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Strategies for Online-education Model for Project and Laboratory-based Assessment in Environmental Monitoring and Analysis Course

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ABSTRACT: The global COVID-19 epidemic compelled all educational institutions, including universities, to cease academic instruction. To assure the ongoing process of teaching, learning, and assessment, several universities have transitioned from traditional face-to-face techniques to online ones. The purpose of the study was to examine the online-education experience in an Environmental Engineering course using a virtual lab and simulation software, as well as to determine the student's perception of the implementation of virtual labs and simulation software and the benefits of these tools for enhancing learning activities. To familiarize students with various areas of environmental engineering analysis, two simulated experiments were developed: water quality monitoring and adsorption spectroscopy. The virtual labs were generally well-received, as indicated by the responses to the Likert-type questions. Virtual laboratories are more acceptable for senior students than for first-year students, according to the consensus. 88% of respondents agreed with the average of twenty claims, compared with 3% who disagreed and 9% who agreed but disagreed with the statement. This illustrates that, although students believe that substituting virtual laboratories for conventional laboratories is not a complete solution, they believe that virtual laboratories can be used in conjunction with conventional methods to facilitate improved study outside of laboratory hours. Virtual and online learning in engineering labs are still relatively new; additional research is necessary before instructors can effectively utilize this delivery medium and its accompanying technologies to enhance student learning.

KEYWORDS: Online learning; virtual laboratory; environmental engineering; simulation; chemical software

1. Introduction

The coronavirus disease of 2019 (COVID-19) is a pandemic produced by the coronavirus responsible for Severe Acute Respiratory Syndrome (SARS-CoV). The COVID-19 global health epidemic has had a significant influence on global society, disrupting ordinary clinical practices and educational activities. The global COVID-19 epidemic compelled all educational institutions, including universities, to cease academic instruction and learning in order to prevent the virus's spread. This circumstance compels the academic community to seek out new and alternative tactics for student engagement in the learning process. To assure the ongoing process of teaching, learning, and assessment, several universities have transitioned from traditional face-to-face techniques to online ones. Now is the moment to apply flexible learning in higher education, where a learner-centered approach with multiple options is provided to students, allowing them to assume greater responsibility for their own learning [1, 2].

The Curtin University offered numerous lectures on pedagogy and methods for improving teachers' quality and style of teaching, including blended learning (online and face-to-face instruction), the flipped classroom, and problem-based learning. To enable instructors and students to master the use of Blackboard Collaborate Ultra and to train them on how to use Blackboard to create class sessions, online assignments, quizzes, tests, and final exams while using the lockdown browser and webcam monitor, all teaching and learning activities were conducted online and intensively during the lockdown. These activities were intended to supplement the material covered prior to the lockdown. Clearly, the suggested assignment must be tailored to the students' knowledge and maturity level. During the pandemic, teaching and learning activities aided instructors who had extensive knowledge of online eLearning but lacked the necessary skills to deliver this online education.During the COVD-19 pandemic, distant learning proved to be a viable option, particularly for students of chemical engineering and other engineering disciplines, as well as science, medicine, and technology [3, 4].The quarantine had various consequences for instructors and students, depending on, among other things, their level of expertise with computers and virtual tools prior to the quarantine.

During the COVID-19 pandemic, mandatory supporting courses for environmental engineering curricula, such as introductory chemistry, were greatly impacted [5, 6]. Several domains of environmental engineering and related disciplines were shown to positively apply creative and effective solutions in the fight against COVID-19 [7, 8]. The COVID-19 pandemic impacted fields outside of chemical engineering education. Researchers identified the obstacles and opportunities that impeded the mainstream application of overall operational effectiveness. The learning process is more important and sustainable if members of the remote learning community actively participate and engage with dedication and support [9, 10]. The purpose of the study was to examine the online-education experience in an Environmental Engineering course using a virtual lab and simulation software, as well as to determine the student's perception of the implementation of virtual labs and simulation software and the benefits of these tools for enhancing learning activities.

2. Materials and Methods

Two simulated experiments were created to familiarise students with various aspects of environmental engineering analysis.

2.1.Water quality monitoring

Water quality analysis is a critical component of environmental monitoring. When water quality is poor, it has an adverse effect not just on aquatic life but also on the surrounding environment. The critical factors that must be considered while evaluating the quality of drinking water are as follows: determination of total solids (TS), total dissolved solids (TDS), and total suspended solids (TSS) in water; determination of alkalinity in water; determination of chloride in water; determination of pH; determination of biological oxygen demand;

determination of chemical oxygen demand; determination of dissolved oxygen in water; and determination of turbidity in water.

2.2.Adsorption spectroscopy

Spectroscopy is a critical technique for analytical experiments because it is used to investigate the absorption, emission, or scattering of electromagnetic radiation by atoms, molecules, or their ions. Numerous molecular spectroscopic methods were used, including UV-Vis (absorption) spectroscopy, fluorescence (emission) spectroscopy, and some virtual experiments:

- Familiarization with the UV-Visible Absorption Spectroscopy. This instrument was utilized in a variety of scientific fields, such as bacterial cultivation, drug identification, and nucleic acid purity checks and quantification, as well as quality control in the beverage industry and chemical research.
- Solvent Effects on the UV-visible Absorption Spectra. The influence of solvent polarity on absorption spectra and the link between dye structures and UV-Visible spectrophotometer absorption were examined.
- Effects of sample path length and sample concentration on dependence of absorbance (Beer-Lambert Law). In chemistry, this law is used to measure chemical solution concentration, analyze oxidation, and quantify polymer deterioration.

2.3.Virtual lab set up

The simulation's setup was dependent on the mode of operation; when the simulation program was launched, it was conducted simultaneously. The student might choose an experiment and get information about it, such as the objective, theory, method, simulation, post-test, reference, and feedback. Students were expected to follow the instructions shown in the figures during the simulation. Then, utilizing graphs, statistical analysis, and correlation between parameters, statistical data were examined and interpreted. Figures 1 and 2 provide example simulations for a water quality parameter experiment and an adsorption spectroscopy experiment, respectively.

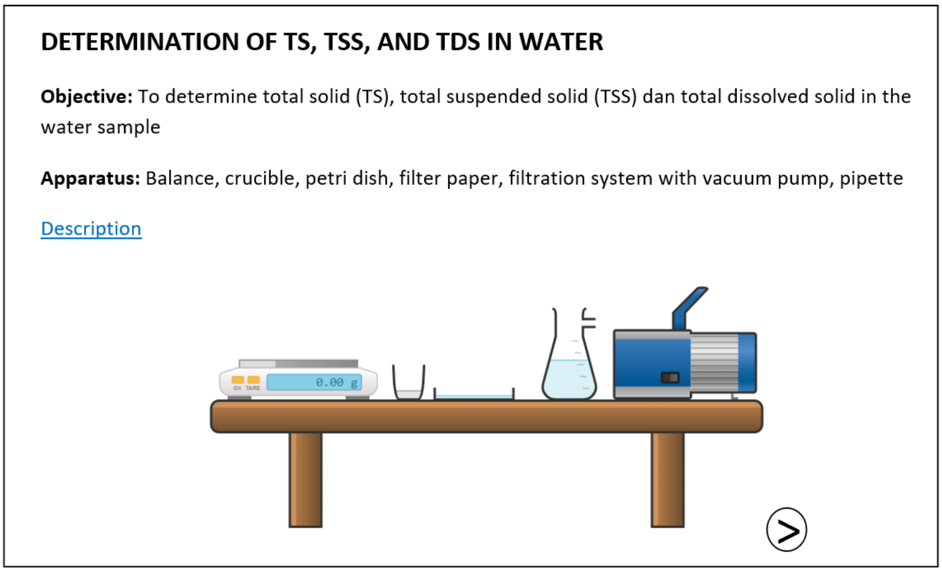

Figure 1. Example of simulation set-up for water quality parameters experiment.

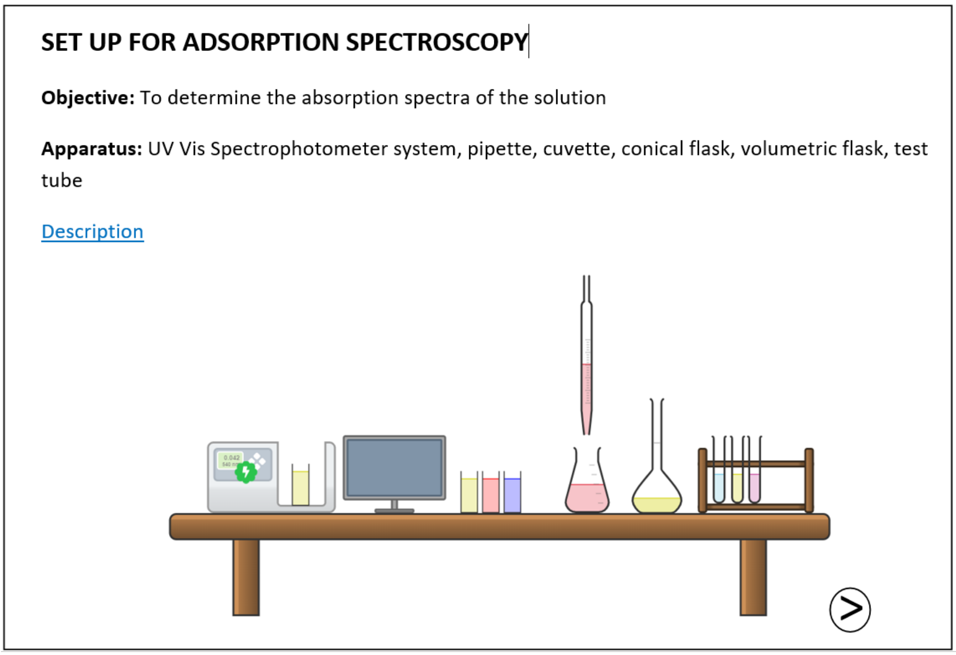

Figure 2. Example of simulation set-up for adsorption spectroscopy experiment.

2.4. Software

Chemsketch is an application for molecular modeling that permits the creation and editing of images of chemical structures. It is a collection of freeware tools that permits the rapid construction of three-dimensional molecular representations. The program contains various complex features, including the capacity to rotate and color molecules for enhanced visibility. It has many templates with ions and functional groups, as well as the ability to add text and use other tools to enhance the outputs of the software. Figure 3 displays the Chemsketch user interface.

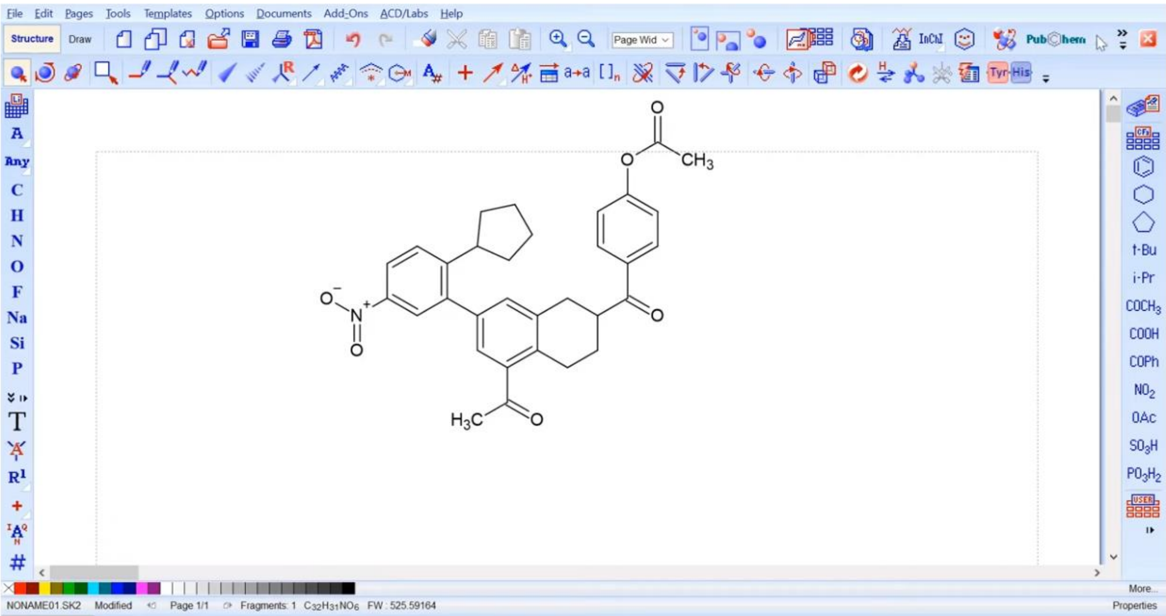

Figure 3. Interface of Chemsketch.

3. Result and Discussion

The group of students in the Environmental Engineering Unit was requested to conduct the virtual experiment. A significant issue in Experiment 1 was that, although the guide accurately represented a real-world scenario, the solution recommended included too many assumptions. The students want to increase the problem's complexity in order to minimize their assumptions. A typical water quality monitoring experiment included the measurement of TS, TDS, and TSS concentrations in water, as well as the determination of alkalinity. TDS is the total quantity of inorganic and organic compounds suspended in a liquid in molecular, ionized, or microgranular form (colloidal sol). Total dissolved solids are often addressed exclusively in relation to freshwater systems since salinity contains some of the ions included in the TDS definition. TSS are solids that can be removed from water with a filter. TSS may be composed of a broad variety of substances, including silt, decomposing plant and animal debris, industrial wastes, and sewage. Suspended sediment concentrations over a certain level may pose a number of issues for stream health and aquatic life. TSS and TDS may be added to get TS. The alkalinity of water refers to its ability to neutralize acid [11–13]. It is often represented in water as total alkalinity or caustic alkalinity. It is critical in a variety of applications and treatments for natural waters and wastewaters. Titrimetry was used to determine alkalinity by titrating against diluted sulfuric acid. To show pH 8.3 and pH 4.3, phenolphthalein and methyl orange are employed as indicators. Phenolphthalein produces a pink color when the pH is more than 8.3 and a colorless product when the pH is less than 8.3. The anticipated findings for the water quality parameter experiment are given in Figure 4.

DETERMINATION OF TS, TSS, AND TDS IN WATER

Observation: Sample volume = 100ml

Total Suspended Solid (TSS): $TSS = \frac{(S_2 - S_1)}{V} \times 1000$

Weight of petri dish and filter paper (S_1) = 20.334 g

Weight of petri dish, filter paper, solids (S_2) = 20.388 g

Total Suspended Solid (TSS) =______mg/l Check

Figure 4. Results expected for water quality parameters experiment.

Solvent impact on UV-visible adsorption spectra and the effect of sample route length on adsorbance were two examples of adsorption spectroscopy study experiments (Lambert law). The purpose of this experiment was to identify the impact of solvents on a molecule's UV-visible absorption spectrum and to comprehend and determine the connection between the sample route length and the absorbance of a particular sample. The term "solvent effects" refers to the sum of a solvent's bulk characteristics, such as polarity, dielectric constant, dispersive-induction-polarization interactions, viscosity, and/or particular solute-solvent interactions. The term "generic solvent effects" refers to the solvent-dependent spectrum changes that result from the interaction of the chromophore with the whole set of surrounding solvent molecules and do not require any chemical interactions or particular solvent-chromophore interactions. In such situations, the energy difference between the ground and excited states is influenced by the dipole interaction between the solvent and the chromophore, which is determined by the refractive index and dielectric constant of the solvent. The quantity of light absorbed is proportional to the distance traveled by the light via the absorbing material. Lambert law is the name given to this connection (Bouguer-Lambert law). Lambert's law states that each layer of similar thickness in a material absorbs an equal proportion of the light passing through it [14]. In other words, the percentage of absorbed light is proportional to the length of the sample route. As an example, suppose a beam of monochromatic light with an intensity of Io lands on a sample. For a route length dl (with unit cross-section, l is the path length), the intensity decreases by dI owing to radiation absorption. The anticipated findings of the adsorption spectroscopy experiment are shown in Figure 5.

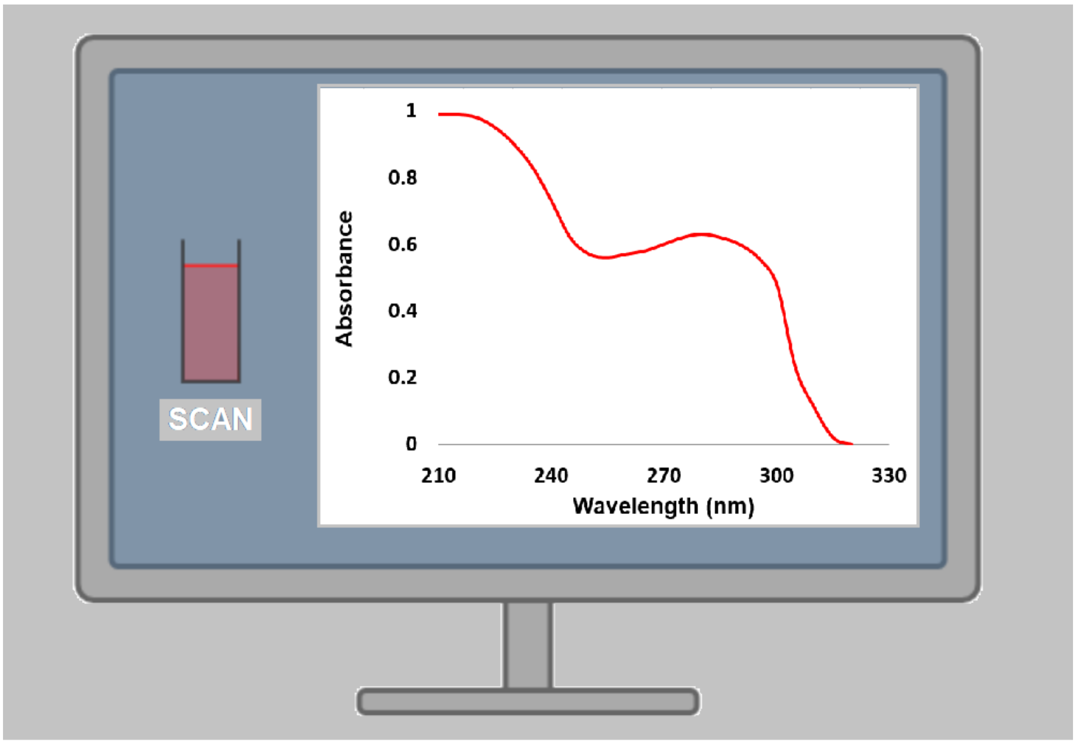

Figure 5. Results expected for adsorption spectroscopy experiment.

Students were challenged in experiments 1 and 2 to find a correlation between parameters of water quality and the adsorption capacity of a specific adsorbent. The student viewed these experiments as a logical advance from the more traditional problems used to introduce the investigation of pollution and treatment possibilities. Given that the students were already familiar with parameters and the statistical data analysis that they learned during the lecture session, a statistical analysis was conducted to find the mean value, variance, and standard deviation of the parameter for the values obtained from the sites or laboratory results. Regression was used to analyze the correlation of the water quality parameters. After the physicochemical analysis of water quality parameters, the Water Quality Index (WQI), derived from the Interim National Water Quality Standards (INWQS), was applied to classify the status of the river water. Water quality parameters falling in Classes I–III based on the INWQS denote that the water quality level can sustain macroaquatic life. For drinking water supply, Class II water quality requires a conventional treatment system, whereas Class III water needs an advanced treatment system. Water categorized as Class IV can only be used for irrigation, while Class V water has minimal usage. Nevertheless, students considered the real-life nature of both experiments, particularly Experiment 2, to be confusing because both problems seemed to be more related to a research laboratory than to a practical engineering use case [15].

Figure 6 shows the range for the 11 parameters, and Table 1 shows the Pearson Coefficient of physicochemical methods for a water sample. Higher total dissolved solids (TDS) and total suspended solids (TSS) were observed in the downstream river, with an average value of 4298.63 mg/l and the latter at 227.88 mg/l. As observed from Table 1 and the result tabulation from the laboratory experiment, TDS and TSS are relatively higher at the downstream end of the river stream during daytime. TDS and TSS correlate with alkalinity (R^2 = 0.4689, 0.5576)2 = 0.5523, 0.7275), BOD (R^2= 0.8246, 0.7659), and fluoride concentration (R^2 = 0.7752, 0.8372).

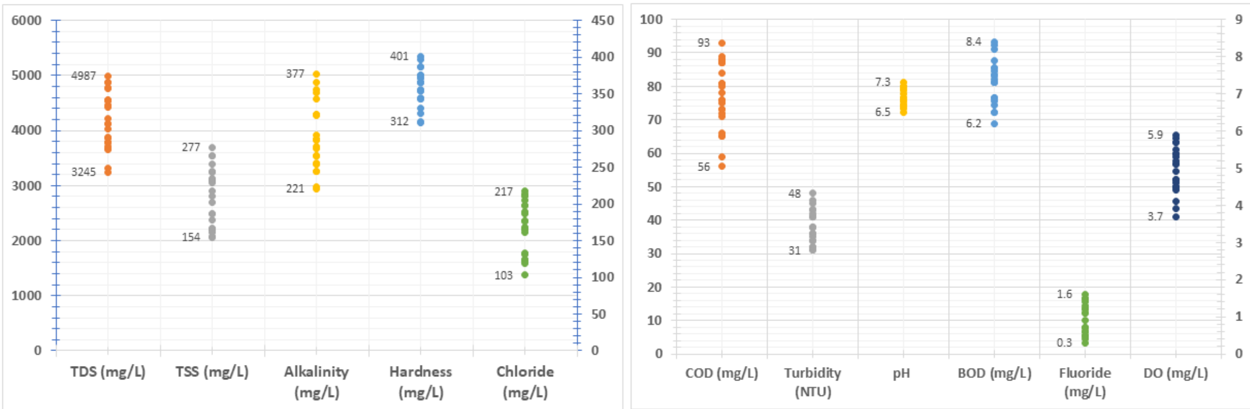

Figure 6. Statistical data of water quality parameters experiment.

Table 1. Pearson Coefficient of physicochemical methods for water sample.

Parameter	TDS (mg/L)	TSS (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)	Chloride (mg/L)	pH	BOD (mg/L)	COD (mg/L)	Fluoride (mg/)	DO (mg/L)	Turbidity (NTU)
TDS (mg/L)	1										
TSS (mg/L)	0.9599	1									
Alkalinity (mg/L)	0.4689	0.5576	1								
Hardness (mg/L)	0.5523	0.7275	0.6892	1							
Chloride (mg/L)	0.0669	0.1805	0.5705	0.6436	1						
pH	0.0676	0.1704	0.0587	0.355	0.265	1					
BOD (mg/L)	0.8246	0.7659	0.4807	0.331	0.0365	0.0432	1				
COD (mg/L)	0.2888	0.4775	0.6116	0.9056	0.833	0.5234	0.1792	1			
Fluoride (mg/)	0.7752	0.8372	0.7582	0.8325	0.3465	0.0825	0.5132	0.5763	1		
DO (mg/L)	0.0076	0.0115	0.0105	0.0252	0.0128	0.2333	0.0047	0.0219	0.0182	1	
Turbidity (NTU)	0.0219	0.0427	0.4555	0.136	0.2486	0.0581	0.1023	0.2128	0.1397	0.0558	1

From the data, the river stream has the highest TDS and TSS values because dissolved and suspended solids are more abundant when it is flowing. Among the three locations, downstream has the highest amount recorded; this might be due to the accumulation of substances from the upper stream and the middle stream. The TSS value obtained from the 3 sites falls in the Class IV category, which is only suitable for irrigation purposes and is not a favorable condition for aquatic life. According to regression analysis, there is no significant relationship between alkalinity and pH (R^2= 0.0587) or DO (R^2= 0.0105). The upper stream has a lower alkalinity compared to the middle stream and downstream, which both have almost the same alkalinity value of around 312 mg/l. The alkalinity value is lower at the riverbank compared to when it is at the river stream for both the middle stream and downstream river. Typically, at all locations, the alkalinity value increases from daytime to nighttime. The rise in alkalinity is due to an increase in bicarbonate ions released into the water sample. Figure 7 outlines the UV absorbance results for each concentration. A calibration curve of absorbance against the concentrations of a synthetic dye, Remazol Brilliant Blue R (RBBR), was derived from the known concentrations of RBBR dye solutions (in the range of 0.01–0.05 g/l). From the linear calibration curve, the absorptivity constant is represented by the gradient of the best-fit line y =13.69x + 0.0627. The data were fitted with a high correlation coefficient (r^2 = 0.9983), which legitimizes the molar absorptivity constant as being constant throughout the investigated concentration range. Therefore, the experimental readings determined in the batch analysis are precise.

There are just a few issues with using ChemSketch to create chemical structures, including issues with some commands in the Cut, Paste, and Print capabilities. The majority of students provide good feedback and a sense of assistance throughout the process of sketching the structures of compounds and molecules, which includes identifying radicals on compounds and drawing fragmentation arrows. Nonetheless, in order to keep the virtual experiment focused on the solution of the real-world engineering challenge, it is the experiment supervisor's responsibility to minimize any software-related issues. This is true even when the software is generously discounted and supported (as was the case here), and implementing this kind of approach in the education of engineers needs close cooperation and continuous effort on the part of academic and industry partners.

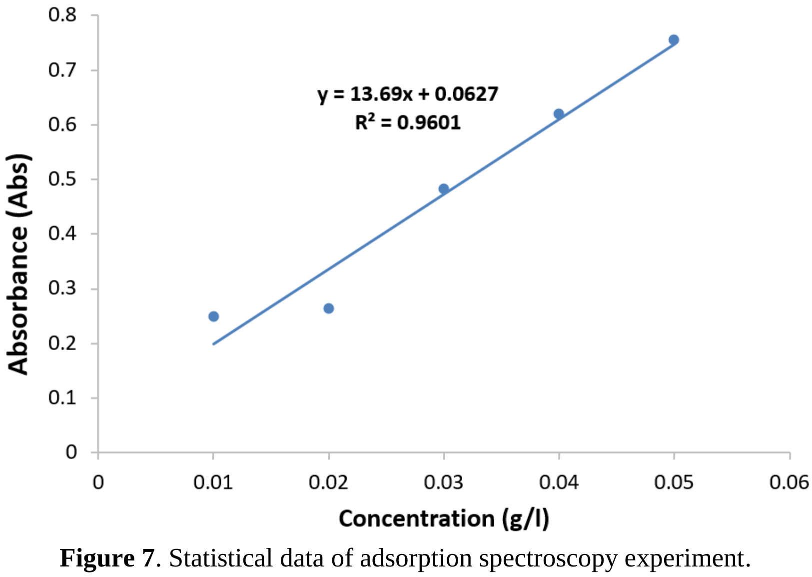

Figure 7. Statistical data of adsorption spectroscopy experiment.

Seven students (six domestic and one foreign) enrolled in the Environmental Engineering Analysis unit gave feedback on the virtual lab's implementation. According to the responses to the Likert-type questions, the virtual labs were generally well-received. The following table summarizes student responses to many assertions regarding virtual laboratories [17, 18]. Students expressed their agreement or disagreement with each Likert-type question (Table 2).

Table 2. Student feedback statement in virtual laboratory

No	Question	Agree	Neutral	Disagree
1	Virtual lab help you to understand the water quality monitoring	86%	14%	-

2	Virtual lab help you to understand the adsorption experiment	86%	14%	-
3	After completion of virtual lab, I am able to explain the principles of adsorption processes?	71%	-	29%
4	The virtual lab has helped in the analysis and interpretation of the results	57%	29%	14%
5	Virtual lab complement the use of related hands-on labs?	100%	-	-
6	Immediate exposure to virtual lab has helped me to apply classroom theoretical knowledge to practical experience	86%	14%	-
7	A step by step procedure of the experiment in virtual lab has helped me to perform experiment in a systematic way	86%	14%	-
8	After completion of virtual lab, I am able to perform a environmental engineering analysis correctly without the help of an instructor	71%	29%	-
9	I believe the virtual lab allowed me to undertake the hands-on experiment effectively	100%	-	-
10	Enables laboratory experience at any time and anywhere	100%	-	-
11	Allows students more opportunities to practice experiments, particularly for those that may not be easily replicated due to resources, time and safety issues	100%	-	-
12	Provides a safe workshop environment without the need for supervision	100%	-	-
13	Enhances students' enthusiasm for learning through interactivity	86%	14%	-
14	Increase students' IT literacy	100%		-
15	Discourages students from learning the physical instruments and real devices	100%	-	-
16	Remote access discourages direct collaboration and interaction amongst students and teachers	100%	-	-
17	Increased risk of plagiarism in assessment	71%	29%	-
18	Physical, practical skills that are expected of an engineer are not honed	71%	29%	-
19	The virtual lab is easy to use	86%	-	14%
20	The particular virtual lab is closely related to Environmental Engineering Analysis Unit	100%	-	-

There was widespread agreement that virtual labs are more appropriate for senior students than for first-year students. According to the poll results, 88% of respondents agreed with the average of twenty assertions, compared to 3% who disagreed, while 9% agreed but disagreed with the statement. However, all students agreed with the statements "virtual lab complements the use of related hands-on labs," "virtual lab allowed me to effectively undertake the hands-on experiment," "enables laboratory experience at any time and anywhere," "allows students more opportunities to practice experiments," "provides a safe workshop environment without the need for supervision," "increases students' IT literacy," and so on. In addition, some students have provided their opinions on the implementation of virtual laboratories. They commented that:

'Virtual labs prevent us from conducting the lab wrongly because detail procedure is provided, but virtual labs could be confusing at the same time because students might not fully know what and why it happen like this.'
'When time and resources are limited, virtual lab would be the best choice to learn form lab.'
'Virtual lab allows me to have more time to understand and complete an experiment better. I can also repeat the experiment many times as I want to observe different results. While in hands-on lab, I usually have to complete an experiment within a limited time and I can only do it for one time.'

This demonstrates that although students believe that substituting virtual labs for conventional labs is not the full answer, they believe that virtual labs may be used in conjunction with traditional techniques to enable improved study outside of laboratory hours. This is an area of particular concern for educators since companies have prioritized transferrable abilities as required graduate characteristics in recent years [18–20]. In a later phase of this research project, we want to get more ideas and opinions in order to improve how we test and develop our students' transferable skills through virtual labs (by using technologies like forums and real-time feedback).

4. Conclusions

The virtual laboratory is a new educational trend in engineering. Students can perform experiments efficiently and affordably using a computer. This new environment for laboratory training has a number of advantages, including increased time and space flexibility, increased student enthusiasm for learning through interactivity, increased time efficiency, simplified complex procedures to allow for more complicated workshops to be conducted, a safe workshop environment, and a convenient platform for student assessments. Virtual workshops, on the other hand, may deter students from getting acquainted with actual equipment and gadgets. In terms of transferrable skills such as cooperation and communication, which are often discovered and taught in conventional laboratory training, the remote access characteristics of virtual laboratory training may inhibit direct collaboration and contact. Additional effort is needed to develop the curriculum for virtual laboratory training in order to include collaborative tasks and conversations that may help students improve their transferrable abilities. Laboratory training needs for engineering students are constantly changing, and as with many other new technologies, the advantages are often accompanied by drawbacks. On the whole, however, the virtual laboratory has the potential to meet some of the most pressing demands on engineering education imposed by contemporary industry, economics, and society. The current study was the beginning of a potential research program, but further development of the virtual laboratory as an instructional tool and delivery of its learning results will need to be accomplished. Virtual and online learning in the field of engineering labs is still relatively new in many respects, and more study is required before educators can fully use this delivery medium and its associated technologies to improve teaching and student learning.

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Competing Interest

All authors declare no competing interest.

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