any outliers, but no serious outliers were found. The reliability coefficient (Cronbach's alpha) for 24 Likert type five-point items was found to be 0.939 in the final data, which was above the general acceptance level of 0.6 [76].

4.7. Analysis and Interpretation

The analysis of the collected data was performed using the IBM Statistical Package for the Social Sciences (IBM SPSS 26). In the next stage, reliability was analyzed by calculating Cronbach's alpha (α) for the scales of the questionnaire used as a tool in the study. The researchers decided to perform a non-parametric test based on normality tests by Shapiro-Wilk and Kolmogorov-Smirnov tests for the six variables—CT, CS, CI, TA, PL, and OA. A One-Sample Wilcoxon Signed Ranked Test was deployed. This was followed by the Mann Whitney U test, which was conducted to identify potentially confounding interrelationships among participants' demographic characteristics (gender and nationality). Afterwards, the Kruskal-Wallis test was performed to examine and compare the statistical differences of more than two independent groups of the study (grades 10–12). Finally, Spearman's rank correlation analysis was conducted to examine if there were any significant associations between the pairs of six variables.

5. Results

In this study, 112 students received the questionnaire, and 101 filled out the questionnaires received, resulting in a response rate of 91.8%. In this study, 51 (50.5%) female students and 50 (49.5%) male students responded to the online questionnaires. Descriptive statistics of mean and standard deviations were computed for each categorical variable (Table 2). The descriptive statistics of mean values showed that students had a greater degree of participation that followed with a greater sense of achievement during online and distance learning of chemistry. However, critical thinking (CT) had the lowest degree of agreement of the participants with smaller degrees of variations (standard deviation). Except critical thinking (CT), all the other indicators were negatively skewed distributions. Creativity and innovation (CI) had the highest and collaborative skills (CS) had the lowest Kurtosis value. The sampling error ranged from 0.12 to 0.22 for the six variables. The levels of sampling error were high due to small sample size of 101 students at 0.05 level of significance. Both Kolmogorov and Shapiro statistical tests showed that the variables were not normally distributed (p-value < 0.05) (Table 3).

Table 3. Normality test of the variables.

Variables	Kolmogorov-Smirnov [a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Critical Thinking (CT)	0.159	101	0.000	0.950	101	0.001
Collaborative Skills (CS)	0.109	101	0.005	0.958	101	0.003
Creativity and Innovation (CI)	0.144	101	0.000	0.951	101	0.001
Technology Application (TA)	0.132	101	0.000	0.920	101	0.000
Achievement	0.148	101	0.000	0.895	101	0.000
Participation	0.142	101	0.000	0.900	101	0.000

[a] Lilliefors significance correction.

5.1. Critical Thinking (CT)

A one-sample Wilcoxon Signed Rank Test was performed to examine the critical thinking (CT) of students in chemistry during online classes (Table 4). The test results showed that the students agreed that it was easy to understand chemistry concepts in online classes (T = 1398.50, Z = 2.48, $p = 0.013 < 0.05$) and they could understand online (virtual) demonstrations of chemical experiments by their teachers (T = 1713.00, Z = 3.31, $p = 0.001 < 0.05$). However, their views on the online (virtual) lab being interactive, online projects in chemistry to be not so challenging, no difficulty in virtual lab reports, and ease of online assessments were all not statistically significantly different from the neutral views ($p >= 0.05$). Overall, students agreed that their creative thinking skills had been significantly enhanced during the online classes (T = 2123.50, Z = 2.919, $p = 0.004 < 0.05$) (Table 4).

Table 4. One-Sample Wilcoxon Signed Ranked Test for CT.

Measures/Items	Total N	Test Statistics	Standard Error	Standard Test-Statistic (Z)	Asymptotic Sig. (2-tail)
Q11. In my opinion, it is easy to understand new concepts in chemistry in online classes.	101	1398.5	144.68	2.480	0.013
Q12. In my opinion, virtual (online) lab experiments are interactive.	101	1567	165.24	1.964	0.050
Q13. In my opinion, online projects in chemistry are challenging.	101	1266.5	183.41	−0.864	0.387
Q14. In my opinion, writing virtual lab observation reports are difficult.	101	1291.5	163.32	0.300	0.764
Q15. In my opinion, online chemistry summative assessments are tough.	101	1011.5	128.39	0.985	0.324
Q16: In my opinion, I can easily understand online demonstration of chemical experiments by the teacher.	101	1713	158.46	3.310	0.001
Overall CT	101	2123.5	199.75	2.919	0.004

5.2. Collaborative Skills (CS)

A one-sample Wilcoxon Signed Rank Test was performed to examine the collaborative skills (CS) of students in chemistry during online classes (Table 5). The test results showed that the students agreed that they were always engaged in collaborative learning activities in online chemistry classes (T = 1581.00, Z = 2.045, $p = 0.041 < 0.05$). They felt that working in group activities in online chemistry classes had improved their relationships with classmates (T = 2584.50, Z = 4.52, $p = 0.000 < 0.05$). They also agreed that the online chemistry classes enhanced their collaborative learning activities (T = 1410.50, Z = 3.14, $p = 0.002 < 0.05$), and it was easy to present their projects in online chemistry classes (T = 1472.00, Z = 3.005, $p = 0.003 < 0.05$). However, their views on whether online chemistry classes provided various opportunities for collaborative group work and whether it was easy to work in groups in online chemistry classes were not significantly different from the neutral view ($p > 0.05$). Overall, students agreed that their collaborative skills had been significantly enhanced during the online classes (T = 2549.50, Z = 2.694, $p = 0.007 < 0.05$) (Table 5).

Table 5. One-Sample Wilcoxon Signed Ranked Test for CS.

Measures/Items	Total N	Test Statistics	Standard Error	Standard Test-Statistic (Z)	Asymptotic Sig. (2-Tail)
Q17: I think online chemistry classes provide various opportunities for collaborative group work.	101	1286.5	161.79	0.488	0.625
Q18. I am always engaged in collaborative learning activities in online chemistry classes.	101	1581	165.52	2.045	0.041
Q19. I think it is easy to work in groups in online chemistry classes.	101	1789	194.41	1.278	0.201
Q20. I think working in group activities in online chemistry classes has improved my relationship with my classmates.	101	2584.5	204.42	4.520	0.000
Q21. I noticed that online chemistry classes enhance my collaborative learning activities.	101	1410.5	138.20	3.140	0.002
Q22. I think it is easy to present our projects in online chemistry classes.	101	1472	143.78	3.005	0.003
Overall CS	101	2549.5	235.91	2.694	0.007

5.3. Creativity and Innovation (CI)

A one-sample Wilcoxon Signed Rank Test was performed to examine students' creativity and innovative skills (CI) in chemistry during online classes (Table 6). The test results showed that the students agreed that online chemistry lessons boosted their idea creation techniques such as brainstorming (T = 1673.50, Z = 3.156, $p = 0.002 < 0.05$), and online chemistry classes motivated them to solve complex problems (T = 1865.50, Z = 3.486, $p = 0.000 < 0.05$). However, they neither agreed nor disagreed on the view that online chemistry classes limited their ability to be innovative ($p > 0.05$). Overall, the students agreed that the online or distance chemistry classes enhanced their creativity and innovative skills (T = 2287.00, Z = 4.028, $p = 0.000 < 0.05$) (Table 6).

Table 6. One-Sample Wilcoxon Signed Ranked Test for CI.

Measures/Items	Total N	Test Statistics	Standard Error	Standard Test-Statistic (Z)	Asymptotic Sig. (2-Tail)
Q23. I think online chemistry lessons boost my idea creation techniques such as brainstorming.	101	1673.5	158.58	3.156	0.002
Q24. I think online chemistry classes motivate me to solve complex problems.	101	1865.5	168.55	3.486	0.000
Q25. I think online chemistry classes limit my ability to be innovative.	101	1255	164.50	0.076	0.939
Overall CI	101	2287	195.01	4.028	0.000

5.4. Technology Application (TA)

A one-sample Wilcoxon Signed Rank Test was performed to examine students' technology application skills (TA) in chemistry during online classes (Table 7). The test results showed that the students agreed that using technology saves time in online chemistry classes (T = 2162.00, Z = 3.748, $p = 0.000 < 0.05$). They felt very confident when it came to working with new apps/tools in online chemistry classes (T = 1857.00, Z = 4.324, $p = 0.000 < 0.05$). They understood chemistry concepts much better when they were integrated with technology (T = 1954.00, Z = 3.151, $p = 0.002 < 0.05$). However, they neither agreed nor disagreed on the view that they enjoyed using technology for their online chemistry classes ($p > 0.05$). Overall, the students agreed that the online or distance chemistry classes enhanced their technology application skills in chemistry learning (T = 2769.50, Z = 4.414, $p = 0.000 < 0.05$) (Table 7).

Table 7. One-Sample Wilcoxon Signed Ranked Test for TA.

Measures/Items	Total N	Test Statistics	Standard Error	Standard Test-Statistic (Z)	Asymptotic Sig. (2-Tail)
Q26-I enjoy using technology for my online chemistry classes.	101	1230	164.5	−0.076	0.939
Q27-I think using technology saves time in online chemistry classes.	101	2162	186.52	3.748	0.000
Q28- I feel very confident when it comes to working with new apps/tools in online chemistry classes.	101	1957	165.24	4.324	0.000
Q29- I understand chemistry concept much better when they are integrated with technology.	101	1954	179.8	3.151	0.002
Overall, TA	101	2769.5	223.04	4.414	0.000

5.5. Participation Level (PL)

A one-sample Wilcoxon Signed Rank Test was performed to examine students' participation in chemistry learning during online classes (Table 8). The test results showed that the students rated their punctuality/attendance in online chemistry classes to be significantly higher than fair (either good or very good) (T = 1673.50, Z = 3.156, $p = 0.002 < 0.05$). They also highly rated their level of engagement in online chemistry classes (good or very good) (T = 1865.50, Z = 3.486, $p = 0.000 < 0.05$). However, they rated (neutral) motivation in online chemistry classes as just fair ($p > 0.05$). Overall, the students rated their active participation in the online or distance chemistry classes as high (T = 2287.00, Z = 4.028, $p = 0.000 < 0.05$) (Table 8).

Table 8. One-Sample Wilcoxon Signed Ranked Test for Participation.

Measures/Items	Attendance	Engagement	Motivation	Participation Level (PL)
Total N	101	101	101	101
Test Statistics	1673.50	1865.50	1255.00	2287.00
Standard Error	158.58	168.55	164.50	195.01
Standard Test-Statistic (Z)	3.156	3.486	0.076	4.028
Asymptotic Sig. (2-tail)	0.002	0.000	0.939	0.000

5.6. Overall Achievement (OA)

A one-sample Wilcoxon Signed Rank Test was performed to examine students' achievement in chemistry learning during online classes (Table 9). The test results showed that the students rated their grades in online chemistry classes to be significantly higher than fair (either good or very good) (T = 1926.00, Z = 4.436, $p = 0.000 < 0.05$). They also rated their performance in online chemistry classes as high (good or very good) (T = 1983.00, Z = 5.152, $p = 0.000 < 0.05$). Overall, the students rated their achievement in the online or distance chemistry classes as high (T = 2339.00, Z = 5.195, $p = 0.000 < 0.05$) (Table 9).

Table 9. One-Sample Wilcoxon Signed Ranked Test for achievement.

Measures/Items	Grades	Performance	Overall Achievement (OA)
Total N	101	101	101
Test Statistics	1926.00	1983.00	2339.00
Standard Error	161.98	157.23	183.16
Standard Test-Statistic (Z)	4.436	5.152	5.195
Asymptotic Sig. (2-tail)	0.000	0.000	0.000

5.7. Gender Differences

A Mann-Whitney U Test was performed to examine if there was a significant difference between the male and female students on critical thinking, collaborative skills, creativity and innovation, technology application, participation, and achievement during online and distance learning of chemistry (Table 10). The test results showed that there was a statistically significant difference between males and females in terms of their critical thinking (Female: Mean Rank = 57.28, N = 51; Male: Mean Rank = 44.59, N = 50; U = 954.50, $Z = -2.196$, $p = 0.028 < 0.05$). Similarly, the difference between females and males in collaborative skills (CS) was statistically significant (Female: Mean Rank = 64.55, N = 51; Male: Mean Rank = 37.18, N = 50; U = 584.00, $Z = -4.707$, $p = 0.000 < 0.05$). There was a statistically significant difference between females and males in terms of their creativity and innovative skills in online and distance learning of chemistry (Female: Mean Rank = 61.26, N = 51; Male: Mean Rank = 40.53, N = 50; U = 751.50, $Z = -3.607$, $p = 0.000 < 0.05$). There was a statistically significant difference between female and male students' ability in using technological tools in online and distance learning of chemistry (Female: Mean Rank = 63.80, N = 51; Male: Mean Rank = 37.94, N = 50; U = 622.00, $Z = -4.478$, $p = 0.000 < 0.05$). Likewise, there was a statistically significant difference between female and students in terms of their participation in online and distance chemistry classes (Female: Mean Rank = 64.79, N = 51; Male: Mean Rank = 36.93, N = 50; U = 571.50, $Z = -4.86$, $p = 0.000 < 0.05$). The female students had a greater sense of achievement than male students in online and distance chemistry classes and the difference was statistically significant (Female: Mean Rank = 64.92, N = 51; Male: Mean Rank = 36.80, N = 50; U = 565.00, Z = −4.933, p = 0.000 < 0.05) (Table 10).

Table 10. Man-Whitney U Test for gender differences for CT, CS, CI, TA, PL, and OA.

Measures/Variables	CT	CS	CI	TA	PL	OA
Total N	101	101	101	101	101	101
Mann-Whitney U	954.50	584.00	751.50	622.00	571.50	565.00
Wilcoxon W	2229.50	1859.00	2026.50	1897.00	1846.50	1840.00
Mean Rank (Female)	57.28	64.55	61.26	63.80	64.79	64.92
Mean Rank (Male)	44.59	37.18	40.53	37.94	36.93	36.80
Standard Error	145.93	146.80	145.13	145.826	144.74	143.938
Standard Test Statistic (Z)	−2.196	−4.707	−3.607	−4.478	−4.86	−4.933
Asymptotic Sig. (2-tail)	0.028	0.000	0.000	0.000	0.000	0.000

5.8. Nationality Differences

A Mann-Whitney U Test was performed to examine if there was a significant difference between the nationality of the students on critical thinking, collaborative skills, creativity and innovation, technology application, participation, and achievement during online and distance learning of chemistry (Table 11). The test results showed that there was a statistically significant difference between Emirati and non-Emirati students in terms of their critical thinking (Emirati: Mean Rank = 43.75, N = 68; non-Emirati: Mean Rank = 65.94, N = 33; U = 1615.00, Z = 3.601, p = 0.000 < 0.05). The difference between Emirati and non-Emirati students in collaborative skills (CS) in online and distance chemistry class was statistically significant (Emirati: Mean Rank = 45.48, N = 68; non-Emirati: Mean Rank = 62.38, N = 33; U = 1497.50, Z = 2.727, p = 0.006 < 0.05). There was a statistically significant difference between Emirati and non-Emirati students in terms of their creativity and innovative (CI) skills in online and distance learning of chemistry (Emirati: Mean Rank = 45.04, N = 68; non-Emirati: Mean Rank = 63.27, N = 33; U = 1527.00, Z = 2.875, p = 0.003 < 0.05). Likewise, there was a statistically significant difference between Emirati and non-Emirati students in terms of their participation in online and distance chemistry classes (Emirati: Mean Rank = 45.68, N = 68; non-Emirati: Mean Rank = 61.97, N = 33; U = 1484.00, Z = 2.666, p = 0.008 < 0.05). The non-Emirati students had a greater sense of achievement than Emirati students did in online and distance chemistry classes and the difference was statistically significant (Emirati: Mean Rank = 46.05, N = 68; non-Emirati: Mean Rank = 61.20, N = 33; U = 1458.50, Z = 2.492, p = 0.013 < 0.05). However, there was no statistically significant difference between Emirati and non-Emirati students' ability in using technological tools in online and distance learning of chemistry (Emirati: Mean Rank = 47.71, N = 68; non-Emirati: Mean Rank = 57.77, N = 33; U = 1345.50, Z = 1.634, p = 0.102 > 0.05) (Table 11).

Table 11. Man-Whitney U Test for nationality differences for CT, CS, CI, TA, PL, and OA.

Measures/Variables	CT	CS	CI	TA	PL	OA
Total N	101	101	101	101	101	101
Mann-Whitney U	1615.00	1497.50	1527.00	1345.50	1484.00	1458.50
Wilcoxon W	2176.00	2058.50	2088.00	1906.50	2045.00	2019.50
Mean Rank (Emirati, N = 68)	43.75	45.48	45.04	47.71	45.68	46.05
Mean Rank (non-Emirati, N = 33)	65.94	62.38	63.27	57.77	61.97	61.20
Standard Error	136.89	137.71	136.15	136.98	135.78	135.03
Standard Test Statistic	3.601	2.727	2.975	1.634	2.666	2.492
Asymptotic Sig. (2-tail)	0.000	0.006	0.003	0.102	0.008	0.013

5.9. Grade Level Differences

An independent-sample Kruskal-Wallis Test for grouping variables grade levels was performed to examine if the students' grades made any significant difference in their critical thinking, collaborative skills, creativity and innovation, technology application, participation, and achievement (Table 12). The test results showed that there was no statistically significant difference between the students of grades 10, 11, and 12 regarding their critical thinking, collaborative skills, technology application, participation, and achievement ($p > 0.05$). However, there was a statistically significant difference between some grades regarding creativity and innovation in online and distance learning experiences (T = 11.843, df = 2, $p = 0.003 < 0.05$). The pairwise post-hoc test (Table 13) showed that the difference was statistically significant between the students of grades 11 and 12 at 0.05 level of significance ($p < 0.05$).

Table 12. Independent samples Kruskal-Wallis Test (grade levels) for CT, CS, CI, TA, PL, and OA.

Measures/Variables	CT	CS	CI	TA	PL	OA
Total N	101	101	101	101	101	101
Test Statistic	4.339	2.418	11.843	1.360	3.453	1.353
Degree of Freedom	2	2	2	2	2	2
Asymptotic Sig. (2-tail)	0.114	0.299	0.003	0.507	0.178	0.508

Table 13. Pairwise Comparisons of Grades for CI.

Sample1–Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig. (2-Tail)	Adj. Sig.
Grade 12–Grade 10	11.09	13.56	0.82	0.413	1.00
Grade 12–Grade 11	20.29	5.90	3.44	0.001	0.002
Grade 10–Grade 11	−9.20	13.59	−0.68	0.498	1.00

Each row tests the null hypothesis that the sample 1 and sample 2 distributions are the same. Asymptotic significance (2-tail) are displayed at 0.05 level of significance and adjusted by the Bonferroni correction for multiple tests.

5.10. Correlations between CT, CS, CI, TA, PL, and OA

The six variables in the study (CT, CS, CI, TA, PL, and OA) had non-normal distributions. Therefore, Spearman's rank correlations were used to examine the association between these variables that should not be interpreted as cause-and-effect relationships (Table 14). The results of rank correlation analysis showed that CT had the greatest association with CI ($\rho = 0.375$, $p < 0.01$) and the least association with OA ($\rho = 0.327$, $p < 0.01$). The collaborative skills (CS) had the greatest association with OA ($\rho = 0.685$, $p < 0.01$) and the least association with CT ($\rho = 0.344$, $p < 0.01$). The creativity and innovation (CI) had the greatest association with CS ($\rho = 0.621$, $p < 0.01$) and the least association with CT ($\rho = 0.375$, $p < 0.01$). The technology applications had the greatest association with PL ($\rho = 0.682$, $p < 0.01$) and the least association with CT ($\rho = 0.355$, $p < 0.01$). Likewise, the participation level (PL) had the greatest correlation with TA ($\rho = 0.682$, $p < 0.01$) and the least correlation with CT ($\rho = 0.352$, $p < 0.01$). The overall achievement (OA) had the greatest association with CS ($\rho = 0.685$, $p < 0.01$) and the least with CT ($\rho = 0.327$, $p < 0.01$). All these bivariate associations were statistically significant at a 0.01 level of significance ($p < 0.01$).

Table 14. Spearman's Bivariate Rank Correlations between CT, CS, CI, TA, PL, and OA.

Variables	CT	CS	CI	TA	PL	OA
CT	1.000	0.344 **	0.375 **	0.355 **	0.352 **	0.327 **
CS	0.344 **	1.000	0.621 **	0.669 **	0.671 **	0.685 **
CI	0.375 **	0.621 **	1.000	0.534 **	0.584 **	0.508 **
TA	0.355 **	0.669 **	0.534 **	1.000	0.682 **	0.680 **
PL	0.352 **	0.671 **	0.584 **	0.682 **	1.000	0.861 **
OA	0.327 **	0.685 **	0.508 **	0.680 **	0.861 **	1.000

** Correlations were significant at 0.01 level of significance.

6. Discussion

To be successful in both online and face-to-face learning, students need excellent collaborative skills, knowledge of technological application, good creativity and innovative skills, and a high level of critical thinking. In this light, four of the aforementioned 21st century skills are crucial for students' performance in online chemistry classes. Researchers have discussed the benefits of online learning of chemistry for a long time due to its flexibility, accessibility, synchronicity and asynchronicity, and layered presentations of materials, concept-by-concept with well-connected resources and models [8]. It may even offer students an opportunity for self-regulated and self-paced learning of chemistry concepts and problems [77]. The current study results showed that student participation was the indicator with the greatest effect in terms of the highest mean value compared to other indicators of student performance.

Overall, the one-sample Wilcoxon Singed Rank test indicated that students agreed that their creative thinking skills had been significantly enhanced during the online classes (T = 2123.50, Z = 2.919, $p = 0.004 < 0.05$). This finding is consistent with the view of Palevich [78] and Derwin [79]. Next, the findings of this study showed that students agreed that their collaborative skills had been significantly enhanced during the online classes (T = 2549.50, Z = 2.694, $p = 0.007 < 0.05$). This result is consistent with Chao et al. [80], Jahng [81], and Priyambodo [82]. In addition, the students agreed that the online or distance chemistry classes enhanced their creativity and innovative skills (T = 2287.00, Z = 4.028, $p = 0.000 < 0.05$) and this result is consistent with several other studies [83,84]. The students agreed that the online or distance chemistry classes enhanced their technology application skills in chemistry learning (T = 2769.50, Z = 4.414, $p = 0.000 < 0.05$). Such skills not only help students learn independently, but they may also support their cognition through improved retention, critical thinking, and information processing [85]. The participants in the study rated their active participation in the online or distance chemistry classes as high (T = 2287.00, Z = 4.028, $p = 0.000 < 0.05$), and this result is consistent with the findings reported in Zhou et al. [86]. Overall, the students rated their achievement in the online or distance chemistry classes as high (T = 2339.00, Z = 5.195, $p = 0.000 < 0.05$). However, this finding was based on students' self-reported beliefs about their achievement, which might be different from their actual achievement. This view corroborates with the view that students' self-efficacy on chemistry class may not truly represent their academic achievement [87].

The comparison of students' CT, CS, CI, TA, PL, and OA with respect to gender showed that the female students had a greater sense of performance in all areas than their male counterparts at a 0.05 level of significance, indicating that female students outperformed male students. This finding was consistent with other studies [88–91]. This success seems to result from female students having a greater propensity to seek communication, collaboration, and assistance from colleagues [92] compared to male students. However, such results are controversial because this might not be the case for all places and contexts [93]. Similarly, students of non-Emirati nationality outperformed in all aspects compared to their Emirati counterparts. There was no statistically significant difference between students of grades 10, 11, and 12 in all performance indicators, except creativity and innovation, which were significantly different between students of grades 11 and 12.

This finding is in line with a study conducted in the Southern US on students taking online business courses, which revealed that graduate students had higher motivational levels compared with undergraduate students [94]. The results in the current study showed that there was a statistically significant difference between Emirati and non-Emirati students in terms of their critical thinking, collaborative skills, and creativity and innovative (CI) skills in online and distance learning of chemistry. These differences could be due to the social and cultural factors where most non-Emirati students come from families with high motivation for chemistry education compared with the Emirati families who might not consider chemistry education a priority. The non-Emirati students had a greater sense of achievement than the Emirati students did in online and distance chemistry classes, and the difference was statistically significant. However, there was no statistically significant difference between the Emirati and non-Emirati students' ability in using technological tools in online and distance learning of chemistry. There were significant positive correlations among the variables CT, CS, CI, TA, PL, and OA.

The significant positive effect of CS on student performance affirms the social constructivism and activities theory, which states that working collectively to achieve a specific goal creates an influential learning atmosphere that helps in agile knowledge construction [34]. Likewise, the finding on TA corroborates the study by Cao and Hong [33], who found a significant positive correlation between student educational achievement and the use of social media interaction. The positive relationship between CT and student performance in this study is not similar to what [41] and [42] have found. Their findings show that students hardly demonstrate high critical thinking and participation levels in online discussions, which could be seen in conversations that are shallow and uncollaborative.

7. Conclusion, Implications, and Limitations

The findings of the study identified significant correlations among four of the 21st century skills, including critical thinking (CT), collaborative skills (CS), creativity and innovation (CI), and technology application (TA) in addition to student participation level (PL) and overall achievement (OA) in online chemistry classes in the UAE. The students had, in general, a sense of enhancement of their skills in CT, CS, CI, TA, PL, and OA. There was a greater degree of achievement among female students compared to males, and non-Emirati students compared to the Emirati nationals. These findings suggest that the online and distance learning environments have an overall positive impact on students' learning of chemistry, despite the challenges of conducting laboratory-related demonstrations and hands-on activities. Although these findings are based on students' self-reported feelings and opinions about the impact of online learning of chemistry on their performance, it may not represent their actual grades or performance. However, it showed a likelihood of positive influence on students' overall performance in chemistry.

The future of chemistry education in online and distance modes may benefit students with greater flexibility, autonomy, safety, and a sense of community in virtual classes. These findings showed a positive sign of the pedagogical implications of the online and distance teaching-learning of chemistry in a sample high school. The online virtual classes would have the potential to provide flexibility to the students to go back to recorded lessons, would change the mood and modes of communication between students and teachers, and student-to-student social presence in the online modes through threaded discussions, etc. These implications could be explored in the future studies. Moreover, the literature also suggests that blended mode of science classes in general and chemistry teaching-learning, in particular with the integration of online simulations, encourages students' creativity and innovation. The virtual classes with synchronous and asynchronous sessions may provide a broader opportunity for teachers and students to enhance creativity, collaboration, openness, flexibility, innovation, multiple-technological integration with a greater participation, and overall multiple-skills and learning outcomes.

Although the present findings have important implications, there are still limitations. The study focused on only one school in Al Ain that limited its data size. Therefore, there was less randomization and diversification, and we cannot generalize the findings of the study. The participants of this study were below age 18 and researchers were required to acquire parental consent before administering the questionnaire, which is why it was difficult for the researchers to include other schools in a limited time. Most of the participants were non-native English speakers. As a result, this might have affected their responses to the given questionnaire (written in English). The scope of the research was limited, as the researchers carried out research alongside various constraints, such as lack of direct excess to respondents, and many technical issues in conducting online surveys due to COVID-19. During the administration of the instrument in the sample school, the researchers were given limited slots, and they were sometimes not enough. Furthermore, due to the limited allocated time, the researchers were not able to reach the target sample size. Despite all these limitations, the instrument was administered, and research was carried out successfully. The biases and sampling errors could be minimized in future studies by extending the study to several schools and including a larger sample size with cluster sampling or stratified random sampling (instead of purposive sampling of one school) where both public and private schools could be included in the study sample. To have more absolute answers, we suggest that future studies include a larger and more representative sample of participants from different schools and different Emirates in the UAE. Future research should examine cross-cultural differences in students' performance in online chemistry classes. Researchers should also look at factors affecting students' performance in other majors (e.g., Physics and Biology) in the science track in the UAE.

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Appendix A

Online Survey Questionnaire for High School Students' Performance Indicators in Distance Learning in Chemistry during the COVID-19 Pandemic

A. Demographic Information:

Q1. Your grade

1. Grade 10
2. Grade 11
3. Grade 12

Q2. Your age in years

1. Below 16

2. 16–17
3. 18–19
4. Above 19

Q3. Gender:

1. Male
2. Female

Q4. Nationality:

1. Emirati
2. Non-Emirati

Q5. For how long have you been in this School?

1. 1 year
2. 2 years
3. 3 years
4. 4 years
5. 5 years
6. 6 years
7. More than 6 years

B. General Opinion and Experience:

Q6. What statement best describe your online learning?

1. This is my first experience with online learning. ☐
2. I have some experience with online learning. ☐
3. I have extensive experience with online learning. ☐

Q7. What has pleasantly surprised you about distance learning?

1. Flexibility ☐
2. Motivation ☐
3. Innovation ☐
4. Engagement ☐
5. Easy to use. ☐
6. Varieties of apps ☐

Q8. What have been the main challenges for you in switching to online/distance learning?

1. Access to technology—Computer/IPad, software, internet connection etc. ☐
2. Being motivated ☐
3. Being engaged ☐
4. Attendance ☐
5. Online communication (teachers and administrations) ☐

Q9. How helpful your school has been in offering you the resources to learn from home?

1. Very Unhelpful
2. Not helpful
3. Neutral
4. Helpful
5. Extremely Helpful

Q10. How successful has remote learning been for you?

1. Very Unsuccessful
2. Unsuccessful
3. Neutral
4. Successful
5. Very Successful

C. Critical Thinking:

The following statements are related to the influence of online learning on students' Critical thinking skills in chemistry classes. Please select the answer that best represents your opinion. Please note that (1) represents Strongly Disagree; (2) Disagree; (3) Neutral; (4) Agree: and (5) Strongly Agree

Statement	**5. Strongly Agree**	**4. Agree**	**3. Neutral**	**2. Disagree**	**1. Strongly Disagree**
Q11. In my opinion, it is easy to understand new concepts in chemistry in online classes.					
Q12. In my opinion, virtual (online) lab experiments are interactive.					
Q13. In my opinion, online projects in chemistry are challenging.					
Q14. In my opinion, writing virtual lab observation reports are difficult.					
Q15. In my opinion, online chemistry summative assessments are tough.					
Q16: In my opinion, I can easily understand online demonstration of chemical experiments by the teacher.					

D. Collaborative Skills:

The following statements are related to the influence of online learning on students' Collaborative skills in chemistry classes. Please select the answer that best represents your opinion. Please note that (1) represents Strongly Disagree; (2) Disagree; (3) Neutral; (4) Agree: and (5) Strongly Agree

Q17: I think online chemistry classes provide various opportunities for collaborative group work.

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Q18. I am always engaged in collaborative learning activities in online chemistry classes.

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Q19. I think, it is easy to work in groups in online chemistry classes.

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Q20. I think working in group activities in online chemistry classes has improved my relationship with my classmates.

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Q21. I noticed that online chemistry classes enhance my collaborative learning activities.

1. Strongly Disagree

2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Q22. I think it is easy to present our projects in online chemistry classes.

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

E. Creativity and Innovation:
The following statements are related to the influence of online learning on students' Creativity and Innovation skills in chemistry classes. Please select the answer that best represents your opinion. Please note that (1) represents Strongly Disagree; (2) Disagree; (3) Neutral; (4) Agree: and (5) Strongly Agree

Q23. I think online chemistry lessons boost my idea creation techniques such as brainstorming.

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Q24. I think online chemistry classes motivate me to solve complex problems.

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Q25. I think online chemistry classes limit my ability to be innovative.

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

F. Technology Application:
The following statements are related to the influence of online learning on students' Technology Application skills in chemistry classes. Please select the answer that best represents your opinion. Please note that (1) represents Strongly Disagree; (2) Disagree; (3) Neutral; (4) Agree: and (5) Strongly Agree.

Q26. I enjoy using technology for my online chemistry classes.

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Q27. I think using technology saves time in online chemistry classes.

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Q28. I feel very confident when it comes to working with new apps/tools in online chemistry classes.

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Q29. I understand chemistry concept much better when they are integrated with technology.

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

G. Final Questions:

The following questions investigate your overall satisfaction and experience about online chemistry classes. Please note that (1) represents; Very Poor (2) Poor; (3) Fair; (4) Good; and (5) Very Good.

Q30. How would you rate your punctuality/attendance in online chemistry classes?

1. Very Poor
2. Poor
3. Fair
4. Good
5. Very Good

Q31. How would you rate your level of engagement in online chemistry classes?

1. Very Poor
2. Poor
3. Fair
4. Good
5. Very Good

Q32. How would you rate your motivation in online chemistry classes?

1. Very Poor
2. Poor
3. Fair
4. Good
5. Very Good

Q33. Overall, how do you feel about your academic grades in online chemistry classes?

1. Very Poor
2. Poor
3. Fair
4. Good
5. Very Good

Q34. How do you feel generally about your performance in online chemistry classes?

1. Very Poor
2. Poor
3. Fair
4. Good
5. Very Good

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