



Enhancing Engineering Students' Interest in Learning Practical Coagulation Process in Water Treatment Using the Blended Learning Technique

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Abstract

The COVID-19 pandemic created new opportunities for learning methodologies and shifted attitudes among students and educators. One newly introduced learning technique is blended learning, which combines asynchronous and synchronous methods. This study investigates the effectiveness of the Blended Learning Technique in teaching the coagulation process to undergraduate students in the Department of Water Resources and Environmental Engineering at Ahmadu Bello University, Zaria. The researcher shared lecture materials (Laboratory Manual on Coagulation) with students both virtually and in person, then conducted a pre-lecture evaluation to assess student preparation for both in-person and virtual classes. For the lecture, 43 second-year students participated: 22 in person and 21 virtually. Students provided input on the effectiveness of blended learning initiatives through a learner satisfaction survey. The results show that the Blended Learning Technique helps students better understand the coagulation process, as the learning techniques foster interaction. 88% of students found the teaching Model effective.

Keywords: Blended learning, Coagulation, Engineering education, Lecture materials, Students' interest

Introduction

Wastewater generated by various human activities has become a concern because of its negative effects on aquatic life and human health (Iji et al., 2023; Salami et al., 2022; Tetteh et al., 2022). Untreated wastewater can cause poliomyelitis, dysentery, typhoid, and other diseases (Zhao et al., 2021), so it must be treated before discharge into water bodies. Over the years, researchers have developed various treatment methods to reduce contaminants (e.g., total suspended solids, turbidity, and others) in wastewater. These techniques include adsorption processes, membranes, coagulation, and many others (Tetteh & Rathilal, 2020). Coagulation is one of the most common wastewater treatment processes (Sibiya et al., 2022). Coagulation is a chemical treatment process primarily used to remove solid waste by manipulating the electrostatic charges of suspended

particles in wastewater. The coagulation process uses coagulants such as aluminium, ferric chloride, and ferrous sulfate (Iji, Ibrahim, et al., 2023), which are added to water to destabilise the charges on colloids or particles and overcome repulsion. Teaching coagulation processes to undergraduate engineering students at the tertiary level involves both laboratory work and many theoretical concepts that are abstract to many students, leading them to lose interest in the treatment process. These challenges are compounded in developing countries by poor teacher-student ratios, limited teaching materials, limited space, and ineffective teaching techniques (Oloyede et al., 2017).

The closure of schools in developing countries due to the COVID-19 pandemic shows that the traditional teaching model (which involves practical activities, educational evaluation, and



theoretical teaching) needs to be modified, as it is incompatible with guidelines during a possible outbreak (Collado-Valero et al., 2021; Gutierrez-Bucheli et al., 2025). Therefore, this calls for a drastic change in engineering pedagogy by introducing more innovative techniques, such as structured online systems. However, a sudden change in teaching methods might significantly affect not only students but also teachers, as adjusting to a new method can be challenging. Eberemu et al. (2022) reported that several university lecturers use online teaching methods categorised as synchronous, asynchronous, and blended. First, the synchronous teaching method involves delivering lectures via virtual platforms such as Webex, Zoom, Google Meet, and others. These virtual tools replace face-to-face classes and require only sharing the meeting link with students. The second technique is asynchronous learning, which involves using a pre-recorded video uploaded to YouTube, allowing students to watch it at any convenient time. The third approach is blended learning, which integrates both asynchronous and synchronous instruction.

Blended techniques require introducing the subject through pre-lecture activities, such as pre-recorded videos or tests of students' prior knowledge (Hadizadeh & Kanik, 2022; Orwenjo, 2024). The pre-lecture activities are then followed by the main lecture section, delivered either virtually or face-to-face, which encourages detailed discussion and interaction. Several studies have examined the effectiveness of blended teaching pedagogy across various courses (Alammary, 2019; Kumar et al., 2021). Blended learning pedagogy encourages inclusive activities and full student participation, rather than students simply sitting through synchronous or asynchronous sessions. Several instructors recommended using this technique (Chirikure et al., 2025; Tabiri & Afful, 2024). For instance, Alammary (2019) offers recommendations and guidance for tertiary institution instructors on using blended learning effectively in teaching introductory programming courses.

In developing countries (i.e., Nigeria), institutions of learning face several challenges, including a lack of basic amenities such as sufficient instructional resources for mastering technology-based courses, adequate infrastructure, and adequate space for students. Due to these challenges, blended pedagogy appears useful for overcoming them, as it fosters participatory learning at a low cost. Hence, this study examined the effectiveness of Blended learning

pedagogy in teaching the coagulation process to second-year engineering students in the Department of Water Resources and Environmental Engineering at Ahmadu Bello University, Zaria. The study then collected students' opinions on the model's effectiveness.

Methodology

Course and Participants

This study adopted a mixed-methods design using a quasi-experimental study, specifically the non-equivalent control group design (since students were assigned to groups using a standard process), and a descriptive survey (using interviews/online surveys). Undergraduate students in the Department of Water Resources and Environmental Engineering who participated in the Students Work Experience Program (SWEP) in the Sanitary/Chemical Laboratory were taught about the coagulation process. The process uses alum to remove impurities and contaminants from turbid natural water, making it safer for use or further treatment. However, undergraduate SWEP students in the department have little knowledge about the process.

The participants were a group (N=43); 22 participants were assigned to physical practical sessions (group A), while 21 were taught using the virtual laboratory (online) teaching technique (group B). To avoid grouping bias, students were sorted by their current Cumulative Grade Point Average (CGPA), allowing bright and not-so-bright students to be mixed across both groups. Data were collected using an online Google Form.

Design of the teaching environment for undergraduate students

Undergraduate students in the Department of Water Resources and Environmental Engineering participating in the SWEP in the Sanitary/Chemical Laboratory were divided into two groups: A and B. The teaching began with a pre-lecture assessment for all students and concluded with a post-lecture assessment. To evaluate the effectiveness of the two teaching methods, the experimental group took part in four (4) activities, which included:

Activity 1: Pre-class activities

A WhatsApp group was established to facilitate communication among the students and provide an avenue for supplementary learning outside the classroom. Before the teaching sessions began,

students completed a preliminary assessment to gauge their existing knowledge of the coagulation process and stimulate their interest in the topic. The pre-lecture assessment consisted of questions designed to gauge students' prior knowledge and understanding of the topic. Students accessed teaching materials, such as a recorded video lecture by the researcher, a developed laboratory manual, and lecture slides, before class. Students received these materials via a WhatsApp group created for this purpose.

Activity 2: Teaching processes (Physical and virtual techniques)

After distributing the learning materials and the pre-class assessment, a class was scheduled to deliver the content of the shared material. For Group A, students learned the concept and application of coagulation through conventional practical sessions, the developed laboratory manual, and a physical practical session held in the laboratory. Students could ask questions, and the instructor provided detailed answers. Group B was taught using the virtual method of teaching (a mode of teaching and learning that takes place primarily over the Internet or through digital technologies). The students were given access to teaching materials: a recorded video lecture by the researcher, a developed laboratory manual, and lecture slides. The instructor shared these materials with the students via a WhatsApp group created for this purpose. The instructor also provided a detailed lecture on the shared materials via Zoom. The lecture session also allowed students to ask questions about areas that were initially unclear, and it gave the instructor a chance to shed more light on the concept and application of coagulation in water treatment. To further enhance this step, the lecture recording was shared with the students. The instructor joined the group and assisted students with any questions they had.

Activity 3: Post-class assessment

The post-lecture assessment evaluated the lecture's effectiveness in terms of students' comprehension, retention, and ability to apply the concepts taught. For Group A, the students were then assessed with a written test immediately after completing the practical in the laboratory. Group B was assessed using an online Google Form.

Activity 4: Online learner satisfaction survey

The online learner satisfaction survey used the LSS questionnaires to gather students' opinions on the blended teaching method. The LSS questionnaires were created in Google Forms and shared with participants. The questionnaire contains a Likert-scale item through which respondents rate the extent to which they agree or disagree with the statement provided. The online questionnaire uses a 5-point Likert scale: "1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), and 5 (strongly agree)". Immediately after the post-class assessment, the researchers administered questionnaires to collect participants' responses and comments.

Data Processing

The researchers collected and analysed students' results from the pre-class assessment, post-class assessment, and online learner satisfaction survey using Microsoft Excel. Using Excel, the researchers calculated descriptive statistics from the collected data to obtain the mean, frequency, and percentage. The students' responses to the LSS questionnaire were processed using the LSS 5-point Likert scale.

Results and Discussion

Pre-lecture Assessment Analysis

The pre-lecture assessment was given to forty-three (43) students before face-to-face and online teaching. A total of 22 students participated in the assessment via the physical medium, and 21 via the online medium. The assessment measured students' knowledge based on the shared teaching materials and their readiness for the lectures. The assessment was administered via a timed Google Form questionnaire with multiple-choice answers for online students, while physical students received printed questions. Students answered 10 questions in 15 minutes. Figure 1 illustrates the students' scores from the pre-class assessment. Overall, 56% of students scored below 5, with 0%, 5%, 14%, 19%, and 19% scoring 0, 1, 2, 3, and 4, respectively, while 44% scored between 5 and 9. The pre-lecture assessment results show that most students scored above 3, indicating that the teaching materials shared with students may have stimulated their interest in learning about coagulation processes to some extent. However, this differs from the norm, which is to give students materials after or during class.

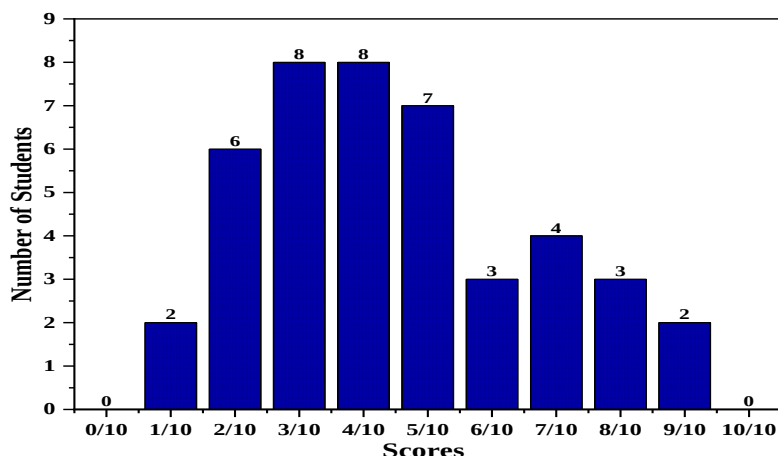


Figure 1: Scores of students for the pre-lecture assessment

Analysis of the students' performance for Group A and Group B

Figure 2 presents the pre-lecture and post-lecture scores of the students taught via the physical medium (Group A). After classroom instruction, the students were assessed (post-lecture assessment) to evaluate the effectiveness of the teaching method. The pre-lecture assessment results show that a higher percentage of students (72%) scored below 5 out of the overall score (10). This suggests that students' performance on the pre-test was generally low, indicating they may not have had an adequate understanding of the coagulation process as presented in the teaching materials. Hence, the students may have found the teaching materials challenging and misaligned with their learning needs, making it

difficult for them to engage with the pre-lecture content. However, the post-class assessment scores show that no students scored below 50%. As seen in Figure 2, 23%, 45%, and 27% of the students scored 7, 8, and 9, respectively, on the overall score. This shows that face-to-face teaching improved students' knowledge of the coagulation process, and this improvement could be attributed to several factors. First, the physical section provides opportunities for discussion with the instructor, hands-on activities, and interactive learning (Yannier et al., 2021). The physical class also gives students opportunities to participate actively. It helps them clarify the concept of coagulation in water treatment and develop a solid understanding of the process.

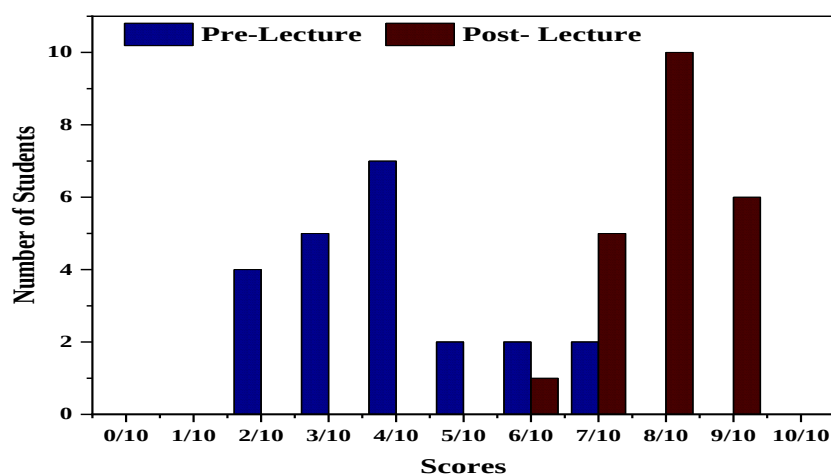


Figure 2: Comparison of physical students' scores for pre-lecture and post-lecture assessment

To examine the effect of physical teaching on the students' performance, statistical analysis was

conducted. As seen in Table 1, the students' pre-lecture mean was 3.95, and the post-lecture mean was

7.95, indicating a 50% increase. This shows that the physical class positively impacted students' knowledge of the coagulation process. A significant difference ($p < 0.05$) was also observed between pre-

and post-class assessment scores, suggesting that the lectures and hands-on activities influenced students' performance.

Table 1: Independent-samples t-test on the effect of physical and online teaching on the students' performance

		N	Mean	Std. Deviation	Std. Error Mean	T	P	95% Confidence Interval of the Difference	
Lectures								Lower	Upper
Group A	Pre-Lecture	22	3.95	1.527	.326	-10.755	.000	-4.751	-3.249
	Post-Lecture	22	7.95	.844	.180				
Group B	Pre-Lecture	21	6.05	2.559	.558	-2.981	.005	-3.516	-.675
	Post-Lecture	21	8.14	1.957	.427				

Figure 3 shows the results for Group B (students from the online class) and indicates that a significant number (67%) scored above 50% on the overall pre-class test. This could be attributed to several factors. Group B students might have found the teaching materials easier to explore than Group A students did. Also, students might have been actively engaged with their gadgets, such as phones and laptops, which may have made it more appealing to go through the materials virtually. A study by Galindo (2014) suggests that collaborative learning improves students' understanding of a subject. For the post-lecture assessment, 95% of students scored above 50% of the overall score. This shows that the students' performance increased from 67% on the pre-lecture assessment to 95% on the post-lecture assessment. The score increase may be attributed to the effective communication of the lecture materials during the virtual class. These results are similar to those of Obada et al. (2022), who found that students' scores increased to 93.65% after the online class. The pre-lecture assessment may also have contributed to the improvement observed in the post-lecture assessment

score, since the pre-test helps the instructor/lecturer identify areas students found difficult to understand. Therefore, the lecture places much more emphasis on these areas. The data from the pre-lecture and post-lecture assessments show that pre-lecture activities promote students' understanding of the coagulation process in water and wastewater treatment.

However, these virtual activities should not be relied on solely, as they may be counterproductive and leave students feeling disconnected from the instructor/lecturer, thereby reducing motivation. Therefore, pre-lecture activities should be followed by synchronous sessions that allow for more effective dialogue and greater clarity on the subject. As shown in Table 1, the students' pre-lecture mean was 6.05, rising to 8.15, a 26% gain. This demonstrates that the synchronous section had a favourable influence on students' knowledge of the coagulation process. There was also a significant difference ($p < 0.05$) between the pre-class and post-class evaluation scores, indicating that the lecture activities affected students' performance.

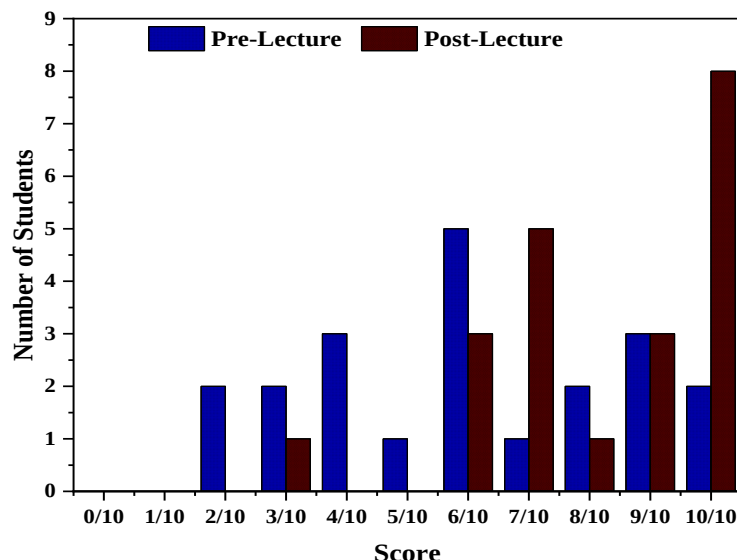


Figure 3: Comparison of online students' scores for pre-lecture and post-lecture assessment

Comparison of the post-lecture assessment scores for groups A and B

To compare the effectiveness of physical and online classes, I analysed post-lecture assessment scores (see Figure 4). The post-lecture assessment for group A shows that no students scored below 6, and no students answered all the questions correctly. Overall, group A's scores ranged from 6 to 9. However, the post-lecture assessment scores for online students (group B) showed that 95% scored

between 6 and 10, while 5% scored below 5. It was also observed that 38% of the students taught online answered all the questions correctly, compared to the physical class, where none did. According to the statistical analysis in Table 2, the mean for group A is 7.95, compared to 8.14 for group B, for a slight difference of 0.19. Also, no significant difference was observed between groups A and B, as the p-value was greater than 0.05 ($p > 0.05$).

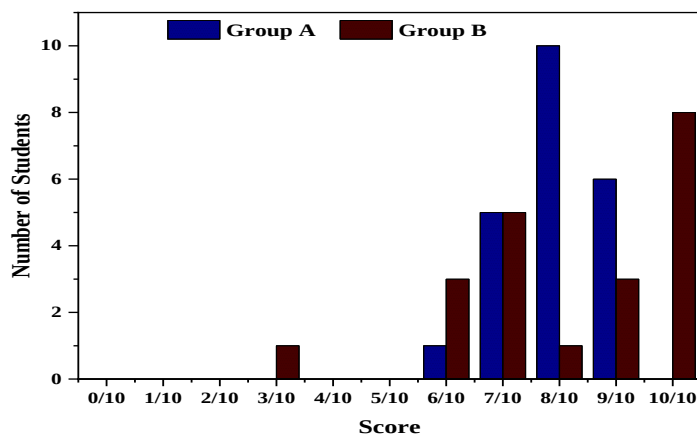


Figure 4: Comparison of post-lecture assessment scores of group A and B

Table 2: Independent Sample T-test on the relationship between Online (Group B) and Physical (Group A) Teaching Methods on the Performance of the Students

	N	Mean	Std. Deviation	Std. Error Mean	T	P	95% Confidence Interval of the Difference	
							Lower	Upper
Group B	21	8.14	1.957	.427	0.413	0.188	-.732	1.109
Group A	22	7.95	.844	.180				

Online Learners' Satisfaction Survey

As shown in Figure 5, the online learners' satisfaction survey was administered to group B students after the post-lecture assessment to obtain their opinions on the use of the online learning medium. The survey used a five-point Likert scale, ranging from strongly agree to strongly disagree. In the first question of the survey, the students were asked if "The online learning method used was sufficient to achieve the learning outcomes". Eighty-eight per cent (88%) of students said the online learning technique was adequate for achieving their learning goals, 6% were uncertain, and 6% believed the learning method was not sufficient. Some comments from the students include:

Comment #1: *It's an excellent and efficient way of testing the capabilities of students.*

Comment #2: *The teaching method was very effective; it would be nice if all lecturers adopted it.*

Comment #3: *Thank you so much. I learnt a lot from the session, and you took your time to explain, add information, and answer questions. I was very satisfied.*

Comment #4: *I have gained some more experience from the class*

Comment #5: *It was good and friendly; I strongly advise that it should be emulated in Engineering.*

Comment #6: *I enjoyed the whole process and was able to learn new things*

Comment #7: *The whole idea of having a test before a class tricks the brain into wanting to know. I therefore suggest this mode of learning should be introduced*

Comment #8: *This is how the SWEP should have been held. Online classes are sufficient for everything we have been taught throughout the SWEP period.*

Comment #9: *Online learning is a good method of learning that should be applied in tertiary institutions.*

The word cloud generated from students' responses, presented in Figure 6, also supports these findings. In the second survey item, students indicated their level of agreement with the statement, "I could easily answer the post-lecture questions after homogeneous mixing and participating in the lecture session." The responses indicated that 81.3% of the participants considered the pre-lecture activities and lecture session helpful in enabling them to answer the post-lecture questions. A further 12.5% were undecided, whereas 6.3% indicated that participation in the lecture session did not improve their ability to complete the post-lecture assessment (Figure 5).

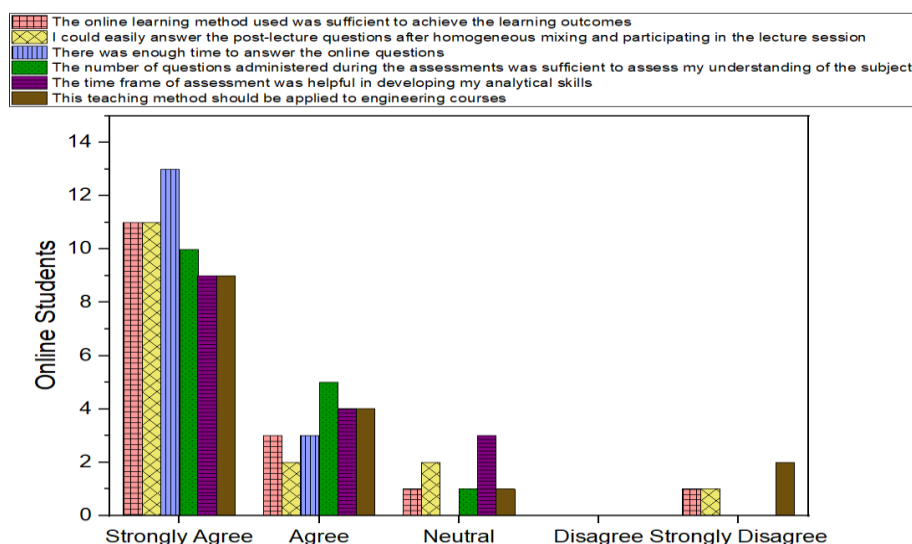


Figure 5: Online Learners' Satisfaction Survey

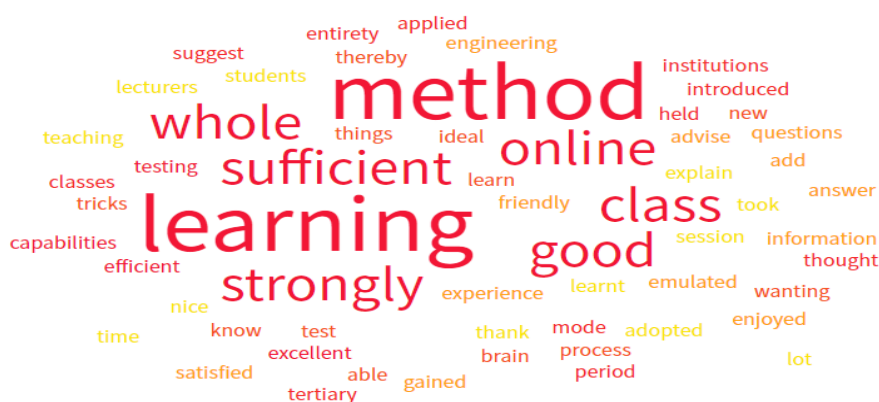


Figure 6: Word cloud analysis on the open-ended feedback section

Questions 3–5 examined students' perceptions of the assessment process. These items asked whether students had enough time to complete the online questions, whether the number of questions adequately evaluated their understanding of the subject, and whether the allotted assessment time contributed to developing their analytical skills. The responses suggested that most students regarded the number of questions as adequate for evaluating their understanding of the subject matter. They also indicated that the time allocated for the assessments helped develop their problem-solving skills. The final survey item assessed whether the teaching approach could be extended to other engineering courses. Most participants (81%) supported its application in other engineering courses, while 13% expressed disagreement and 6% remained undecided (Figure 5). These responses indicate a generally positive

perception of the blended teaching approach among the participating students.

Conclusion

The post-COVID-19 pandemic has created new opportunities for different learning techniques, giving students and instructors a different perspective. Instructors/teachers need to shift from traditional teaching techniques to more recent, technology-based pedagogies. It is important to measure the effectiveness of this Model and understand students' views on this new method. Hence, this study examined the effectiveness of the blended learning method, in teaching undergraduate students in the Department of Water Resources and Environmental Engineering at Ahmadu Bello University, Zaria, on the coagulation process. The outcomes from this study are as follows:

The pre-lecture assessment shows that 56% of students scored below 5, while 44% scored between 5

and 9. The results suggest that most students scored above 3, indicating that the instructional materials may have stimulated students' interest in learning about coagulation processes.

The post-class assessment score for students taught in the physical medium (Group A) shows that none scored below 50%. This shows that face-to-face teaching improves students' understanding of the coagulation process. The physical section might have allowed students to interact with the instructor and seek clarity on the overall concept. From the statistical analysis, the students' pre-lecture mean was 3.95, which rose to 7.95 in the post-lecture mean, suggesting a 50% increase. This shows that the physical session positively affected students' understanding of the coagulation process.

In the post-lecture assessment, 95% of students who attended the online lecture (group B) scored above 50% overall. This demonstrates that the students' scores increased from 67% on the pre-lecture assessment to 95% on the post-lecture evaluation. The pre-lecture assessment may have improved post-lecture scores by allowing the instructor/lecturer to identify areas where students struggled to grasp the material. Pre-class and post-class assessment ratings also differed significantly ($p < 0.05$), showing that the lectures and hands-on activities influenced students' performance.

We compared the post-lecture assessments for groups A and B. The post-lecture mean for group A is 7.95, compared with 8.14 for group B, yielding a difference of 0.19. Furthermore, no significant difference was observed between groups A and B, as the p-value was greater than 0.05 ($p > 0.05$).

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