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Indicators of senior high school students' performance in online chemistry learning during the COVID-19 pandemic

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Abstract

Due to the COVID-19 pandemic, all private and public schools in the Philippines were forced to conduct all their classes online. In light of this, the study's objective was to look at the performance indicators of senior high school students taking online chemistry lessons in both public and private institutions in Northern Mindanao, Philippines. With 100 participants, a quantitative investigation using an online survey questionnaire was conducted. The results showed a statistically significant positive impact on collaborative skills (CS), creativity and innovation (CI) during online and distance chemistry learning. By gender, there were statistically significant differences in students' overall achievement (OA), participation level (PL), and collaborative skills (CS). The strongest correlations among the six performance indicators for students were seen in the areas of collaborative skills (CS) and technology application (TA). These results showed that, in the students' perspective, the COVID-19 pandemic gave chances for students' performance in online chemistry classes to strengthen their creativity and critical thinking skills.

Keywords: Performance indicators; Senior high school; COVID-19 pandemic; Survey; Chemistry Education

1 Introduction

The fast advancement and integration of technology into education have led to the emergence of online teaching and learning as popular approaches and viable supplements to traditional face-to-face teaching and learning. To achieve learning objectives, technology can be a powerful instrument for piquing students' interest in and participation in educational events [1]. Numerous research papers have examined viewpoints from students and teachers using various technologies for online learning and pedagogies for online teaching during the past few years [2-5]. Asynchronous learning, cyber-learning, virtual teaching, and internet education are terms frequently used to describe online education. According to Kearsley [6], the fundamental themes that define online education are community, discovery, shared knowledge, multisensory experience, collaboration, connectedness, student-centeredness, unboundedness, and authenticity.

Numerous research has demonstrated that education fosters students' communication, efficiency, diversity, imagination, and creativity. Nevertheless, numerous studies [7] have shown that there is a growing need to enhance the teaching of science, mathematics, and technology, particularly at the high school level. The production of the materials required for every country's socioeconomic, scientific, and technological growth is centered on chemistry when it comes to science.

Because of its contributions to other sciences, including biology, physics, nutrition, and health, chemistry is regarded as the foundational science [8]. However, chemistry is generally regarded as one of the most difficult science courses to comprehend, and as a result, fewer students choose to enroll in it [9]. Despite the crucial function and significance of

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chemistry, the failure rate has remained relatively high. Poor student performance in chemistry may be caused by a variety of issues, including students' backgrounds, uninterested teachers, teachers who lack expertise, and outdated teaching methods that use subpar teaching materials [10]. In their 2017 study, Hussain et al. [11] looked at three tiers of obstacles to ICT use in chemistry lectures. The teacher, school, and system levels are those that may have an impact on students' learning attitudes. Opportunities for professional development for science teachers may also have an impact on how well students perform in chemistry classes.

In the Philippines, schools now use a variety of online platforms to give high-quality instruction as a result of the current coronavirus (COVID-19) outbreak. Despite the difficulties, it presents for both educators and students, online or distance learning has emerged as a remedy for this unparalleled global pandemic [12]. Parallel to this, the pandemic has revealed numerous chances for new and inventive forms of education and digitization in educational systems all over the world, allowing them to "learn lessons from the COVID-19 pandemic that could make educational policies more evidence-based, inclusive, responsive, and transparent" [13]. But the shift from conventional face-to-face chemistry instruction to online chemistry instruction can be a completely different experience for students and teachers, which they must adapt to with few or no other options about modifications in lessons, homework, and learning techniques [14]. Due to the virtual nature of classes with online and distant education, teaching and learning chemistry that necessitates some practical activities, such as lab demonstrations and hands-on modeling, has become more difficult [15].

Numerous research on students' performance and other elements influencing their high school science classes have been done [16-19]. However, the Philippines only has a few studies in this field. To the best of my knowledge, this study is the first to be done at the high school level in Northern Mindanao, Philippines, regarding students' performance and factors impacting those performances in online chemistry classes. Additionally, this study makes the case that, once it offers all students comparable learning experiences, online chemistry instruction may be a superior and more efficient alternative than traditional teaching and learning techniques. The evaluation of students' success or performance in the online and remote learning of chemistry during COVID-19 may provide guidance for creating new pedagogical strategies and regulations to address the coming educational challenges.

2 Research Methodology

2.1 Research Design

This study employed a quantitative method. A quantitative research method emphasizes collecting quantifiable and analyzable information using statistical tools to examine hypotheses or research questions to support or refute the knowledge claims [20]. In a quantitative research method, a researcher deals with quantifying and analyzing variables to achieve results. It involves using and analyzing numerical data using specific statistical techniques to answer the research questions [21].

2.2 Research Instrument

To answer the research questions, a fully adapted research questionnaire by AlMahdawi et al. [22] was used in an online survey for the study. According to Roopa and Rani [23], the participants fill out a well-designed and organized questionnaire that asks questions about their age, gender, occupation, education, income, and other relevant characteristics. The questionnaire used in the study contained demographic information (e.g., gender, grade level, age, and school type), 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 examining 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.

2.3 Sampling

A purposive sampling technique was used to select participants (N=100) from public and private schools in Northern Mindanao to participate in this study. In purposive sampling, the researcher determines what information is necessary to have and then searches for individuals who can and are willing to supply it to the best of their ability or experience [24, 25]. All the 100 participants studying chemistry were selected to collect the quantitative data. Chemistry was one of the core subjects of the selected participants. Senior high school students (Grades 11 and 12) responded using an online questionnaire.

2.4 Data Collection Procedure

The senior high school coordinators approved the study plan and questionnaire, and we had to distribute our online questionnaire. After receiving their official approval, questionnaire links were shared with the students to participate in the study. Before data collection, all participants in the study were informed of the purpose of the study. Regarding confidentiality, the name of the school and participants ensured 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 one week to respond to the questionnaire.

2.5 Sample Distribution

The demographic information included students' gender, grade level, age, and school type. As shown in Table 1, about 64% were female students, and 36% were male students. Approximately 65% were from Grade 11, and 35% were from Grade 12. About 2% were under 16, 56% were between the ages of 16-17 years, 35% were between 18-19 years, and 7% were above 19. Approximately 46% were in public schools, and 54% were in private schools.

Table 1 Demographic Statistics

	Category	**N**	**%**
Gender	Female	64	64
	Male	36	36
Grade Level	11	65	65
	12	35	35
Age	Below 16 yrs. old	2	2
	16-17 yrs. old	56	56
	18-19 yrs. old	35	35
	Above 19 yrs. old	7	7
School Type	Public	46	46
	Private	54	54

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

Variables	**CT**	**CS**	**CI**	**TA**	**PL**	**OA**
Mean	2.697	2.948	3.093	2.993	3.040	3.075
Std. Deviation	0.526	0.878	0.490	0.797	0.995	1.093
Std. Error	0.053	0.088	0.049	0.080	0.100	0.109
Skewness	-0.117	-0.307	-0.188	-0.435	-0.265	-0.071
Kurtosis	1.440	-0.457	0.305	0.269	-1.087	-1.236
Sample size (N)	100	100	100	100	100	100
Sampling Error (Zx Std. Error)	0.100	0.100	0.100	0.100	0.100	0.100

2.6 Validity and Reliability

According to Cousineau and Chartier [26], a few outliers are sometimes enough to mislead the group results, for example, altering the average performance and increasing variability. Therefore, the previous study's data were examined for any outliers, but no severe 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 [27].

2.7 Analysis and Interpretation

The analysis of the collected data was performed using the IBM Statistical Package for the Social Sciences (IBM SPSS 23). In the next stage, the researcher decided to conduct a non-parametric test based on the 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 differences). Finally, Spearman's rank correlation analysis examines if there were any significant associations between the pairs of six variables.

3 Results

In this study, 100 students received the questionnaire. 64 (64%) female and 36 (36%) male students responded to the online questionnaires. Descriptive mean and standard deviation statistics were computed for each categorical variable (Table 2). The descriptive statistics of mean values showed that critical thinking (CT) had the highest degree of agreement among the participants, followed by greater achievement (OA) during online and distance learning on chemistry. However, collaborative skills (CS) had the lowest degree of agreement among the participants, with smaller degrees of variations (standard deviation). All of the indicators were negatively skewed distributions. Creativity and innovation (CI) had the highest, and Overall achievement (OA) had the lowest Kurtosis value. The sampling error is 0.100 for the six variables. Both Kolmogorov and Shapiro's statistical tests showed that the variables were not normally distributed (p-value < 0.05) except for collaborative skills (CS) (Table 3).

Table 3 Normality Test of the Variables

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Critical Thinking (CT)	0.526	0.878	0.490	0.797	0.995	1.093
Collaborative Skills (CS)	0.053	0.088	0.049	0.080	0.100	0.109
Creativity and Innovation (CI)	-0.117	-0.307	-0.188	-0.435	-0.265	-0.071
Technology Application (TA)	1.440	-0.457	0.305	0.269	-1.087	-1.236
Participation Level (PL)	100	100	100	100	100	100
Overall Participation (OP)	0.100	0.100	0.100	0.100	0.100	0.100

a. Lilliefors Significance Correction

3.1 Critical Thinking (CT)

Table 4 One-Sample Wilcoxon Signed Ranked Test for CT

	Item	**N**	**Mean**	**SD**	**SE**	**Sig.**
1.	In my opinion, it is easy to understand new concepts in chemistry in online classes.	100	2.910	0.8299	0.0830	0.249
2.	In my opinion, virtual (online) lab experiments are interactive.	100	2.690	1.051	0.1051	0.003
3.	In my opinion, online projects in chemistry are challenging.	100	3.430	1.157	0.1157	0.002
4.	In my opinion, writing virtual lab observation reports are difficult.	100	3.410	1.093	0.1093	0.001
5.	In my opinion, online chemistry summative assessments are tough.	100	3.420	1.056	0.1056	0.001
6.	In my opinion, I can easily understand online demonstration of chemical experiments by the teacher.	100	2.840	1.022	0.1022	0.109
	Overall CT	100	3.117	0.704	0.0704	0.0489

A one-sample Wilcoxon Signed Rank Test was performed to examine chemistry students' critical thinking (CT) during online classes (Table 4). The test results showed that the students agreed that it was easy to understand chemistry in online classes ($p=0.000 < 0.05$), virtual (online) lab experiments are interactive ($p=0.000 < 0.05$), online projects in chemistry are challenging ($p=0.033 < 0.05$), and students can easily understand online demonstration of chemical experiments by the teacher ($p=0.000 < 0.05$). However, their views on the difficulty in virtual lab reports and the ease of online assessments were not statistically significant from the neutral views ($p=0.149;0.061 > 0.05$). Overall, students agreed that their creative thinking skills had been significantly enhanced during the online classes ($p=0.0489 < 0.05$).

3.2 Collaborative Skills (CS)

A one-sample Wilcoxon Signed Rank Test was performed to examine chemistry students' collaborative skills (CS) during online classes (Table 5). Their views on being provided with various opportunities for collaborative group work ($p=0.562 > 0.05$), constantly engaged in collaborative learning activities ($p=0.071 > 0.05$), easy to work in groups ($p=0.168 > 0.05$), working in group activities had improved their relationships with classmates ($p=0.645 > 0.05$), enhanced their collaborative learning activities ($p=0.751 > 0.05$) and to present easily on their projects during online chemistry classes were not significantly different from the neutral view ($p>0.05$). Overall, students neither agreed nor disagreed that their collaborative skills were considerably enhanced during the online classes ($p=0.812 > 0.05$).

Table 5 One-Sample Wilcoxon Signed Ranked Test for CS

	Item	**N**	**Mean**	**SD**	**SE**	**Sig.**
7.	I think online chemistry classes provide various opportunities for collaborative group work.	100	2.980	1.063	0.1063	0.562
8.	I am always engaged in collaborative learning activities in online chemistry classes.	100	2.840	0.8958	0.0896	0.071
9.	I think it is easy to work in groups in online chemistry classes.	100	2.840	1.229	0.1129	0.168
10.	I think working in group activities in online chemistry classes has improved my relationship with my classmates.	100	3.100	1.219	0.1219	0.645
11.	I noticed that online chemistry classes enhance my collaborative learning activities.	100	3.000	1.073	0.1073	0.751
12.	I think it is easy to present our projects in online chemistry classes.	100	2.930	0.9018	0.0902	0.434
	Overall CS	100	2.948	0.8780	0.0878	0.812

3.3 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). Test results showed that the students agreed that online chemistry lessons boosted their idea-creation techniques, such as brainstorming ($p=0.021 < 0.05$). However, they neither agreed nor disagreed on the views that it motivates them to solve complex problems ($p=0.275 > 0.05$) and limits their ability to be innovative ($p=0.000 > 0.835$). Overall, the students neither agreed nor disagreed that the online or distance chemistry classes enhanced their creativity and innovative skills ($p>0.05$).

Table 6 One-Sample Wilcoxon Signed Ranked Test for CI

	Item	**N**	**Mean**	**SD**	**SE**	**Sig.**
13.	I think online chemistry classes lessons boost my idea creation techniques such as brainstorming.	100	3.210	0.8563	0.0856	0.021
14.	I think online chemistry classes motivate me to solve complex problems.	100	3.110	0.9939	0.0994	0.275
15.	I think online chemistry classes limit my ability to be innovative.	100	3.040	0.9203	0.0920	0.835
	Overall CI	100	3.120	0.7439	0.0744	0.035

3.4 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 neither agreed nor disagreed that students enjoyed using technology for their online chemistry classes ($p=0.562 > 0.05$), using technology saved time ($p=0.071 > 0.05$), and were very confident when it comes to working with new apps or tools ($p=0.168 > 0.05$), and understood chemistry concept much better when integrated with technology ($p=0.645 > 0.05$). Overall, the students neither agreed nor disagreed that the online or distance chemistry classes enhanced their technology application skills in chemistry learning ($p=0.812 > 0.05$) (Table 7).

Table 7 One-Sample Wilcoxon Signed Ranked Test for TA

	Item	N	Mean	SD	SE	Sig.
16.	I enjoy using technology for my online chemistry classes.	100	3.080	0.9394	0.0939	0.454
17.	I think using technology saves time in online chemistry classes.	100	3.080	0.8490	0.0849	0.355
18.	I feel very confident when it comes to working with new apps/tools in online chemistry classes.	100	2.890	0.9523	0.0952	0.216
19	I understand chemistry concept much better when they are integrated with technology.	100	2.920	1.012	0.1012	0.364
	Overall TA	100	2.99	0.7965	0.0797	0.761

3.5 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 engagement level in online chemistry classes ($p=0.014 < 0.05$). However, they rated their attendance and motivation in online chemistry classes fairly ($p>0.05$). Overall, the students rated their active participation in the online or distance chemistry classes as neutral ($p=0.064 > 0.05$).

Table 8 One-Sample Wilcoxon Signed Ranked Test for PL

	Item	N	Mean	SD	SE	Sig.
20.	Attendance	100	3.180	1.009	1.009	0.081
21.	Engagement	100	2.950	1.048	0.1048	0.557
22.	Motivation	100	2.990	1.168	0.1168	0.772
	Overall PL	100	3.040	.9953	0.0995	0.901

3.6 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 significantly low ($p=0.400 > 0.05$). They also rated their performance in online chemistry classes low ($p=0.626 > 0.05$). Overall, the students rated their achievement in the online or distance chemistry classes as low ($p=0.668 > 0.05$) (Table 9).

Table 9 One-Sample Wilcoxon Signed Ranked Test for OA

	Item	N	Mean	SD	SE	Sig.
23.	Grades	100	3.100	1.168	0.1168	0.400
24.	Performance	100	3.050	1.104	0.1104	0.626
	Overall Achievement	100	3.075	1.093	0.1093	0.668

3.7 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 a statistically significant difference between males and females in terms of their critical thinking (Female: Mean Rank=44.72, N=64; Male: Mean Rank=60.78, N=36; U=782.00, Z=-2.671, p=0.008<0.05). Similarly, the difference between females and males in collaborative skills (CS) was statistically significant (Female: Mean Rank=45.78, N=64; Male: Mean Rank=58.89, N=36; U=850.00, Z=-2.175, p=0.030<0.05). There was a statistically significant difference between females and males regarding their creativity and innovative skills in online and distance learning of chemistry (Female: Mean Rank=45.31, N=64; Male: Mean Rank=59.72, N=36; U=820.00, Z=-2.423, p=0.015<0.05). There was a statistically significant difference between female and male students' ability to use technological tools in online and distance learning of chemistry (Female: Mean Rank=44.97, N=64; Male: Mean Rank=60.33, N=36; U=798.00, Z=-2.563, p=0.010<0.05). Likewise, there was a statistically significant difference between female and male students in terms of their participation in online and distance chemistry classes (Female: Mean Rank=42.31, N=64; Male: Mean Rank=65.06, N=36; U=628.00, Z=-3.801, p=0.000<0.05). The male students had a greater sense of achievement than female students in online and distance chemistry classes, and the difference was statistically significant (Female: Mean Rank=44.22, N=64; Male: Mean Rank=61.67, N=36; U=750.00, Z=-2.938, p=0.003<0.05) (Table 10).

Table 10 Mann-Whitney U test for gender differences for CT, CS, CI, TA, PL, and OA

Measures	CT	CS	CI	TA	PL	OA
Total N	100	100	100	100	100	100
Mann-Whitney U	1152.00	850.00	992.00	798.00	628.00	750.00
Wilcoxon W	1818.00	2930.00	3072.00	2878.00	2708.00	2830.00
Mean Rank (Female)	50.50	45.78	48.00	44.97	42.31	44.22
Mean Rank (Male)	50.50	58.89	54.94	60.33	65.06	61.67
Standard Test Statistic (Z)	0.000	-2.175	-1.175	-2.563	-3.801	-2.938
Asymptotic Sig. (2-tail)	1.000	0.030	0.240	0.010	0.000	0.003

3.8 Correlations between CT, CS, CI, TA, PL, and OA

Table 11 Spearman's Bivariate Rank Correlations between CT, CS, CI, TA, PL, and OA

Variables	CT	CS	CI	TA	PL	OA
CT	1.000	0.009	0.075	0.106	-0.203*	-0.124
CS	0.009	1.000	0.497**	0.599**	0.355**	0.270**
CI	0.075	0.497**	1.000	0.476**	0.343**	0.392**
TA	0.106	0.599**	0.476**	1.000	0.488**	0.506**
PL	-0.203*	0.355**	0.343**	0.488**	1.000	0.829**
OA	-0.124	0.270**	0.392**	0.506**	0.829**	1.000

*Correlation is significant at the 0.05 level of significance (2-tailed); **Correlation is significant at the 0.01 level of significance (2-tailed).

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 11). The results of rank correlation analysis showed that CT had the most significant association with CS (ρ=.692, p<0.01) and the least association with OA (ρ=.411, p<0.01). Collaborative skills (CS) had the most significant association with CT (ρ=.692, p<0.01) and the least association with OA (ρ=.270, p<0.01). Creativity and innovation (CI) had the most significant association with TA (ρ=.665, p<0.01) and the least association with PL (ρ=.609, p<0.01). The technology applications had the most significant association with CI (ρ=.665, p<0.01) and the least association with PL (ρ=.488, p<0.01). Likewise, the participation level (PL) had the most significant correlation with OA (ρ=.829, p<0.01) and the least correlation with CS (ρ=.355, p<0.01). The overall achievement (OA) had the most significant association with PL (ρ=.829, $p<0.01$) and the least with CS (ρ=.270, $p<0.01$). All these bivariate associations were statistically significant at a 0.01 level of significance ($p<0.01$).

4 Discussion

To succeed in online and face-to-face learning, students need excellent collaborative skills, knowledge of technological applications, good creativity, innovative skills, and a high level of critical thinking. Researchers have discussed the benefits of online chemistry learning for a long time due to its flexibility, accessibility, synchronicity, asynchronicity, layered presentations of materials, and concept-by-concept with well-connected resources and models [28]. It may even offer students an opportunity for self-regulated and self-paced learning of chemistry concepts and problems [29]. The current study results showed that creativity and innovation had the most significant effect in terms of the highest mean value compared to other student performance indicators.

Overall, the one-sample Wilcoxon Signed Rank test indicated that students agreed that their creative thinking skills had been significantly enhanced during the online classes ($p=0.0489 < 0.05$). This finding is consistent with Palevich [30] and Derwin [31]. Next, the results of this study showed that students neither agreed nor disagreed that their collaborative skills had been significantly enhanced during the online classes ($p=0.812 > 0.05$). This result is consistent with Andres & Shipps [32]. In addition, the students neither agreed nor disagreed that the online or distance chemistry classes enhanced their creativity and innovative skills ($p=0.059 > 0.05$), and this result is consistent with several other studies [33-35]. The students neither agreed nor disagreed that the online or distance chemistry classes enhanced their technology application skills in chemistry learning ($p=0.812 > 0.05$). This result is consistent with the study by Abu Talib et al. [36]. The participants in the survey rated their active participation in the online or distance chemistry classes as low ($p=0.064> 0.05$), and this result is consistent with the findings reported [37]. The students rated their achievement in the online or distance chemistry classes as low ($p=0.668 > 0.05$). However, this finding was based on students' self-reported beliefs about their achievement, which might differ from their actual achievement. This view corroborates the idea that students' self-efficacy in a chemistry class may not truly represent their academic achievement [38].

The comparison of students' CT, CS, CI, TA, PL, and OA with respect to gender showed that the male students had a greater sense of performance in all areas than their female counterparts at a 0.05 level of significance, indicating that male students outperformed female students. This finding was consistent with other studies [39]. However, such results are controversial because this might not be true for all places and contexts [40].

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 [41]. Likewise, the finding on TA corroborates the study by Cao and Hong [42], who found a significant positive correlation between student educational achievement and social media interaction. The positive correlation between CT and student performance in this study is not similar to what Ertmer et al. [43] and Hew et al. [44] have found. Their findings show that students hardly demonstrate high critical thinking and participation levels in online discussions, which could be seen in shallow and uncollaborative conversations.

5 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. The students had, in some, a sense of enhancement of their skills in CT and CI. There was a greater degree of achievement among male students compared to females. These findings suggest that the online and distance learning environments could have a positive, negative, or no impact on students' chemistry learning, 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 chemistry learning on their performance, they may not represent their actual grades or performance.

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 varied responses to the pedagogical implications of the online and distance teaching-learning of chemistry. Moreover, the literature also suggests that the blended mode of science classes in general and chemistry teaching-learning, particularly 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, and multiple-technological integration with greater participation and overall multiple skills and learning outcomes.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors whose names are listed immediately above report the following details of affiliation or involvement in an organization or entity with a financial or non-financial interest in the subject matter or materials discussed in this manuscript.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

[1] Lee, C.B.; Hanham, J.; Kannangara, K.; Qi, J. Exploring user experience of digital pen and tablet technology for learning chemistry: Applying an activity theory lens. Heliyon 2021, 7, e06020.

[2] Bailey, C.J.; Card, K.A. Effective pedagogical practices for online teaching: Perception of experienced instructors. Internet High. Educ. 2009, 12, 152–155.

[3] Ellis, R.A.; Hughes, J.; Weyers, M.; Riding, P. University teacher approaches to design, teaching, and concepts of learning technologies. Teach. Teach. Educ. 2009, 25, 109–117.

[4] Motaghian, H.; Hassanzadeh, A.; Moghadam, D.K. Factors affecting university instructors' adoption of web-based learning systems: Case study of Iran. Comput. Educ. 2013, 61, 158–167.

[5] Zingaro, D.; Porter, L. Peer instruction in computing: The value of instructor intervention. Comput. Educ. 2014, 71, 87–96.

[6] Kearsley, G. Online Education: Learning and Teaching in Cyberspace; Wadsworth Thomson Learning: Boston, MA, USA, 2000.

[7] National Board for Professional Teaching Standards. Voices of Influence: Advancing High-Quality Teaching through National Board Certification; NBPTS: Arlington, VA, USA, 2009.

[8] Abarro, R.Q.; Asuncion, J.E. Metacognition in chemistry education. ISJ Theor. Appl. Sci. 2021, 3, 1–22.

[9] Cardellini, L. Chemistry: Why the Subject is Difficult? Educ. Química 2012, 23, 305–310.

[10] Hassan, A.A.; Ali, H.I.; Salum, A.A.; Kassim, A.M.; Elmoge, Y.N.; Amour, A.A. Factors affecting students' performance in chemistry: Case study in Zanzibar secondary schools. Int. J. Educ. Pedagog. Sci. 2015, 9, 4086–4093.

[11] Hussain, I.; Suleman, Q.; Naseer-Ud-Din, M.; Shafique, F. Effects of Information and Communication Technology (ICT) on Students' Academic Achievement and Retention in Chemistry at Secondary Level. J. Educ. Educ. Dev. 2017, 4, 73–93.

[12] Erfurth, M.; Ridge, N. The Impact of COVID-19 on Education in the UAE; Sheikh Saud Bin Saqr Al Qasimi Foundation for Policy Research: Ras Al-Khaimah, United Arab Emirates, 2020.

[13] Grob-Zakhary, R. COVID-19 Is an Opportunity to RESET Education; World Economic Forum: Cologny, Switzerland, 2020.

[14] Anokhin, E.O.; Aleshin, G.Y.; Tishkin, A.A.; Korolev, V.V.; Sobol, A.G.; Evdokimov, K.M.; Chepiga, A.A. Not great, not terrible: Distance learning of chemistry in Russian secondary schools during COVID-19. Chem. Teach. Int. 2021.

[15] Sari, I.; Sinaga, P.; Hernani, S. Chemistry learning via distance learning during the COVID-19 pandemic. Tadris J. Educ. Teach. Train. 2020, 5, 155–165.

[16] Areepattamannil, S., & Kaur, B. (2013). Factors predicting science achievement of immigrant and non-immigrant students: A multilevel analysis. International Journal of Science and Mathematics Education, 11(5), 1183-1207.

[17] Ceylan, E.; Berberoğlu, G. Factors related with students' science achievement: A modeling study. Educ. Sci. 2007, 32, 36–48.

[18] Liu, C.C.; Wang, T.Y. A study of factors affecting science achievements of junior high school female students. J. Balt. Sci. Educ. 2019, 18, 39–50.

[19] Tatar, E.; Tuysuz, C.; Tosun, C.; Ilhan, N. Investigation of factors affecting students' science achievement according to student science teachers. Int. J. Instr. 2016, 9, 153–166.

[20] Williams, C. Research methods. J. Bus. Econ. Res. 2007, 5, 65–72.

[21] Roni, S.M.; Merga, M.K.; Morris, J.E. Conducting Quantitative Research in Education; Springer: Berlin/Heidelberg, Germany, 2020.

[22] AlMahdawi, M., Senghore, S., Ambrin, H., & Belbase, S. (2021). High School Students' Performance Indicators in Distance Learning in Chemistry during the COVID-19 Pandemic. Education Sciences, 11(11), 672.

[23] Roopa, S.; Rani, M. Questionnaire designing for a survey. J. Indian Orthod. Soc. 2012, 46, 273–277.

[24] Bernard, H.R. 2002. Research Methods in Anthropology: Qualitative and quantitative methods. 3rd edition. AltaMira Press ,Walnut Creek, California.

[25] Lewis, J.L. & S.R.J. Sheppard. 2006. Culture and communication: can landscape visualization improve forest management consultation with indigenous communities? Landscape and Urban Planning 77:291–313.

[26] Cousineau, D.; Chartier, S. Outliers' detection and treatment: A review. Int. J. Psychol. Res. 2010, 3, 58–67.

[27] Cohen, L.; Manion, L.; Morrison, K. Research Methods in Education, 5th ed.; Routledge, Taylor & Francis Group: London, UK, 2007.

[28] Long, G.R.; Zielinski, T.J. Teaching chemistry on-line: Why it should be done. Trends Anal. Chem. 1996, 15, 445–451.

[29] Chen, K.Z.; Li, S.C. Sequential, typological, and academic dynamics of self-regulated learners: Learning analytics of an undergraduate chemistry online course. Comput. Educ. Artif. Intell. 2021, 2, 100024.

[30] Palevich, M.O. Teaching Critical Thinking Skills in the Online Classroom. eSchool News: Innovation in Educational Transformation (29 April 2020). 2020.

[31] Derwin, E. Critical thinking in online vs. face-to-face higher education. Media Psychol. Rev. 2009, 2, 1–9.

[32] Andres, H. P., & Shipps, B. P. (2010). Team learning in technology-mediated distributed teams. Journal of information systems education, 21(2), 213.

[33] Laius, A., & Rannikmae, M. (2014). Longitudinal Teacher Training Impact on Students' Attributes of Scientific Literacy. International Journal of Humanities and Social Science, 4(6), 63-72.

[34] Cheng, V. (2010). Teaching Creative Thinking in regular science lessons:Potentials and obstacles of three different approaches in an Asian context. Asia-Pacific Forum on Science Learning and Teaching, 11(1), Article 17, 1.

[35] Risnawati, R., & Saadi, P. (2017). Improving Creative Thinking Ability and Learning Outcomes Through the Creative Problem Solving (CPS) Learning Model on Buffer Solution Material. Quantum: Journal of Science Education Innovation, 7(2), 127-134.

[36] Abu Talib, M., Bettayeb, A. M., & Omer, R. I. (2021). Analytical study on the impact of technology in higher education during the age of COVID-19: Systematic literature review. Education and information technologies, 26(6), 6719-6746.

[37] Hwang, G. J., Chang, S. C., Song, Y., & Hsieh, M. C. (2021). Powering up flipped learning: An online learning environment with a concept map-guided problem-posing strategy. Journal of Computer Assisted Learning, 37(2), 429-445.

[38] Oemig, P. A. (2016). Mapping classroom experiences through the eyes of enlace students: The development of science literate identities. New Mexico State University.

[39] Korlat, S., Kollmayer, M., Holzer, J., Lüftenegger, M., Pelikan, E. R., Schober, B., & Spiel, C. (2021). Gender differences in digital learning during COVID-19: competence beliefs, intrinsic value, learning engagement, and perceived teacher support. Frontiers in psychology, 12, 637776.

[40] Nistor, N. Stability of attitudes and participation in online university courses: Gender and location effects. Comput. Educ. 2013, 68, 284–292.

[41] Van Merrienboer, J.J.; Paas, F. Powerful learning and the many faces of instructional design: Toward a framework for the design of powerful learning environments. In Powerful Learning Environments: Unraveling Basic Components and Dimensions; De Corte, L.E., Verschaffel, N.E., van Merrienboer, J., Eds.; Emerald Group Publishing Limited: Bingley, UK, 2003; pp. 3–20.

[42] Cao, Y.; Hong, P. Antecedents and consequences of social media utilization in college teaching: A proposed model with mixed-methods investigation. Horizon 2011, 19, 297–306.

[43] Ertmer, P.A.; Sadaf, A.; Ertmer, D.J. Student-content interactions in online courses: The role of question prompts in facilitating higher-level engagement with course content. J. Comput. High. Educ. 2011, 23, 157.