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Case-Based Instruction in the Forensic Chemistry Classroom: Effects on Students' Motivation and Achievement

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Abstract. Forensic chemistry students need to be motivated and develop critical thinking, problem-solving, and higher-order thinking skills and not just accumulate many facts to be good evidence collectors and investigators in the future. As case-based instruction has been utilized in various fields to this effect, this study aimed to determine the effects of such a method on students' motivation towards forensic chemistry learning and their success in understanding the taught concepts through their achievement scores. A pre-test post-test control group design was employed to involve two forensic chemistry classes with 42 students each, identified through the purposive sampling technique. One class was taught through case-based instruction, while the other through the lecture method. The classes were assigned to experimental and control groups to examine the study's treatment process effects through a coin toss. The t-test for independent samples was used to determine significant differences in students' pre/post-test scores in the treatment and the control group for the motivation and achievement tests. The two groups of respondents exhibited increased motivation and achievement mean scores with significant differences. However, those exposed to case-based instruction had higher mean scores than those taught with the lecture method. Thus, the use of case-based instruction in the forensic chemistry classroom promotes critical thinking, problem-solving, and higher-order thinking skills leading to significant positive changes in the motivation and achievement of students in the course. Therefore, case-based education is recommended as it is expected to make positive contributions to the forensic chemistry teaching process and science education.

Keywords: case-based instruction; Forensic chemistry; motivation; achievement

1. Introduction

Students' motivation and achievement are essential for consideration in any educational process. Motivated students tend to be more engaged with learning activities, assignments or tasks and work harder to overcome difficulties, accomplish some extent of mastery in their field, and, thus, increase their academic achievement (Reev as cited in Yousefy et al., 2012). Academic motivation and achievement in criminology education, such as in forensic chemistry, are as important as that in other fields of studies. In a state college in the northern part of the Philippines, it was a common observation that criminology students have low achievements in their forensic chemistry courses compared to their other forensic science courses. They consider it a minor course even when given a five-unit credit. Forensic chemistry is a course that applies chemical concepts to the criminal investigation, collecting and examining diverse physical evidence gathered at the crime scene using chemical principles. Criminology students must be sufficiently motivated to receive a significant volume of information on chemical concepts and acquire the related skills to be adept at collecting, handling, and preserving crime scene evidence.

A common reason for students' low achievement in their forensic chemistry course is difficulty understanding the chemical concepts or relating to the material in a meaningful way. Indeed, students experience many difficulties understanding chemistry ideas and concepts (Sirhan, 2007). Also, students consider chemistry as an uninteresting subject and do not appreciate the significance and applicability of learning chemistry concepts to their daily lives and surroundings (Hutchinson, 2000). As a result, students' interest in and enthusiasm for learning forensic chemistry has been low. Educators are trying their best to find methodologies to help change students' perceptions of chemistry and increase their motivation and achievement in the subject. One strategy for increasing learners' enthusiasm is to provide course content in a more student-friendly setting by making it more engaging or applicable to their lives (Testa, 2019). The higher the motivation, the higher the students' achievement; therefore, achievement can be considered an indirect indicator of motivation. (Pintrich & Schunk, 2002). Proper teaching modalities can serve as stimulants for students to learn and enhance their understanding of lessons and increase their achievement. Science teachers are adopting new teaching approaches to promote active learning, such as in-class conversations, games, and learning reflection opportunities for students to improve student engagement in lecture-based courses. Integrating case-based tasks into the curriculum is a technique for fostering an active learning environment (Shahmuradyan & Doughan, 2021).

Case-based instruction is a flexible teaching method that uses actual situations to help students develop analytical and problem-solving skills (Herreid et al., 2011). It involves solving and examining real-world problems and situations and encouraging group discussion, participation, and interaction, promoting an active learning environment (Tarkin, 2017). The real-life nature of cases presented in meaningful learning contexts promotes critical thinking that involves analyzing, evaluating, and applying instead of just recalling knowledge. Data presented in the case must be organized and analyzed by the students, and relevant theory must be considered before the conclusion and solutions (Stanford University, 2018). Similarly, such cases can connect theory and practice as theories, concepts, skills, and strategies learned in specific academic topics are used and applied in solving real-world societal issues (Bonney, 2015). In case-based instruction, the teacher shifts from disseminating information as practiced in the traditional lecture method to a facilitator who guides students to build their knowledge. At the same time, the students become active participants who openly reveal their ideas in discussions.

Case-based instruction was used in business and medical education for years before being adopted in other scientific disciplines such as psychology, biology, nursing, and chemistry (Kaddoura, 2011). A limited number of research works have investigated the effect of case-based teaching on students' chemistry learning (Tarkin & Knodakci, 2017). There is also limited literature on the method's effectiveness in meeting learning objectives (Bonney, 2015). Although there are studies on using case-based instruction in other countries, only a few were performed in the Philippine setting, especially on science education, and none specifically for forensic chemistry. Also, most studies on the impact of case-based instruction on students' learning were conducted through a one-group research design (Agyildiz & Tarhan, 2012).

With the nature of the forensic chemistry course, case studies will be critical in achieving the course's learning objectives. As an active learning philosophy, a case-based discussion could help prepare criminology students for the challenges they will encounter in this world, especially in their profession. The segments of forensic chemistry, such as Techniques in the Forensic Chemistry Laboratory, Forensic Drug Analysis, and Blood and Bloodstains, are timely, essential, and could be linked to crimes happening around the country. Thousands of illegal drug cases are reported yearly; thus, actual local drug cases could be used to study forensic drug analysis. Blood and bloodstains are the essential biological evidence in violent crimes in this country and worldwide. Many crime cases and case simulations on blood and bloodstains could be used to help students understand the lesson better. Technology improvements mean forensic chemistry laboratory techniques to analyze this crime evidence are constantly changing, and students' knowledge and skills on such must be updated. Case-based learning could give students a deeper understanding of how forensic chemistry concepts apply to the real world and what skills are required. Case discussion encourages the development of strong listening and speaking skills, critical and analytic thinking, and an appreciation of the values of forensic chemistry in the criminology profession.

Considering the nature of case-based instruction, it might help make forensic chemistry learning closer to the lives and interests of criminology students. For example, Herreid et al. (2011) found that giving students controversial science problems encountered in the news makes science relevant to their lives. In the same way, using real-life cases might improve students' interest in forensic chemistry, improve their attitudes, motivate them and enhance their understanding of lessons and their achievement. A Philippine study on case-based instruction by Talens (2015) also found that students acquire an in-depth understanding of the lessons to solve real problems and make sound judgments and decisions.

As forensic chemistry deals with evidence collected in crime scenes, case-based instruction may improve students' understanding of the chemical nature of such. Furthermore, problem-solving and higher-order thinking skills and deciding correctly on the proper collection, preservation, and examination may be improved. Therefore, this study's significance lies in its potential contribution to educational research as it considers case-based teaching as an effective strategy to increase the motivation and achievement of students in a forensic chemistry classroom. In addition, it could be a basis for forensic chemistry instructors to determine how to teach the course effectively. Furthermore, this study will help future researchers understand forensic chemistry's teaching and learning phenomenon.

Case-based instruction was investigated to determine its impact in promoting meaningful forensic chemistry learning. The study considered the possible implications of using case teaching to improve achievement and motivation in forensic chemistry and the lack of research on the effects of case teaching in forensic chemistry education through a pre-test post-test control group design. In addition, the study aimed to ascertain how the case study teaching technique affected students' motivation to learn forensic chemistry and how well they understood the subjects. Specifically, it aimed to answer the following problems:
(1) What is the effect of case-based instruction on students' motivation towards forensic chemistry learning?
(2) Is there a significant difference in the motivation scores towards forensic chemistry learning of the students exposed to a case-based instruction and those who were not?
(3) What is the effect of case-based instruction on students' achievement scores in forensic chemistry?
(4) Is there a significant difference in the achievement scores of the students exposed to case-based instruction and those who were not?

2. Review of Related Literature

2.1 Case-based Instruction

Case-based instruction is a constructivist teaching methodology that focuses on students and actively improves their learning as they are challenged to solve a dilemma through studying a case based on everyday life and thus gain higher skills (Bernardi & Pazinato, 2022). It is a teaching and learning technique that employs case studies as active learning aids; case studies analyze specific cases and make conclusions in similar situations. As case-based instruction engages students in the classroom, they use their knowledge to actively solve complex problems identical to those confronted in real-life situations (Etmer, 2005). Cases usually consist of two parts: (a) the case status of the investigation and (b) the questions related to the case. Case study teaching is flexible teaching that emphasizes problem-based learning and develops analytical skills (Herreid et al., 2011).

A more active instructional method, case-based instruction, appeals to students who may be unengaged with a lecture format that concentrates on facts and content rather than developing higher-order and critical thinking skills (Prince, 2006). Case-based instruction helps assess the application of the concept to appropriate professional practice. Case studies help students connect their information to decision-making ability and distinguish between high-priority and low-priority factors by putting students in a real-world situation and requesting decisions. Cases are proposed as a better way for teachers to see if a student has applied knowledge of the subject compared to a lecture and better long-term memory of the subject and student satisfaction (Thistlethwaite et al., 2012).

2.2 Effects of Case-based Learning on Student Motivation and Achievement

Case-based instruction has been reported to increase students' motivation, curiosity, and engagement (Bernardi & Pazinato, 2022; Gholami et al., 2021; Nag, 2020; Raza et al., 2019; Yoo & Park, 2014; Yoo et al., 2010; Yalcikaya, 2010). Nag (2020) demonstrated students' interest in case-based learning in both face-to-face and synchronous virtual classrooms by reviewing and integrating introductory biochemistry concepts through a case-based activity. Yalçinkaya's (2010) study looked at the impact of case-based learning on students' academic accomplishment and perceived motivation in the unit of the human reproductive system and found it enhanced students' academic achievement and task value. Case-based learning effectively stimulates students' interest in the self-directed exploration of course materials on symmetry-related topics and critically processing information to achieve the most acceptable result. (Dong& Zheng, 2021).

Some educators also tried comparing case-based learning with the lecture method. Gholami et al. (2021) established significant differences between the lecture-based learning and case-based learning groups in students' total learning motivation score and all its subscales after the case-based learning intervention. They suggested that the case-based learning method applied through multi-episode cases is a method for increasing nursing students' perceived problem-solving skills and learning motivation. Yoo and Park (2014) also found that the case-based learning group showed significantly greater learning motivation than the lecture-based learning group at post-test. They concluded that case-based learning is a successful teaching strategy based on this and other data. Yoo et al. (2010) found substantial group differences in learning motivation, with the case-based learning group's post-test scores being statistically higher than the control group. They went on to say that case-based learning with video is good in motivating students to study because it encourages self-directed learning and increases interest and curiosity in the subject.

A review of research studies conducted on case-based chemistry instruction in the past decade by Bernardi and Pazinato (2022) suggests that such a technique can help improve higher-order abilities like critical thinking and communication and encourage curiosity and engagement. Similarly, Hereid (2004) and Yadav et al. (2007) also posit that, aside from critical thinking skills, case studies improve students' understanding, problem-solving skills, higher-order thinking skills, their conceptual change, and motivation to study. Through case-based learning, students can grasp topics discussed in class and develop their skills (Raza et al., 2019). It could also improve students' perceptions of learning, increase performance on assessment questions, enhance motivation for learning activities, and promote critical thinking, learning, and participation among learners (Bonney, 2015). Shahmuradyan and Doughan (2021) created a case study project for third-year analytical chemistry students to investigate a fictitious illness epidemic. Because of the case study, students could practice essential skills, including investigation, critical thinking, problem-solving, and communication. As evidenced by course assessments, the assignment was greatly welcomed by students.

Most of the studies that literature has to offer on comparing the effects of case-based instruction with the traditional lecture method on student achievement give positive feedback in favor of case-based learning. For example, Cam (2009) evaluated the impact of case-based learning against traditional learning on the knowledge of solubility equilibrium concepts by eleventh-grade high school students. She also looked at the experimental and control groups' attitudes towards chemistry and epistemological beliefs, which differed significantly from the experimental group. Sendur's (2012) study of case-based learning's effects on first-year students' academic performance in chemistry found that case-based training resulted in a more vital comprehension of gas laws than standard instruction. Furthermore, students in the experimental group could apply gas laws to real-life instances quicker than students in the control group. Adesoji and Idika (2015), in a study involving Nigerian secondary chemistry students, determined the effectiveness of case-based learning in enhancing students' chemistry achievement and attitude. However, residents in a graduate medical education program showed similar engagement and satisfaction with case-based education compared to lectures ((Demetri et al., 2021). There was comparable information gained in an orthopedic resident anatomy course, implying that both case-based learning and lecture-based education are beneficial for highly motivated learners.

These current research studies give possible effects of case-based learning and teaching on students' motivation and achievement in different disciplines but provide limited evidence on the effect in the forensic chemistry classroom in the Philippine context. As Bonney (2015) recommended, it could be informative to compare the effectiveness of case-based instruction with other teaching methods. This study, therefore, addresses this gap in the literature by investigating the effects of case-based instruction on students' motivation and achievement in the forensic chemistry classroom.

3. Methods

3.1 Research Design

Pre-test-post-test control group design was used with an experimental group and a control group. The participants were not randomly assigned to the groups as classes were already set during enrolment. However, the classes were assigned as experimental and control groups through a coin toss. This design uses two forensic chemistry classes; only one class was given the treatment while the other served as the control. Over the same period, the control group received no treatment but took the same tests. Both groups were given pre-tests using the Science Motivation Questionnaire II (SMQ II) and unit achievement tests (AT) before the intervention. Both groups were again given the SMQ II and unit achievement tests as post-tests after the experimental process. The study's experimental design is presented in Table 1.

Table 1: Experimental Design Used in the Study

Experimental Group	$T1_{12}$	X	$T2_{12}$
Control Group	$T1_{12}$		$T2_{12}$

Where:
X - treatment
$T1_1$– SMQ II (pre-test) $T2_1$- SMQ II (post-test)
$T1_2$- academic achievement test(pre-test) $T2_2$- academic achievement test(post-test)

3.2 The Study Context

The study was conducted in Mountain Province State Polytechnic College, Bontoc Campus during the 1st Semester of the School Year 2019-2020. Mountain Province State Polytechnic College is situated at the heart of the Mountain Provinces in the Northern part of the Philippines, with a student population of about 4,000.

3.3 Participants of the Study

The study's participants were identified through a purposive sampling technique. Two forensic chemistry classes of forty-two (42) students in each class were chosen from five classes in Mountain Province State Polytechnic College. All members of the two classes were Bachelor of Science in Criminology students who took the course for the school year 2019-2020. They were chosen due to their enrolment in the class as registered at the Admissions Office. Before the study, the control group was designated to one class and the experimental group to the other through a coin toss. Consent of participation in the study was sought from the participants before the conduct. They were well-informed about what participation entailed. Those who had second thoughts upon consultation were reassured that declining was okay, that they could withdraw their participation verbally, and that their grades would not be affected. All members of the chosen classes signed an informed consent form, and the researcher signed a non-disclosure agreement.

3.4 Instrumentation

In this investigation, two data collection tools were used. First, the Science Motivation Questionnaire II (SMQ II) chemistry-specific version designed by Glynn et al. (2011) presented in Appendix 1 was utilized to assess the students' motivation to learn forensic chemistry. The survey has 25 items on a five-point Likert-type scale: never (0), rarely (1), sometimes (2), often (3), or always (4). The instrument consists of five factors: intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation. Each factor has 20 as its highest score as it has five items to be rated on a scale of 0-4 and a total score of 100. Such an instrument was already reliable and valid and, as suggested by the developers, may be used by instructors, researchers, and research advisers to assess students' motivation to learn science in college courses. Second, the researcher developed achievement tests on the three chosen topics based on the units' objectives to gather data on the students' academic achievement in forensic chemistry. There were 20 multiple choice type questions in each unit test which were reviewed and validated by three forensic chemistry instructors, their suggestions being incorporated in the questionnaires. Each test was also tried out on a forensic chemistry class of 40 students which was not part of the experiment. The tests' reliability was established through split-half methodology using Microsoft Excel Real Statistics Resource Pack. The correlation coefficients ranged from 0.80 to 0.83, indicating highly reliable tests.

3.5 Data Gathering Procedures

The college president's approval was sought to conduct the study, which was granted with a research contract. The researcher chose three units from the forensic chemistry syllabus: Techniques in the Forensic Chemistry Laboratory, Forensic Drug Analysis, and Blood and Bloodstains. The researcher pre-tested both groups to determine their knowledge of the lessons before starting each unit, using the developed achievement tests. In addition, both groups were also asked to answer the Science Motivation Questionnaire II before the intervention to determine their pre-experimental motivation levels towards forensic chemistry learning.

Case-based teaching was then used to teach the treatment group. Real-world situations were presented at the start of the lessons, and the forensic chemistry concept required to understand the situation was given subsequently. Students were given real-life situations, events, or circumstances to pique their interest. They were asked how and why such events occurred, and the whole class explored them. The researcher prepared relevant and appropriate cases for each unit from news clippings, criminal cases, observations, and everyday life. These were given to the students to investigate, discuss in groups, analyze, and relate to given forensic chemistry concepts. Representatives from each group presented their results to the class, including cases and questions regarding them. As forensic cases were usually associated with evidence, discussions usually ended at pointing out the possible sources of evidence being investigated. The instructor's role was to encourage students to analyze the case and share the analysis and results with the class. The control group was likewise taught the same concepts through the usual lecture format, which may have been enhanced with PowerPoint presentations. The lessons were for one-hour periods, three times a week. Thus, the three units were taught for 24 lecture hours and 42 laboratory hours. The researcher was the instructor for both the experimental and control groups. She distributed the data gathering instruments to the respondents and was able to retrieve all of them.

After the experimental period, the researcher distributed the SMQ II and the achievement tests to both groups as post-tests. The students' pre-test and post-test scores were gathered for statistical analysis. Research data, especially the students' achievement scores in the pre-tests and post-tests, were protected from their collection to the paper's publication.

3.6 Data Analysis

The t-test for independent samples was used to establish a significant difference in the groups' pre/post-test scores for the SMQ II and the achievement test using Microsoft Excel Real Statistics Resource Pack.

4. Results

4.1 Effects of Case-Based Instruction on Students' Motivation towards Forensic Chemistry Learning

Table 2 reveals an increase in the mean motivation scores of the students in both the control and experimental groups from almost the same pre-test mean scores. The mean score of the experimental group had an increase of 28.55, while that of the control group was only 6.12. These values show that case-based instruction and lecture methods increase students' motivation for forensic chemistry learning. However, case-based instruction has a more significant effect than the lecture method. This finding implies more and better learning for the students taught through the case-based method than those taught through the lecture method, as indicated by the higher mean post-test scores.

Table 2. Mean Motivation Scores of the Students in the Two Groups of Respondents

Groups	η	$\bar{x}$ (pre-test)	$\bar{x}$ (post-test)
Experimental	42	49.38	77.93
Control	42	49.86	55.98

4.2 Differences in the Students' Motivation Scores towards Forensic Chemistry Learning

An independent samples T-test was employed to establish differences between the two groups' motivation levels towards forensic chemistry learning before conducting the case-based approach in teaching. Table 3 compares the means of the students' pre-test motivation scores in the experimental and control groups.

Table 3. Comparison of Mean Pre-test Motivation Scores of the Two Groups of Respondents

Groups	η	$\bar{x}$	Std. Dev.	Df	t	p
Experimental	42	49.38	3.44	65	0.44	**0.66**
Control	42	49.86	6.06			

*p> .05; t(65)= 0.44 < 1.9971 = tcrit

The experimental group's average score was found as x̄experimental = 49.38+3.44, and the control group's average pre-test scores as x̄control= 49.86+6.06. Since t(81)= 0.44 < 1.9971 = tcrit (or p-value = .66 > .05 = α). At 0.05 level, the results show no statistically significant difference between the mean pre-test motivation scores of the two groups of students. Before the experiment, the two groups had almost the same motivation towards forensic chemistry. They were comparable in terms of motivation level prior to the experiment. Post-tests were done after the experimental period, and the scores were evaluated to determine the students' mean post-test motivation scores in each of the experimental and control groups. These were compared using independent samples t-test as presented in Table 4.

Table 4. Comparison of Mean Post-test Motivation Scores of the Two Groups of Respondents

Groups	η	x̄	Std.Dev.	Df	t	p
Experimental	**42**	**77.93**	**3.04**	80	35.31	**0.00**
Control	42	55.98	2.65			

*p< .05; t(80)= 35.31 > 1.9900= tcrit

The mean post-test motivation score of the experimental group was found as x̄experimental = 77.93+3.04, and the mean post-test motivation score of the control group as x̄control= 55.98+2.65. Since t(80)= 35.31 > 1.9900 = tcrit (or p-value = .000 < .05 = α). The results show a noteworthy difference between the mean post-test motivation scores of the group exposed to case-based instruction and those who were not. This further means the students taught using case analyses felt a significantly higher motivation towards forensic chemistry than those taught the same lessons traditionally.

4.3 Effects of Case-Based Instruction on Students' Achievement

Table 5 shows the mean scores of both the control and experimental groups for the 20-item achievement tests given for each lesson. An increase is shown in both groups' post-test mean scores from almost the same mean score in the pre-test. However, the experimental group had a higher increase of 9.93 in their mean score than the control group, with only an increase of 4.29. These values show that case-based instruction increased the achievement level of the students in forensic chemistry. The traditional method used in the control group's class also increased students' achievement level, but to a lesser extent than the case-based method.

Table 5. Mean Pretest and Post-test Achievement Scores of the Experimental and the Control Groups

Groups	η	x̄ (pre-test)	x̄ (post-test)
Experimental	42	6.26	16.19
Control	42	6.07	10.36

4.4 Differences in the Students' Achievement Scores in Forensic Chemistry

To ascertain if the experimental and the control groups exhibit statistically significant differences concerning their pre-knowledge of the lessons to be tackled on Techniques in the Forensic Chemistry Laboratory, Forensic Drug Analysis, and Blood and Bloodstains, independent samples t-test was utilized. Table 6 presents the statistical analysis results of the experimental and control groups' mean pre-test achievement scores.

Table 6. Comparison of Mean Pre-test Achievement Scores of the Experimental and the Control Groups

Groups	ɳ	$\bar{x}$	Std. Dev.	Df	t	p
Experimental	42	6.26	1.95	80	0.48	**0.63**
Control	42	6.07	1.66			

*p> .05; t(80)= 0.48 < 1.9900 = tcrit

The experimental group's average score was found as $\bar{x}$experimental = 6.26+1.95, and the control group's average pre-test scores as $\bar{x}$control= 6.07+1.66. Since t(80)= 0.48 < 1.9900 = tcrit (or p-value = .63 > .05 = α). These results show that at a 0.05 level of significance, no statistically significant difference exists between the mean pre-test achievement scores of the two groups of respondents. When lessons were introduced prior to conducting the experiment, both control and experimental groups had about the same level of understanding about the forensic chemistry lessons, specifically on Techniques in the Forensic Chemistry Laboratory, Forensic Drug Analysis, and that of Blood and Bloodstains. In terms of achievement prior to the experiment, the two groups of students were equivalent.

Post-tests were conducted at the end of the experimental period, and the scores were analyzed to determine their mean post-test scores. Table 7 compares the experimental groups' post-test achievement scores to the control group using independent samples t-test.

Table 7. Comparison of Mean Post-test Achievement Scores of the Experimental and Control Groups

Groups	ɳ	$\bar{x}$	Std.Dev.	Df	t	p
Experimental	42	16.19	2.00	82	13.49	**0.00**
Control	42	10.36	1.96			

*p< .05; t(82)= 13.49 > 1.9893 = tcrit

As revealed in the table, the mean post-test score of the experimental group is $\bar{x}$experimental = 16.19+2.00, and the mean post-test score of the students in the control group is $\bar{x}$control= 10.36+1.96. Since t(82)= 13.49 > 1.9893= tcrit (or p-value

= .000 < .05 = α). A significant difference exists between the post-test achievement scores of the students taught through case-based instruction and those who were not, as shown by the results. This further means that the group who learned through case-based instruction obtained significantly higher post-test scores than those who received the same lessons through the lecture method.

5. Discussion

5.1 Effect of Case-Based Instruction on Students' Motivation towards Forensic Chemistry Learning

The study determined that case-based instruction increases students' motivation towards forensic chemistry learning. Raza et al. (2020) corroborate such findings as they found out that case-based education boosts learning motivation. Yalçınkaya (2010) also found out that, in Anatolian high schools, students' attitudes and motivation towards chemistry were increased by case-based learning.

Real-life cases indeed spark students' interest, especially when these are relevant to their lives. As students relate the circumstances with things and activities in their surroundings, they become more interested and excited to work on such cases. Thus, intrinsic motivation is ignited. Students realize that the concepts they are learning are relevant to their lives, making learning more engaging, meaningful, and enjoyable. As Cheng (as cited by Sendur, 2012) found, case studies make students actively involved when done in groups; thus, they become enthusiastic about the lesson. They then increase their self-determination by putting enough effort into learning, preparing well, and studying hard for their lessons and examinations, leading them to enjoy learning. Students can be motivated and engaged in learning a task if they are interested and enjoy learning (Pintrich & Schunk, 2002). Thus, case-based education increases learners' interest and enjoyment of education (Yalcinkaya, 2012) and leads to higher satisfaction (Thistlethwaite et al., 2012).

Forensic chemistry cases usually involve evidence in the crime scene and thus link learning concepts to students' careers or jobs in the future. The presentation of possible actual evidence in given cases, such as blood and bloodstains, would attract the students' interest and stimulate them to work and look for what is asked in each case. An analysis of a drug case could ignite their interest and motivation as they relate the given case to actual drug cases in the country. A poisoning case, for instance, could be presented in such a way that students have to determine the possible poison used based on post-mortem observations. Students realize the importance and usefulness of their course to their careers, thereby increasing their career motivation. Again, these will keep them motivated as cases would relate the students' expected career path to their learning concepts. They will realize that their career will involve forensic chemistry and that learning it will help them secure a good job, a career advantage, and the good problem-solving skills needed in their future careers. Students regard case-based training as realistic, demanding, intriguing, entertaining, artistically stimulating, and beneficial to learning, according to Mayo (2002). Students are also more interested in learning while using cases because they participate actively in actual problem situations and reflect on their personal experiences. According to Kaplan (2019), students' fascination with crime investigation can be exploited in all chemistry classrooms to spark students' attention and evoke a strong response when asked to learn something often seen as boring and useless.

5.2. Difference in the Motivation Scores towards Forensic Chemistry Learning of Students Exposed to Case-Based Instruction and Those Who Were Not

A significant difference exists between the post-test motivation scores of students exposed to case-based instruction and those who were not, as shown by the results. This means that the students taught using case analyses felt significantly higher motivation towards forensic chemistry than those traditionally taught the same lessons. This study's findings showed that the case-based learning group exhibited significantly greater learning motivation than the lecture-based learning group was supported by other researchers for different groups of students (Gholami et al., 2021, Yoo & Park, 2014; Yoo et al., 2010). Given that, in case-based learning, students deal with real-life scenarios which could ignite their interest as they realize the relevance of their lessons to their lives. In case-based instruction, students are also better able to express their views, interests, and ideas and learn about the viewpoints of their classmates and friends as they work together on given cases. This will pique their interest and urge them to inquire further. Students become more interested and satisfied as they collaborate rather than listen to lectures. Case-based instruction appeals to students who may be unengaged with a lecture format that concentrates on facts and content rather than developing higher-order and critical thinking skills (Prince, 2006).

5.3 Effect of Case-Based Instruction on the Achievement Scores of Forensic Chemistry Students

For its effect on the students' achievement, the findings imply that learners taught through case-based education learned more and better than those who took the same lessons through the lecture modality, as indicated by the higher mean post-test scores. This is similar to Sendur's (2012) findings that case-based learning positively influences the students' learning and constructs relationships between real-life situations with chemical principles. This also shows that better learning occurred when students were given cases from everyday life to discuss forensic chemistry concepts. With questions and problems posed for students to answer after understanding the given cases, they must critically think as answers must be based on given circumstances. Therefore, students should have critical thinking skills, which will help them solve complex or straightforward problems (Setiana et al., 2021). In a suspected murder case, for instance, where bloodstain samples are analyzed to determine the perpetrator, students must study and understand each examination's results before concluding. This is similar to the unit on laboratory techniques where the cases must be read and analyzed to determine possible evidence that could be collected and, from the pieces of evidence, which technique should be used for analysis. As guessing is not an option, and critical thinking is exercised, it leads to an increased understanding of forensic chemistry concepts and higher achievement. Learning activity cases increase students' achievement by understanding chemistry concepts. This is because critical thinking and understanding are promoted by case-based instruction, as stated by Hereid (2004), Prince (2006), and Yadav et al. (2007).

5.4 Differences between the achievement scores of the students exposed to case-based instruction and those who were not

A significant difference exists between the mean post-test achievement scores of students who received case-based education and those who did not. The students taught with the case-based instruction achieved significantly higher post-test scores than those taught the same lessons through the lecture method. Gunter and Alpat (2019) corroborate that a higher increase in the post-test achievement scores of the case-based learning group may indicate that case-based instruction effectively improves academic achievement in given topics. Also, Cresswell and Loughlin (2017) observed sustained improvements in students' assessment outcomes in first-year forensic science after introducing the case-based scenario.

When students analyze cases, they try to study actual data, apply systematic tools, communicate issues, reflect on their related experiences, and draw decisions, thereby acquiring substantive content knowledge and developing analytic, collaborative, and communication skills. In contrast to lecture-based instruction, where students examine the content, those working with cases engage with the material, making their learning experience more dynamic as they imagine themselves acting in a real-world situation. The learners are no longer passive observers but active participants. Presenting cases brings the lessons to life and helps learners synthesize ideas by putting them in actual settings. Learning and remembering lessons are much more manageable when linked with real-life cases, thereby giving a feel of how essential it is to everyday life. Students are active creators of knowledge rather than passive users of knowledge. They acquire the material more deeply and engage with it at a higher level. They remember more of what they do than what they read, hear, or see.

6. Conclusion

This study investigated the effectiveness of case-based learning on the motivation and achievement of students in forensic chemistry and compared it with the traditional lecture-style format of the content delivery. It is safe to conclude that case-based instruction results in significant positive changes in Forensic chemistry students' motivation in the course. Students exposed to case-based instruction have higher motivation towards forensic chemistry than those who were not. By linking actual scenarios, circumstances, and activities in the real world with the lessons, students' appreciation of forensic chemistry increases in their personal lives and future professions. Students' opinions of chemistry being too theoretical gradually change to more curiosity, enthusiasm, and attention towards the sessions, motivating and encouraging them to love learning forensic chemistry. Also, case-based instruction increases the achievement level of students in forensic chemistry; those exposed to case-based instruction have higher achievement scores than those taught with the lecture method. It promotes critical thinking and better understanding combined with better motivation and positive attitudes, which lead to better learning. Therefore, case-based instruction is an effective learning and teaching method for enhancing the motivation and achievement of students in forensic chemistry. Forensic chemistry educators may consider utilizing case-based instruction to increase their students' motivation and achievement, positively contributing to the forensic chemistry teaching process and science education. Further, case-based learning will motivate forensic chemistry students and develop their significant reasoning, problem-solving, and higher-order thinking skills to be good evidence collectors and investigators.

With all these findings and conclusions, the researcher notes that these may not apply to other groups of students in other universities in the Philippines or other countries. Thus, more studies should be conducted to determine appropriate learning and teaching methods that could increase the motivation and achievement of students in the forensic chemistry classroom.

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Appendix 1
Science Motivation Questionnaire II (SMQ-II)

To better understand what you think and how you feel about your Forensic Chemistry course, please respond to each of the following statements from the perspective of "When I am in a Forensic Chemistry course…"

Components (Scales) and Statements (Items)	Never 0	Rarely 1	Sometimes 2	Often 3	Always 4
Intrinsic Motivation					
The science I learn is relevant to my life.					
Learning forensic chemistry is interesting.					
Learning forensic chemistry makes my life more meaningful.					
I am curious about discoveries in forensic chemistry.					
I enjoy learning forensic chemistry.					
Self-Efficacy					
I am confident I will do well on forensic chemistry tests.					
I am confident I will do well in forensic chemistry labs and projects.					
I believe I can master forensic chemistry knowledge and skills.					
I believe I can earn a grade of "A" in forensic chemistry.					
I am sure I can understand forensic chemistry.					
Self-Determination					
I put enough effort into learning forensic chemistry.					
I use strategies to learn forensic chemistry well.					
I spend a lot of time learning forensic chemistry.					
I prepare well for forensic chemistry tests and labs.					
I study hard to learn forensic chemistry.					
Grade Motivation					
I like to do better than other students on forensic chemistry tests.					
Getting a good forensic chemistry grade is important to me.					

It is important that I get an "A" in forensic chemistry.					
I think about the grade I will get in forensic chemistry.					
Scoring high on forensic chemistry tests and labs matters to me.					
Career Motivation					
Learning forensic chemistry will help me get a good job.					
Knowing forensic chemistry will give me a career advantage.					
Understanding forensic chemistry will benefit me in my career.					
My career will involve forensic chemistry.					
I will use forensic chemistry problem-solving skills in my career.					