JOURNAL OF INTERDISCIPLINARY PERSPECTIVES

ISSN Print: 2984-8288, ISSN Online: 2984-8385
Vol. 2, No. 10, pp. 110-120, October 2024

Utilization of Web-based Laboratory in Expressing Chemical Concentrations

Harley E. Partosa*, **Antonia Gueyndoline B. Despojo, Maria Chona Z. Futalan**
Foundation University, Dumaguete City, Negros Oriental, Philippines

*Corresponding Author Email: harleypartosa@gmail.com

Date received: July 28, 2024
Date revised: August 24, 2024
Date accepted: August 29, 2024

Originality: 95%
Grammarly Score: 99%
Similarity: 5%

Recommended citation:
Partosa, H., Despojo, A.G., & Futalan, M.C. (2024). Utilization of web-based laboratory in expressing chemical concentrations. *Journal of Interdisciplinary Perspectives*, 2(10), 110-120. https://doi.org/10.69569/jip.2024.0381

Abstract. This research was carried out to evaluate students' attitudes toward learning and doing Chemistry activities using web-lab experiments through pre-survey and post-survey assessments. It also assesses their performance in the subject through pretest and posttest and analyzes the influence of web-based laboratory activities on students' attitudes and performance in Chemistry. This research utilized the experimental design, employing the pre-test and post-test strategies. The respondents are the 154 Senior High School students of the Science Technology Engineering and Mathematics (STEM) strand of St. Paul University Dumaguete. However, the data collected from the control group was excluded from this analysis to concentrate on the 79 respondents of the experimental group. This allows for a comprehensive examination of the web-based laboratory experiment's potential benefits on the attitudes and performance of students towards chemistry. The validated survey questionnaire and pretest and posttest questions were used to gather the data. Statistical tools used in the study were Mean, Wilcoxon Test, Spearman's Rank Order Correlation, Paired Samples t-test, and Cohen's d. The results revealed that web-based laboratory experiments effectively improve students' attitudes and performance in chemistry. The perceived value of Chemistry emerged as a crucial factor influencing performance in laboratory tasks. Web-based instruction makes learning fun, emphasizing its real-world application and increasing students' overall value and positive attitude in Chemistry.

Keywords: Chemical concentrations; Conventional laboratory; Web-based laboratory.

1.0 Introduction

Chemistry is an important branch of science. It is a core and a prerequisite subject for offering most science-oriented courses. It is a preparatory subject for those who aspire to become chemical engineers, scientists, medical doctors, and environmentalists, thus opening the doors to numerous job opportunities (Kots, 2021). However, students often struggle with essential chemistry topics, including writing chemical formulas and equations and solving problems involving complex calculations, such as expressing chemical concentrations and stoichiometry. This is linked to negative attitudes, such as hesitancy to engage in laboratory activities and fear of failure due to the subject's complexity. If negative attitude and behavior levels remain unmonitored, students' engagement in the subject declines, and their academic performance will be affected (Musengimana, 2020). Galang et al. (2022) of the American Chemical Society stressed that educators must utilize modern strategies, including web-based and virtual laboratory activities, to counter the declining interest and engagement worldwide. Kolil et al. (2020) highlighted that educators must utilize technology, including interactive online platforms, virtual laboratories, game-based instruction, and video tutorials, to enhance students' learning experiences.

Abarro and Asuncion (2021) revealed that students' interest in chemistry as an academic discipline is declining across the globe. In Philippine schools, chemistry is included in the general education curriculum and is perceived as difficult—a common evaluation of students across secondary and higher education institutions. Non-science majors' primary motivation for taking the course is solely graduation. Students, particularly those with negative high school chemistry experiences, often approach the subject with skepticism and reluctance, which has caused a decline in students' interest in enrolling and engaging in the subject. Alo (2021) stated that improving the quality of education is a significant challenge for Southeast Asian nations. While technology is occasionally used in classrooms, its overall impact on learning has been quite effective. Science is the subject students struggle with most in elementary and high school. Some studies suggest using multimedia and web-based curricula to enhance student learning. In the current era, leveraging information technology is seen as a solution for educational institutions to improve and provide quality instruction.

After reviewing various studies, the researcher found that (a) research about students' attitude, motivation, self-confidence, and interest provides limited quantitative data, (b) no studies have assessed or evaluated the four constructs of attitude in learning and performing chemistry activities, namely, self-confidence, valuing, enjoyment, and motivation, and (c) there have been many studies showing the connection between attitudes towards science and performance in science. Also, the results are not consistent. Some studies indicate that the link between students' attitudes toward science and their science performance is weak, insignificant, or negative.

This research, however, aims to measure students' academic performance through a self-made pretest and posttest and evaluate attitudes through a survey. It analyzed the connection between attitude and academic performance, specifically in the context of web-based laboratories, which are considered an effective method for teaching chemical concentrations. Hence, as a chemistry instructor and a Master of Arts and Education student majoring in General Sciences, the researcher intends to evaluate students' attitudes (self-confidence, valuing, enjoyment, and motivation) and assess students' academic performance in utilizing a web-based laboratory to express chemical concentrations.

2.0 Methodology

2.1 Research Design

The research utilized a True Experimental Design employing the Pretest-Posttest Control Group Design. The experimental group was exposed to web-based laboratory experiments. This involved (a) evaluation of the level of attitude of students about self-confidence, valuing, enjoyment, and motivation, using a survey questionnaire before and after the web-based laboratory experiment of the experimental group, (b) analysis of the significant difference in the level of attitude of the experimental group regarding self-confidence, valuing, enjoyment, and motivation before and after the web-based laboratory, (c) assessment on students' academic performance based on test scores using a test questionnaire before and the given intervention for the experimental group, (d) analysis on the significant difference in the performance of the experimental group before and after the web-based laboratory, and (e) analysis on the significant relationship between the level of attitude of the experimental group in performing Chemistry laboratory after the web-based laboratory experiment and their performance in expressing chemical concentrations.

2.2 Research Locale

The study was conducted at St. Paul University Dumaguete (SPUD), a private Roman Catholic educational institution managed by the Sisters of St. Paul of Chartres (SPC) in Bantayan, Dumaguete, Philippines. Founded on October 29, 1904, SPUD initially operated under the guidance of seven pioneering sisters from Vietnam who responded to an invitation by the diocese bishop based at Iloilo. The university, established initially as an elementary school, has since expanded its educational offerings and now includes basic education and higher education programs. SPUD is one of the 40 educational institutions owned and operated by the SPC Sisters across the Philippines, promoting core values and encouraging social responsibility among its students. The Basic Education Department of SPUD was specifically chosen as the research site for this study due to its conducive academic environment, ease of accessibility, and the availability of a diverse participant pool. This setting provides an ideal backdrop for conducting educational research, ensuring a comprehensive and representative sample.

2.3 Research Participants

The respondents for this study were drawn from the four sections of Senior High School Grade 12 STEM students at the Basic Education Department of St. Paul University Dumaguete. Two sections were designated as the control group, while the other two sections, comprising 79 students, were assigned to the experimental group. A one-stage cluster sampling technique was applied in assigning the classes to either the experimental or control group. This method ensures random assignment by giving every member of the population an equal chance of being included in the sample. Subsequently, a z-test was utilized to determine if there was an equal level of knowledge in science between the two groups. The results indicated that the p-value (0.198) was greater than the significance level (0.05), suggesting no significant difference in their prior knowledge of science. The Grade 12 STEM students were selected as the target population due to their relevance to the research focus, which evaluates attitudes and performance based on test scores before and after utilizing the web-based laboratory for the experimental group and the conventional laboratory experiment for the control group, specifically on the topic of expressing chemical concentrations.

2.4 Research Instrument

The study made use of a modified survey questionnaire rated on a five-point Likert's scale adapted and taken from The Attitudes Toward Mathematics Inventory (ATMI) by Majeed, Darmawan, and Lynch (2013), a survey used to measure the level of confidence, anxiety, motivation, and usefulness of Mathematics. The survey questionnaire was contextualized for science and is divided into three parts. The first part is a disclosure statement; the second part includes the student's profile; the third part is the indicators and the levels of self-confidence, valuing, enjoyment, and motivation.

The researcher constructed test questionnaires for the pretest and posttest based on the Table of Specifications, which included 30 items for molarity and molality, 30 items for percent concentration, and 30 items for parts per million, parts per billion, and mole fraction. The pretest and posttest questionnaires were used to assess students' performance in expressing chemical concentrations.

Moreover, the intervention for the experimental group comprised three web-based experiment activity cards designed by the researcher. Web-based activity 1 is about expressing chemical concentrations—determining the molarity and molality of a solution. Web-based activity 2 expresses chemical concentrations—percent concentrations of cola and sucrose. Web-based activity 3 expresses chemical concentrations—mole fraction, ppm, and ppb of generic cola. The activity cards were the guide in utilizing the web-based laboratory for each mentioned topic in expressing chemical concentrations.

The activity cards, survey questionnaires on attitude, and test questionnaires to assess performance were presented to three experts in the field of science for content validity and cross-checking. Additionally, the validation process involved input from the researcher's subject adviser, statistician, thesis adviser, and other domain experts to ensure the tools were valid and closely aligned with the research objectives and issues. Furthermore, suggestions were considered in the refinement of the different tools.

A dry run of the survey questionnaire on attitude was conducted on thirty (30) Grade 12 students of the Humanities and Social Sciences strand of St. Paul University Dumaguete. The students who participated in the dry run were excluded from the main study. Cronbach's alpha test was used to check the item's reliability and how closely related the items were to each other. In this test, 0.70 is acceptable, and higher alpha values are preferred. The results of the Cronbach's alpha test for the different parts of the questionnaire were as follows: (a) Self-confidence = 0.897; (b) Valuing = 0.896; (c) Enjoyment = 0.892; and (d) Motivation = 0.902. It must be noted that all values are greater than (>) 0.70. Hence, the items are reliable. Meanwhile, a test and retest of the three questionnaires were conducted on thirty (30) first-year nursing students of St. Paul University Dumaguete. Spearman's reliability test was used to check the pretest and posttest scores. Values equal to or greater than 0.70 are regarded as acceptable. The reliability test results are the following: Molarity and Molality = 0.707, Percent Concentration = 0.700, Mole Fraction, ppm, and ppb = 0.701. These values affirm that the items are reliable.

Chemcollective.com is the web-based laboratory platform provided to the experimental group. Links to the online laboratory workbench were provided so that the students could easily access the platform.

2.5 Data Gathering Procedure

The researcher ensured all recommendations and corrections from the panel members were incorporated into the study. The research process was arranged in the following phases: 1.) Design Hearing and Approval of Consent to Study; 2.) Validation Phase; 3.) Testing for Reliability Phase; 4.) Pre-evaluation of Students' Attitude in Learning and Doing Chemistry Activities; 5.) Introduction of the Web-based laboratory; 6.) Lesson Delivery, Administration of Pretest, Conduction of Experiment, and Administration of Posttest for Molarity and Molality; 7.) Lesson Delivery, Administration of Pretest, Conduction of Experiment, and Administration of Posttest for Percent Concentration; 8.) Lesson Delivery, Administration of Pretest, Conduction of Experiment, and Administration of Posttest for Mole Fraction, PPM, and PPB; 9.) Post-evaluation of Students' Attitude in Learning and Doing Chemistry Activities; and 10.) Final phase.

2.6 Data Analysis Procedure

The tools used by the researcher in analyzing the data include: a) Mean was used to determine the level of students' attitudes towards chemistry before and after using web-based laboratory experiments in expressing chemical concentrations. Furthermore, it was utilized to show students' performance in expressing chemical concentrations of the experimental group; b) Wilcoxon Test was used to analyse the significant difference in the attitude of the experimental group towards performing chemistry laboratory before and after the introduction of web-based lab; c) Spearman rank correlation coefficient was employed to determine the extent of the relationship between the level of students' attitude towards performing chemistry laboratory after the web-based laboratory experiment and their performance in expressing chemical concentrations; d) Paired-samples t-test was used to calculate the significant difference in students' academic performance before and after the intervention; and e) Cohen's d was used to determine the effect size of the analysis on the difference in the experimental group's performance in expressing chemical concentrations before and after utilizing the web-based laboratory experiment and the analysis on the difference in the performances of the experimental and control groups after the introduction of the web-based laboratory and conventional method of experiment.

Conversely, the data collected from the control group was excluded from this analysis to concentrate on the experimental group. This allows for a comprehensive examination of the web-based laboratory experiment's potential benefits on students' attitudes and performance toward chemistry.

2.7 Ethical Considerations

Ethical standards were observed throughout the research endeavor, and ethical approval was sought from the Foundation University Research Office's ethical committee. The principles of self-determination, confidentiality, and thorough acknowledgment of the study's potential benefits and risks were underscored.

3.0 Results and Discussion

3.1 Levels of attitude of the Experimental Group in Performing Chemistry Laboratory before and after the Introduction of the Web-based Laboratory Experiment

Tables 1, 2, 3, and 4 present the levels of attitude of the experimental group in performing Chemistry laboratory activities before the introduction of the web-based laboratory experiment in terms of confidence, value, enjoyment, and motivation revealed that the students are "Fairly Confident" ($\bar{x}$ = 3.25), have "Very High" sense of value for Chemistry ($\bar{x}$ = 4.21), manifest "High" enjoyment ($\bar{x}$ = 3.82), and are "Motivated" ($\bar{x}$ = 3.66). Meanwhile, the data also exposed that after the introduction of the web-based laboratory experiment, the students are "Fairly Confident" ($\bar{x}$ = 3.73), have "Very High" sense of value for Chemistry ($\bar{x}$ = 4.29), show "High" enjoyment in performing activities ($\bar{x}$ = 4.08), and are "Motivated" ($\bar{x}$ = 3.99) in performing Chemistry-related tasks.

Table 1. Attitude of the experimental group in performing chemistry laboratory before and after the introduction of the web-based laboratory experiment in terms of self-confidence

Indicators	Before		After	
	$\bar{x}$	VD	$\bar{x}$	VD
1. Working on Chemistry at home makes me feel:	3.72	C	3.95	C
2. When I do chemistry activities, I feel:	3.58	C	3.81	C
3. When I know that my class will be working on Chemistry at school, I feel:	3.57	C	3.96	C
4. Thinking about working on Chemistry in class makes me feel:	3.54	C	3.97	C
5. When I think about Chemistry, I feel:	3.33	FC	3.77	C

6. Compared to other school subjects, Chemistry makes me feel:	3.30	FC	3.80	C
7. When my teacher says that he or she is going to give me a Chemistry activity, I feel:	3.28	FC	3.76	C
8. When I solve Chemistry problems, I feel:	3.15	FC	3.62	C
9. When I know that I am going to have a Chemistry test, I feel:	2.96	FC	3.66	C
10. When the teacher calls on me to answer in Chemistry, I feel:	2.81	FC	3.43	C
11. If I have to solve a Chemistry problem on the board in front of the class, I feel:	2.52	LC	3.29	LC
Composite	**3.25**	**FC**	**3.73**	**C**

Note: 4.21 – 5.00 (Very Confident, VC), 3.41 - 4.20 (Confident, C), 2.61 – 3.40 (Fairly Confident, FC), 1.81 – 2.60 (Less Confident, LC), 1.00–1.80 (Not Confident, NC)

Table 1 presents the self-confidence levels of the experimental group in performing chemistry laboratory tasks before and after the introduction of the web-based laboratory experiment. Before utilizing the web-based laboratory experiment, the students were "fairly confident" in working on chemistry-related activities, as evidenced by the composite mean of 3.25. This finding aligned with the claims of Jabeen (2022) when they noted that the students are only confident in doing Chemistry activities using the lecture-discussion method because the subject poses challenges to them as they frequently develop specific behaviors, such as hesitating to engage in doing experiments. This finding parallels the claims of Abarro and Asuncion (2021) that students, particularly those with negative high school chemistry experiences, approach the subject with resistance.

Furthermore, it can be noticed that after utilizing the web-based laboratory experiment, the students are "confident" in performing Chemistry laboratory activities in school and at home, as signified by the composite mean of 3.73. The result implies that a web-based lab sustains and increases the confidence and skill of the students in carrying out tasks. This result coincides with the findings of Giamattei et al. (2020), who claimed that the web-based lab positively impacts students' interest in participating and boosts their confidence in doing scientific tasks. Similarly, the study of Hernández-de-Menéndez et al. (2019) revealed the same when they found that Virtual laboratories mimic real experiments by simulating everything on computers. Web-based labs sustain and increase the confidence and skill of students in carrying out tasks.

Habiddin et al. (2020) also found that when students feel more assured about their capability to learn a subject, it can positively impact their overall grasp of the material and contribute to a more effective and meaningful learning experience. Students' confidence in chemistry, physical chemistry, and chemical kinetics made them appreciate the concepts in these areas.

Table 2. Attitude of the experimental group in performing chemistry laboratory before and after the introduction of the web-based laboratory experiment in terms of value

Indicators	Before			After		
	$\bar{x}$	VD	EoV	$\bar{x}$	VD	EoV
1. The concepts in Chemistry can be applied in the real world.	4.49	SA	VH	4.49	SA	VH
2. Performing experiments in Chemistry engages me to focus, a skill that can also be applied to other areas.	4.29	SA	VH	4.30	SA	VH
3. Doing activities in Chemistry, like experimentation, develops my scientific skills.	4.23	SA	VH	4.22	SA	VH
4. Chemistry, like other sciences, encourages me to stay curious and engaged.	4.23	SA	VH	4.27	SA	VH
5. Chemistry helps me to understand daily life and practical concepts.	4.18	A	H	4.33	SA	VH
6. Chemistry nurtures a sense of curiosity and inquiry.	4.18	A	H	4.28	SA	VH
7. Chemistry helps me to develop analytical skills.	4.13	A	H	4.34	SA	VH
8. Chemistry is one of the most important disciplines.	4.13	A	H	4.18	A	H
9. Conducting experiments in Chemistry can develop my independence.	4.00	A	H	4.22	SA	VH
Composite	**4.21**	**SA**	**VH**	**4.29**	**SA**	**VH**

Note: 4.21 – 5.00 (Strongly Agree, SA - Very High, VH), 3.41 - 4.20 (Agree, A – High, H), 2.61 – 3.40 (Moderately Agree, M – Moderate, M), 1.81 – 2.60 (Disagree, D – Low, L), 1.00 – 1.80 (Strongly Disagree, SD - Very Low, VL)

Table 2 presents the experimental group's perceived value of chemistry laboratory tasks before and after the introduction of the web-based laboratory experiment. It can be gleaned from the result that the level of attitude in valuing the experimental group before and after the given intervention in this aspect is "Very High," having composite means of 4.21 and 4.29. It can be observed that the experimental group rated "Very high" on the following indicators: a) Chemistry concepts can be applied in the real world; b) Chemistry experiments are engaging; c) Chemistry experiments develop their scientific skills; and d) Chemistry sustained students' curiosity and engagement with weighted means ranging from 4.22 to 4.29. The results suggest that the respondents highly recognized the importance of learning the concepts relevant to Chemistry as these could greatly help develop their scientific and analytical thinking skills.

The research carried out by Iyamuremye et al. (2023) unveiled that the students highly valued conventional science laboratories and appreciated them because of their essential role in transforming the learning environment. It allows students to work cooperatively in groups, enhancing their understanding of scientific concepts, inquiry skills, and scientific attitude as they investigate scientific phenomena. Hensen and Barbera (2019) expressed similar observations when they claimed that the traditional lab is useful and valuable to the learning process since it provides students with hands-on experience, enabling them to engage directly with materials and equipment, thereby reinforcing theoretical concepts learned in lectures and textbooks.

Conversely, Trúchly et al. (2019) expressed that students show appreciation and prominent value upon utilizing online resources such as the web-based laboratory. They further observed that students' motivation to learn and their knowledge acquisition truly improved when the virtual lab was introduced. This is backed up by the claims of De Las Heras et al. (2021), who divulged that students show great value in utilizing or integrating virtual laboratories as it is well-received and appreciated. Its use shortens the time needed to conduct experiments.

Table 3. Attitude of the experimental group in performing chemistry laboratory before and after the introduction of the web-based laboratory experiment in terms of enjoyment

Indicators	Before			After		
	$\bar{x}$	VD	EoE	$\bar{x}$	VD	EoE
1. I enjoyed participating in the chemistry experiment.	4.18	A	H	4.29	SA	VH
2. I look forward to participating in Chemistry activities.	4.00	A	H	4.13	A	H
3. The activity enhances my enjoyment of doing activities in Chemistry.	3.99	A	H	4.23	SA	VH
4. I derive satisfaction from understanding chemical reactions through web-based activities.	3.85	A	H	4.03	A	H
5. Completing chemistry activities online is a fun experience for me.	3.76	A	H	4.05	A	H
6. The interactive nature of online chemistry experiments makes the activities more enjoyable.	3.75	A	H	4.09	A	H
7. Overall, I enjoy the interactive aspects of learning chemistry through online activities.	3.63	A	H	4.04	A	H
8. I find pleasure in exploring chemistry concepts through web-based simulations.	3.61	A	H	3.94	A	H
9. Overall, I enjoy the interactive aspects of learning chemistry through online activities.	3.61	A	H	3.97	A	H
Composite	**3.82**	**A**	**H**	**4.08**	**A**	**H**

Note: 4.21 – 5.00 (Strongly Agree, SA - Very High, VH), 3.41 - 4.20 (Agree, A – High, H), 2.61 – 3.40 (Moderately Agree, M – Moderate, M), 1.81 – 2.60 (Disagree, D – Low, L), 1.00 – 1.80 (Strongly Disagree, SD - Very Low, VL)

Table 3 presents the enjoyment levels of the experimental group in performing chemistry laboratory tasks before and after the introduction of the web-based laboratory experiment. The data disclosed that the experimental group "Agree" that they "Highly" enjoy performing laboratory activities in Chemistry before and after the web-based laboratory is utilized, as revealed in its composite mean of 3.82 and 4.08, respectively. Specifically, the data reveal that the experimental group "strongly agree" that they enjoyed very much when web-based experiments were used as they actively performed chemistry experiments and that doing the activities brings them considerable enjoyment, as revealed in its weighted means of 4.29 and 4.23. These findings indicate that the students exhibit a positive attitude towards performing Web-based chemistry laboratory activities; thus, they enjoyed what they were doing, leading them to become productive.

Adkins (2020) revealed that students find conventional or hands-on laboratory activities more interesting and enjoyable. Formella-Zimmermann et al. (2022) also claimed that students are more into the hands-on approach and considered these activities very engaging, which resulted in higher perceived enjoyment scores among the participants. Salame and Makki (2021) presented their opposite claims when they found that interactive simulations, which are like web-based instruction, positively impact students' attitudes and develop students' conceptual understanding of chemistry concepts. They also added that interactive simulations provide students with quality learning opportunities and enjoyment in class. Also, Engelberger et al. (2021), in their study also discovered that students show enjoyment and positive attitude towards cloud-based or online software because it allows them to understand concepts and it also improves their ability to perform activities within reasonable time frames and their enjoyment during their execution.

Table 4. Level of Attitude of the experimental group in performing chemistry laboratory before and after the introduction of the web-based laboratory experiment in terms of motivation

Indicators	Before		After	
	x̄	VD	x̄	VD
1. Doing laboratory experiments in Chemistry makes me feel:	4.10	M	4.28	EM
2. Participating in chemistry class makes me feel:	3.82	M	4.04	M
3. Learning chemistry makes me feel:	3.78	M	3.99	M
4. Mastering Chemistry concepts makes me feel:	3.77	M	4.20	M
5. Exploring advanced topics in chemistry makes me feel:	3.76	M	4.00	M
6. Thinking about working on Chemistry in class makes me feel:	3.76	M	4.01	M
7. Working on Chemistry at home makes me feel:	3.66	M	3.94	M
8. Engaging myself in online chemistry tasks or activities makes me feel:	3.63	M	3.97	M
9. Chemistry assignments make me feel:	3.38	FM	3.87	M
10. Solving Chemistry problems makes me feel:	3.38	FM	3.73	M
11. Knowing that I am going to have a Chemistry test makes me feel:	3.22	FM	3.67	M
Composite	**3.66**	**M**	**3.99**	**M**

Note: 4.21 – 5.00 (Extremely Motivated, EM), 3.41 - 4.20 (Motivated, M), 2.61 – 3.40 (Fairly Motivated, FM), 1.81 – 2.60 (Less Motivated, LM), 1.00 – 1.80 (Not Motivated, NM)

Table 4 presents the motivation levels of the experimental group in performing chemistry laboratory tasks before and after the introduction of the web-based laboratory experiment. The results disclosed that students in the experimental group are motivated to perform chemistry laboratory experiments before and after web-based experiments, as reflected in its composite means of 3.66 and 3.99. The findings further reveal that the students agree that they are extremely motivated to do chemistry laboratory experiments. The results suggest that students in the experimental group find the laboratory experiments interesting and engaging as they are more likely to participate in the activities and seek to understand the concepts fully. It fosters a deeper engagement with the subject matter as students become more enthusiastic and proactive in their learning. The same finding was unveiled by Elford et al. (2022), who claimed that online learning on inorganic stereochemistry has engaged and motivated students. Viitaharju et al. (2021) also noted that the classroom environment is engaging and effective when the teacher utilizes a web-based activity in performing their laboratory experiments. This result coincides with the findings of Trúchly et al. (2019), who posited that students' motivation to learn when the web-based lab was introduced to them. Interactive and accessible virtual labs improve motivation for studying, potentially leading to increased learning outcomes and a more positive educational experience.

3.2 Difference in the Level of Attitude among the Experimental Group in Performing Chemistry Laboratory Before and after the Introduction of the Web-based Laboratory Experiment

Table 5 illustrates the significant difference in attitude among the experimental group of students performing laboratory tasks before and after implementing the web-based laboratory experiment, and the data indicated the following results: (a) Self-Confidence: $p = .001$ (significant); (b) Perceived Value: $p = 0.022$ (significant); (c) Enjoyment: $p = .001$ (significant); and Motivation: $p = 0.368$ (not significant).

Table 5. Difference in the attitude of the experimental group in performing chemistry laboratory before and after the introduction of the web-based laboratory experiment (n = 79)

Variables	Median		Difference	W	p-value	Remark
	Before	After				
Self-Confidence	3.27	3.73	0.46	211.5	<.001	Significant
Value	4.33	4.44	0.11	678.0	0.022	Significant
Enjoyment	3.78	4.11	0.33	767.5	<.001	Significant
Motivation	3.64	4.00	0.36	542.0	0.368	Not significant

Wilcoxon Test at 5% level of significance

Conversely, the Wilcoxon Test reveals a significant difference in students' attitudes in terms of their self-confidence ($p <.001$), perceived value ($p = 0.002$), and enjoyment ($p <.001$) in learning Chemistry. This indicates that the introduction of the web-based laboratory experiment has effectively enhanced students' confidence in conducting Chemistry laboratory work, increased their appreciation of the subject's value, and boosted their enjoyment in learning Chemistry.

The results agree with the claims of Oladejo et al (2021), who stressed that the use of varied teaching strategies in chemistry education, in contrast to traditional teaching methods such as the use of computer simulation or technology-based activities, is effective, therefore improving students' attitudes in learning such as self-confidence. According to Habiddin et al. (2020), students' confidence in chemistry can affect their achievement positively. Moreover, in the increase in appreciation of the subject's value, Nikolic (2015) supports that students' appreciation of online resources as a tool for learning will enhance their learning experiences, increase productivity, and improve teaching and learning methods. Furthermore, in terms of student's enjoyment in learning Chemistry, Engelberger et al. (2021) explained that students show enjoyment and positive attitude towards cloud-based or online software on different topics in science because it helps them understand the concepts and improve their abilities to perform activities within reasonable time frames. In their study, Salame and Makki (2021) discovered that a web-based laboratory allows students to grasp, enjoy, and connect chemical systems and sub-microscopic phenomena through dynamic visualizations.

The data also indicate no significant difference in students' motivation ($p = 0.368 > \alpha = 0.05$) before and after implementing the web-based laboratory experiment. This suggests that while the web-based approach successfully enhanced self-confidence, perceived value, and enjoyment, it did not significantly affect students' overall motivation. One possible explanation is that factors beyond the scope of the web-based laboratory may influence motivation.

This result is in opposition to the claims of Viitaharju et al. (2021), who noted that a classroom environment is effective when a teacher utilizes a web-based activity in performing laboratory experiments, as it heightened student involvement and motivation, resulting in improved learning outcomes. Elford et al. (2022) also mentioned that online learning on inorganic stereochemistry has engaged and motivated students.

3.3 Performance of the Experimental Group on Expressing Chemical Concentrations before and after Utilizing the Web-based Laboratory Experiment

Table 6 shows that the experimental group received very satisfactory ratings on expressing concentrations before and after utilizing the web-based laboratory experiment, with mean ratings of 85.54 % and 86.50 %, respectively.

Table 6. Performance of the experimental group on expressing chemical concentrations before and after utilizing the web-based laboratory experiment (n =79)

Rating	Verbal Description	Before		After	
		f	%	f	%
90 – 100	Outstanding (O)	12	15.19	20	25.32
85 – 89	Very Satisfactory (VS)	41	51.90	31	39.24
80 – 84	Satisfactory (S)	18	22.78	25	31.65
75 – 79	Fairly Satisfactory (FS)	8	10.13	3	3.80
≤ 74	Did Not Meet Expectations (DNME)	---	---	---	---
Total		79	100.00	79	100.00
Mean		**85.54% (VS)**		**86.50% (VS)**	
SD		**4.13**		**3.87**	

Performance improved after utilizing the web-based lab. The percentage of the students in the "Outstanding" category increased from 15.19% to 25.32%. The mean score also increased from 85.54% to 86.50%, indicating a slight overall improvement in performance. There is a shift from lower to higher categories in the distribution of scores. For instance, the "Fairly satisfactory" category decreased from 10.13% to 3.80%, and the "Satisfactory" category increased from 22.78% to 31.65%. This suggests that students who previously scored in the Fairly Satisfactory level improved up to Satisfactory, Very Satisfactory, and others, even in the Outstanding levels. The standard deviation decreased from 4.13 to 3.87, indicating that the scores became slightly more consistent after the intervention. The results revealed that no students are classified under the "Did Not Meet Expectations" category either, which is a positive sign of overall competency in the group.

The result is congruent with the study conducted by Theresia et al. (2023) using a one-group pretest-posttest design to assess the impact of virtual laboratory media on student learning outcomes, specifically acid-base titration concepts. They disclosed a significant enhancement in student learning, highlighting the effectiveness of the virtual lab in facilitating a deeper comprehension of the subject matter. The virtual lab helped students grasp complex concepts more effectively by providing an interactive and engaging learning environment, leading to notable improvements in their academic performance and practical skills.

3.4 Difference in the Performance of the Experimental Group on Expressing Chemical Concentrations Before and after Utilizing the Web-based Laboratory Experiment

Table 7 unveils a significant difference in the experimental group's performance on expressing chemical concentrations before and after engaging with the web-based laboratory experiment, with a p-value of 0.009.

Table 7. Analysis table on the difference in the performance of the experimental group on expressing chemical concentrations before and after utilizing the web-based laboratory experiment (n = 79)

Performance	$\bar{x}$	D	t	p-value	Decision	Remark	Effect Size
Before	85.54	0.96	2.68	0.009	Reject H_{o4}	Significant	0.301
After	86.50						

Level of significance = 0.05; Cohen's d Effect Size Interpretation: d=0.2 (small); d=0.5 (medium); d =0.8 (large)

Meanwhile, the table presents data indicating a significant difference (p = 0.009) in the experimental group's performance expressing chemical concentrations before and after engaging with the web-based laboratory experiment. The data illustrates an improvement in their performance following the implementation of the web-based laboratory experiment, signifying its effectiveness in enhancing their proficiency in this aspect of Chemistry. Also, the outlined data reveal an effect size of 0.301, indicating a small but significant improvement in the experimental group's performance on expressing chemical concentrations after utilizing the web-based laboratory experiment. This suggests that while the web-based lab positively impacted student performance, the magnitude of the improvement was modest. The finding parallels the claims of Elford et al. (2022), who disclosed that online learning platforms improve students' overall performance. Viitaharju et al. (2021) also stressed the same when they revealed that web-based activities in performing laboratory experiments heighten student involvement and learning outcomes.

3.5 Relationship between the Level of Attitude of the Experimental Group in Performing Chemistry Laboratory after the Web-based Laboratory Experiment and their Performance in Expressing Chemical Concentrations

Table 8 reveals that there is no significant relationship between the level of Attitude of the Experimental Group in Performing Chemistry Laboratory activities after the Web-based Laboratory Experiment and their Performance in Expressing Chemical Concentrations in the following constructs: (a) Self-Confidence: p = 0.492; (b) Enjoyment: p = 0.341; and (c) Motivation: p = 0.096. Furthermore, the results also divulge that a significant relationship existed between students' perceived Value: p = 0.011 and their performance in expressing Chemical Concentrations.

Table 8. Relationship between the students' level of attitude of the experimental group in performing chemistry laboratory after the web-based laboratory experiment and their performance in expressing chemical concentrations

Performance Correlated to the Following Attitude Constructs:	r_s	p-value	Remark
Self-Confidence	0.078	0.492	Not significant
Value	0.285	0.011	Significant
Enjoyment	0.109	0.341	Not significant
Motivation	0.189	0.096	Not significant

Level of significance = 0.05; n = 16 in each group

Moreover, the data outlined indicate that among the four constructs of students' attitude in the experimental group, only their perceived value of Chemistry demonstrates a significant relationship (p = 0.011) with their performance in expressing chemical concentrations. This implies that as students' perceived value of Chemistry increases, their performance in the mentioned area also improves.

The result of the study is in line with the findings of Nikolic (2015) as he indicated that students' appreciation of online resources, particularly the Training Laboratory, as a tool in teaching chemistry laboratory activities, contributes to enhanced learning experiences, increased productivity, and improvements in students' academic performance. Trúchly et al. (2019) also revealed in their study that students appreciated and valued the virtual laboratory since it improved their learning and increased their motivation to learn. De Las Heras et al. (2021), in their study, claimed that students show great value in utilizing virtual laboratories as it shortens the time to conduct experiments. In addition, the study of Eya and Tjprc (2020) highlighted a significant positive relationship between students' attitude to chemistry and their performance in the subject. Meanwhile, the lack of a significant relationship between students' attitudes regarding self-confidence, enjoyment, and motivation and their performance indicates that changes in their degrees of self-confidence, enjoyment, and motivation are not associated with shifts in their performance in expressing chemical concentrations.

4.0 Conclusion

The findings collectively underscore the effectiveness of innovative teaching methods, particularly web-based laboratory experiments, in enhancing students' attitudes regarding motivation, engagement, enjoyment, putting value to chemistry, and students' performance in Chemistry education. Web-based laboratory activities are important in enhancing students' performance and attitude toward chemistry. This hands-on experience deepens their understanding of complex concepts, leading to improved academic performance. The flexibility and convenience of web-based experiments increase engagement, as students can learn at their own pace and re-examine experiments as needed. Moreover, the interactive nature of web-based instruction makes learning more fun, nurturing students' positive attitudes toward chemistry and emphasizing its real-world applications, thus increasing students' overall valuing of the subject. This study uniquely contributes to existing educational practices by highlighting how web-based laboratory experiments can be effectively integrated into traditional curricula to improve student outcomes. The small effect size observed in the significant difference in the experimental group's performance on expressing chemical concentrations before and after utilizing the web-based laboratory suggests that while there was a positive impact, the magnitude of improvement was modest. This could be due to the novelty of the web-based approach, initial adjustment periods for students, or variations in individual student engagement and learning styles. Building on these findings, future research could focus on refining web-based laboratory experiments by integrating adaptive learning technologies or offering additional resources to assist students in adapting to this mode of instruction. Further studies might also consider examining these approaches' long-term impact and adaptability across various educational environments. For educators, incorporating web-based labs into their teaching strategies can significantly enhance student engagement and boost academic performance. To achieve the best outcomes, it would be beneficial to introduce these tools gradually and consistently gather and respond to student feedback to improve the learning experience.

5.0 Contributions of Authors

The author responsible for data collection also took the lead in conceptualizing the study. Concurrently, the adviser contributed by thoroughly reviewing and refining the manuscript, ensuring its academic quality. Moreover, specialists in statistics and methodology played a key role in developing research methods and performing data analyses. The authors affirm their collaborative efforts throughout the research, and each participated in the final review and approval of the paper.

6.0 Funding

This research did not receive funding from any funding agency.

7.0 Conflict of Interests

This study has no conflict of interest of any sort.

8.0 Acknowledgment

The authors extend their deepest gratitude to everyone who contributed to the success of this study.

9.0 References

Abarro, R. Q., & Asuncion, J. E. (2021). Metacognition in chemistry education. ISJ Theoretical & Applied Science, 3(95), 1-22. https://dx.doi.org/10.15863/TAS.2021.03.95.1

Adkins, D. (2020). Effects of hands-on experiences on student achievement, interest, and attitude in chemistry. Electronic Theses and Dissertations. https://scholarworks.sfasu.edu/etds/343

Alo, M. P., & Origines JR, D. V. (2021). Integrated Web-Based Learning Approach and The Students' Academic Achievement. In Proceeding of International Conference on Science, Health, And Technology, Surakarta, Indonesia, 235-240

De Las Heras, S. C., Kensington-Miller, B., Young, B., Gonzalez, V., Krühne, U., Mansouri, S. S., & Baroutian, S. (2021). Benefits and challenges of a virtual laboratory in chemical and Biochemical Engineering: Students' experiences in fermentation. Journal of Chemical Education, 98(3), 866–875. https://doi.org/10.1021/acs.jchemed.0c01227

Elford, D., Lancaster, S. J., & Jones, G. A. (2022). Fostering Motivation toward Chemistry through Augmented Reality Educational Escape Activities. A Self-Determination Theory Approach. Journal of Chemical Education, 99(10), 3406–3417. https://doi.org/10.1021/acs.jchemed.2c00428

Engelberger, F., Galaz-Davison, P., Bravo, G., Rivera, M., & Ramírez-Sarmiento, C. A. (2021). Developing and implementing Cloud-Based tutorials that combine bioinformatics software, interactive coding, and visualization exercises for distance learning on structural bioinformatics. Journal of Chemical Education, 98(5), 1801–1807 https://doi.org/10.1021/acs.jchemed.1c00022

Eya, N. M., & Tjprc. (2020). Socio-Psychological factors as correlates of students' performance in chemistry, implication for science and engineering education. International Journal of Mechanical and Production Engineering Research and Development, 10(4), 239–248. https://doi.org/10.24247/ijmperdaug202021

Formella-Zimmermann, S., Kleespies, M. W., & Dierkes, P. W. (2022). Motivation and Technology Acceptance in a Neuroscience Student Lab—An empirical comparison between virtual experiments with and without hands-on elements. Frontiers in Education, 7. https://doi.org/10.3389/feduc.2022.817598

Galang, A., Snow, M. A., Benvenuto, P., & Ks, K. (2022). Designing virtual laboratory exercises using Microsoft Forms. Journal of Chemical Education, 99(4), 1620–1627. https://doi.org/10.1021/acs.jchemed.1c0100

Giamattei, M., Yahosseini, K. S., Gächter, S., & Molleman, L. (2020). LIONESS Lab: a free web-based platform for conducting interactive experiments online. Journal of the Economic Science Association, 6(1), 95–111. https://doi.org/10.1007/s40881-020-00087-0

Habiddin, H., Page, E. M., Herunata, H., Sulistina, O., Winartiasih, W., Mu'arifin, M., & Maysara, M. (2020). Does students' confidence in chemistry boost their understanding? Nucleation and Atmospheric Aerosols. In: The 3rd International Conference On Mathematics And Science Education, Malang, Indonesia

Hensen, C., & Barbera, J. (2019). Assessing Affective Differences between a Virtual General Chemistry Experiment and a Similar Hands-On Experiment. Journal of Chemical Education, 96(10), 2097–2108. https://doi.org/10.1021/acs.jchemed.9b00561

Hernández-de-Menéndez, M., Vallejo Guevara, A., & Morales-Menendez, R. (2019). Virtual reality laboratories: a review of experiences. International Journal on Interactive Design and Manufacturing (IJIDeM), 13, 947-966. https://doi.org/10.1007/s12008-019-00558-7

Iyamuremye, A., Nsabayez, E., Ngendabanga, C., & Hagenimana, F. (2023). Effectiveness of hands-on practical activities in teaching and learning chemistry: An exploration of students' engagement, experience, and academic performance. African Journal of Educational Studies in Mathematics and Sciences, 19(1), 97–107. https://www.ajol.info/index.php/ajesms/article/view/261605

Siddique, M., Ahmed, M., Feroz, M., Shoukat, W., Jabeen, S. (2022). Attitude Towards Learning Chemistry: A Case Of Secondary School Students In Pakistan. Journal of Positive School Psychology, 6(12), 1031-1055. https://rb.gy/ipwklz

Kolil, V. K., Muthupalani, S., & Achuthan, K. (2020). Virtual experimental platforms in chemistry laboratory education and its impact on experimental self-efficacy. International Journal of Educational Technology in Higher Education, 17(1), 30. https://doi.org/10.1186/s41239-020-00204-3

Kots, K. (2021). Why is chemistry important & why you should study chemistry. Retrieved from https://rb.gy/f3acro

Musengimana, J., Kampire, E., & Ntawiha, P. (2021). Factors affecting secondary schools students' attitudes toward learning chemistry: A review of literature. Eurasia Journal of Mathematics, Science and Technology Education, 17(1), 1931. https://doi.org/10.29333/ejmste/9379

Nikolic, S. (2015). Understanding how students use and appreciate online resources in the teaching laboratory. International Journal of Online and Biomedical Engineering, 11(4), 8–13. https://doi.org/10.3991/ijoe.v11i4.4562

Salame, I. I., & Makki, J. (2021). Examining the Use of PHET Simulations on Students' Attitudes and Learning in General Chemistry II. Interdisciplinary Journal of Environmental and Science Education, 17(4), e2247. https://doi.org/10.21601/ijese/10966

Trúchly, P., Medvecký, M., Podhradský, P., & El Mawas, N. (2019). STEM education supported by virtual laboratory incorporated in self-directed learning process. Journal of Electrical Engineering, 70(4), 332-344. https://intapi.sciendo.com/pdf/10.2478/jee-2019-0065

Viitaharju, P., Yliniemi, K., Nieminen, M., & Karttunen, A. J. (2021). Learning experiences from digital laboratory safety training. Education for Chemical Engineers, 34, 87–93. https://doi.org/10.1016/j.ece.2020.11.009