



Analysis of Cognitive Understanding and Science Process Skills of Criminology Students in an Organic Chemistry Hybrid Class: Basis for an Enhanced Hybrid Chemistry Instructional Plan

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ABSTRACT

This quantitative descriptive-correlational study examined the cognitive understanding and science process skills of 84 criminology students enrolled in an organic chemistry hybrid class. Data were gathered using tests on cognitive understanding and science process skills and a scale measuring hybrid-learning difficulty. Descriptive statistics and Pearson product-moment correlation were employed to analyze the data. Results showed Developing cognitive understanding ($M = 20.89$, $SD = 4.26$) and Approaching Proficiency in science process skills ($M = 22.05$, $SD = 3.95$). Hybrid-learning difficulties were experienced to a Moderate Extent ($M = 2.72$, $SD = 0.24$), particularly in laboratory and simulation activities. Cognitive understanding was significantly and positively related to science process skills, $r(82) = .441$, $p < .001$. The findings support strengthening foundational concepts, laboratory and simulation experiences, online-to-classroom integration, and scientific inquiry through forensic applications. An enhanced instructional plan is recommended to address the identified learning needs and improve students' performance in organic chemistry

INTRODUCTION

Organic chemistry provides a scientific foundation for understanding the composition, properties, reactions, and identification of carbon-containing substances. Within criminology education, this knowledge supports later learning about drugs, toxic substances, fuels and accelerants, biological materials, trace residues, and other forms of physical evidence. Criminology students are not expected to become analytical chemists through one course, but they need sufficient chemical understanding to recognize why evidence behaves in particular ways, why laboratory procedures require controls, and why conclusions must remain consistent with the available data.

The educational value of organic chemistry extends beyond the recall of names, formulas, and reactions. Students must coordinate multiple representations, including molecular structures, functional-group labels, reaction equations, observable changes, and particle-level explanations. Recent research has shown that students may obtain correct answers while relying on memorized procedures or surface features, which can mask incomplete understanding of chemical ideas (Stowe et al., 2022). Meaningful cognitive understanding therefore requires learners to explain, apply, and analyze concepts in both familiar and unfamiliar situations.

Organic chemistry is commonly perceived as demanding because learners must move between symbolic, molecular, and macroscopic representations. Wang et al. (2022) demonstrated the value of intentionally linking these representations through immersive technology, while Iyamuremye et al. (2025) reported that structured web-based discussion improved conceptual understanding in organic chemistry. These findings suggest that technology can support comprehension when it is integrated with purposeful questions, explanations, and evidence rather than used only to distribute content.

Hybrid instruction combines planned face-to-face learning with structured online learning. The format can provide repeated access to explanations, multimedia representations, practice activities, and discussion while preserving opportunities for direct interaction, demonstration, and supervised investigation. Dai et al. (2021) found that project-based organic chemistry delivered through a blended model supported students' self-study capacity. However, the benefits of hybrid instruction depend on instructional alignment, access to appropriate technology, timely feedback, and meaningful connection between the online and classroom components.

For criminology students, a hybrid organic chemistry class may be useful because online environments can provide flexible review of unfamiliar chemical representations and face-to-face sessions can focus on demonstrations, case applications, problem solving, and laboratory reasoning. The same arrangement may also create barriers. Unstable connectivity, dependence on mobile devices, limited access to laboratory materials, insufficient interaction, delayed feedback, and weak coordination of course activities can reduce learning opportunities. Describing these difficulties is necessary when the intended output is an instructional plan tailored to the actual context of students.

Cognitive understanding represents only one dimension of science learning. Students also require science process skills, which are the practices used to obtain, organize, interpret, and evaluate evidence. These include observing, classifying, measuring, predicting, inferring, formulating hypotheses, identifying and controlling variables, interpreting data, and drawing conclusions. Research in chemistry education has emphasized that learners may struggle to identify relevant patterns and connect evidence to defensible explanations, even when they possess related factual knowledge (Berg & Moon, 2022).

Science process skills are particularly relevant to criminology because evidence-based practice depends on careful observation, measurement, comparison, documentation, control of contamination, interpretation of test results, and awareness of alternative explanations. These skills do not replace professional forensic training, but they provide a foundation for disciplined reasoning. Rusmini et al. (2021) found that chemistry students' science process skills could be developed through self-project-based learning, highlighting the importance of tasks that require students to plan, observe, analyze, and communicate rather than passively receive information.

Cognitive understanding and science process skills were retained as separate outcomes in this descriptive study. A student may remember functional groups yet struggle to interpret experimental data, or may follow a procedure without understanding the chemical basis of the result. Assessing the two areas separately permits a clearer description of strengths and needs. The design does not test whether one outcome causes or predicts the other; instead, it establishes performance profiles that can guide instruction.

The proposed study also examines students' difficulties in the hybrid learning environment. This additional descriptive component connects learning outcomes to actionable aspects of course delivery without claiming causation. By identifying the least-mastered chemistry domains, weakest process skills, and most frequently reported instructional difficulties, the researcher can formulate a plan that directs resources toward specific online, classroom, laboratory, assessment, and remediation needs.

Recent literature consistently supports purposeful integration of digital and face-to-face learning in chemistry. Blended project work, web-based discussion, and immersive representations can support self-directed learning and conceptual understanding when activities require interaction with ideas rather than passive exposure (Dai et al., 2021; Iyamuremye et al., 2025; Wang et al., 2022). The literature also shows that chemistry learning should be evaluated through both content understanding and the practices used to interpret evidence (Alberto et al., 2024; Berg & Moon, 2022).

Studies of organic chemistry problem solving show that learners need structured reasoning to connect concepts with predicted outcomes (Stowe et al., 2022). Research on science process skills similarly emphasizes learner involvement in observation, investigation, data analysis, and conclusion formation (Gizaw & Sota, 2023; Rusmini et al., 2021). Together, these findings

support the separate assessment of cognitive understanding and science process skills and the use of domain-level results for instructional planning.

However, the reviewed literature primarily involved chemistry students, secondary learners, preservice teachers, or general science populations. There remains limited contextual evidence describing criminology students' performance in organic chemistry hybrid classes. The combination of objective cognitive and process-skills assessment with a structured description of hybrid-learning difficulties is also underrepresented. The present study addresses this gap through a descriptive-quantitative design and uses the resulting performance and difficulty profiles as the basis for an enhanced hybrid chemistry instructional plan.

Available research has examined blended chemistry learning, web-based discussions, conceptual understanding, problem solving, and science process skills. However, fewer studies have focused on criminology students taking organic chemistry as a supporting discipline, and fewer still have combined objective measures of cognitive understanding and science process skills with a descriptive assessment of hybrid-learning difficulties. The present study addresses this contextual gap and produces an enhanced hybrid chemistry instructional plan grounded in the respondent's demonstrated performance and reported experiences.

THEORITICAL REVIEW

The study is informed by constructivist and inquiry-oriented perspectives as represented in recent chemistry education literature. Constructivist learning treats understanding as an active process in which learners connect new information with prior ideas, representations, experiences, and feedback. In chemistry, this process is important because students must reconcile what they observe with symbolic and molecular explanations. Recent technology-enhanced chemistry studies have shown that learning resources become more useful when they enable students to examine relationships among representations and explain the reasoning behind an answer (Iyamuremye et al., 2025; Wang et al., 2022).

An inquiry-oriented perspective complements constructivism by emphasizing the practices through which scientific knowledge is developed and evaluated. Students learn science not only by receiving established explanations but also by observing, measuring, comparing, controlling variables, interpreting evidence, and defending conclusions. Alberto et al. (2024) identified inquiry, experimentation, modeling, and research-related practices as recurring strategies for strengthening science learning. The perspective supports the inclusion of an objective science process skills measure in the present study.

The hybrid learning environment was treated as the instructional context rather than an independent variable. Online and face-to-face components were expected to perform complementary functions. Online spaces could provide accessible resources, repeated practice, visualization, and asynchronous reflection, while face-to-face sessions could support immediate clarification, collaboration, demonstration, and guided practical work. The study therefore

described difficulties affecting both components and their integration so that the proposed plan could address the whole learning environment.

Conceptual Framework

The conceptual framework organized the study around three descriptive evidence sources: cognitive understanding, science process skills, and hybrid-learning difficulties. Cognitive understanding was represented by performance in structure and bonding, nomenclature and functional groups, isomerism and physical properties, organic reactions, and forensic applications. Science process skills were represented by basic and integrated practices used to investigate and interpret scientific questions. Hybrid-learning difficulties included access, interaction, laboratory or simulation opportunities, feedback, assessment, and integration of online and face-to-face learning.

Each evidence source was analyzed independently through frequencies, percentages, means, standard deviations, percentage scores, and rankings as appropriate. The framework did not posit a causal or predictive relationship among the three components. Instead, the results were combined during instructional planning. Low-performing domains and frequently reported difficulties were translated into priorities for online learning materials, face-to-face teaching, laboratory or simulation work, formative assessment, feedback, and remediation.

Figure 1 presents the descriptive input-to-output framework. The three measured components supplied complementary information, while the enhanced hybrid chemistry instructional plan represented the study's proposed output. The arrows indicate that findings from each component informed the plan; they do not indicate causation.

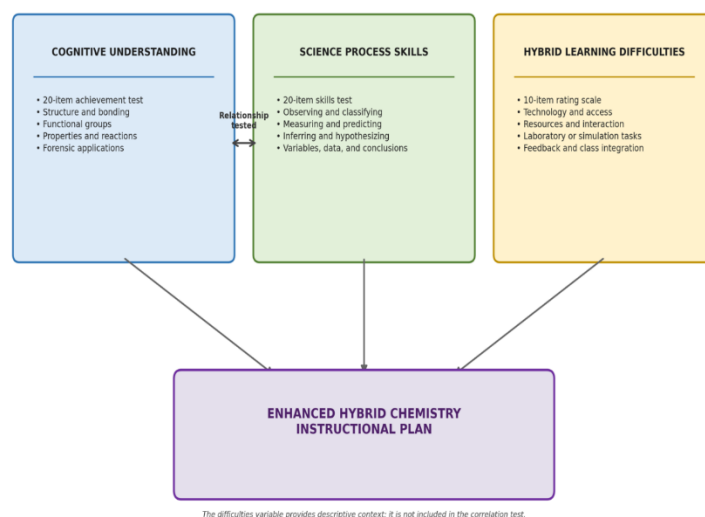


Figure 1. *Conceptual Framework of the Descriptive Quantitative Study*

Statement of the Problem

This study aimed to determine the cognitive understanding, science process skills, and hybrid-learning difficulties of criminology students enrolled

in an organic chemistry hybrid class as the basis for an enhanced hybrid chemistry instructional plan.

Specifically, it sought to answer the following questions:

1. What is the demographic and learning profile of the respondents in terms of:
 - a. age;
 - b. sex;
 - c. previous chemistry grade;
 - d. primary device used for online learning;
 - e. internet reliability;
 - f. frequency of online participation; and
 - g. frequency of face-to-face participation?
2. What was the profile of the respondents in terms of age, sex, year level, section, and previous chemistry grade?
3. What was the level of the respondents' cognitive understanding of organic chemistry?
4. What was the level of the respondents' science process skills?
5. What difficulties did the respondents experience in the Organic Chemistry hybrid class?
6. Was there a statistically significant relationship between the respondents' cognitive understanding and science process skills?
7. Based on the findings, what enhanced hybrid chemistry instructional plan could be developed?

METHODOLOGY

The study was conducted at Universidad de Manila in the City of Manila, Philippines. The respondents consisted of criminology students enrolled in Organic Chemistry during the first semester of School Year 2026–2027.

The study employed purposive sampling to select criminology students who were officially enrolled in Organic Chemistry during the study period. The required sample consisted of approximately 84 respondents. The sample size was based on an a priori power analysis for a two-tailed correlation using a .05 level of significance, .80 statistical power, and a medium anticipated effect size of $r = .30$. When students came from multiple sections, the 84 respondents were proportionally distributed to ensure adequate representation of each section.

The study used a quantitative descriptive-correlational research design. The descriptive component determined the respondents' levels of cognitive understanding and science process skills. The correlational component determined whether a statistically significant relationship existed between their cognitive understanding of organic chemistry and science process skills. The results served as the basis for developing an enhanced hybrid chemistry instructional plan for criminology students.

The researcher first secured an approved letter from the appropriate university authorities authorizing the conduct of the study. The purpose, procedures, expected duration, and ethical considerations of the research were explained to the students. Only students who were officially enrolled in Organic Chemistry, willing to participate, and able to provide informed consent were included.

The researcher used the Researcher-Developed Organic Chemistry Learning Assessment for Criminology Students. Part I obtained the respondents' demographic and learning profiles. Part II consisted of 30 multiple-choice questions measuring cognitive understanding of structure and bonding, nomenclature and functional groups, isomerism and physical properties, organic reactions, and forensic applications. Part III consisted of 30 situational multiple-choice questions measuring science process skills such as observing, classifying, measuring, predicting, inferring, formulating hypotheses, identifying and controlling variables, interpreting data, and drawing conclusions.

The instrument was evaluated by experts in organic chemistry, science education, educational assessment, and criminology or forensic science. It was pilot-tested among students who possessed characteristics similar to those of the target respondents but were not included in the main study. Item analysis was conducted to determine item difficulty, discrimination, and distractor effectiveness. Kuder-Richardson Formula 20 was used to determine the internal consistency of the two objective tests.

The assessment was administered during the students' available time. Clear and standardized instructions were provided before the test, and procedural questions were immediately addressed. The assessment was conducted in person to ensure consistent administration and provide assistance when necessary. Each correct response received one point, while each incorrect or unanswered response received zero.

Frequency and percentage were used to describe the respondents' profiles. Mean, standard deviation, percentage scores, and ranking were used to determine their levels of cognitive understanding and science process skills. Pearson's product-moment correlation was used to determine the relationship between cognitive understanding and science process skills. Spearman's rank-order correlation was used when the assumptions for Pearson's correlation were not adequately satisfied. The null hypothesis was tested at the .05 level of significance.

Participation was voluntary, and the respondents were informed that they could decline or withdraw without academic penalty. Their identities and individual scores were kept confidential and used only for research purposes. The study was conducted with the approval of the appropriate university authorities and in accordance with Republic Act No. 10173, otherwise known as the Data Privacy Act of 2012.

RESEARCH RESULTS

This section presents the descriptive and correlational findings for the 84 respondent records. Frequencies and percentages describe the respondent profile. Means, standard deviations, percentages, and mastery classifications summarize cognitive understanding, science process skills, and hybrid-learning difficulties. Pearson's product-moment correlation tests the relationship between cognitive understanding and science process skills at the .05 level of significance.

Respondent Profile

Table 1. Demographic and Learning Profile of Respondents

Variable	Category	n	%
Age	18	11	13.1
	19	19	22.6
	20	27	32.1
	21	8	9.5
	22	9	10.7
	23	5	6.0
	24	5	6.0
Sex	Female	41	48.8
	Male	39	46.4
	Prefer not to say	4	4.8
Primary device	Smartphone	52	61.9
	Laptop or desktop	22	26.2
	Tablet	10	11.9
Internet reliability	Consistently reliable	11	13.1
	Usually, reliable	30	35.7
	Sometimes unreliable	30	35.7
	Frequently unreliable	13	15.5
Online participation	Every activity	17	20.2
	Most activities	38	45.2
	Some activities	24	28.6
	Rarely	5	6.0
Face-to-face participation	Every session	42	50.0
	Most sessions	30	35.7
	Some sessions	12	14.3

As shown in Table 1, the largest age group was 20 years old (32.1%), followed by 19 years old (22.6%). Female students represented 48.8% of the sample, while male students represented 46.4%. Smartphones were the primary online-learning device for 61.9% of respondents. Only 13.1% reported consistently reliable internet, whereas 51.2% reported either sometimes or frequently unreliable internet. Most students participated in most or all online activities (65.4%) and most or all face-to-face sessions (85.7%). The mean previous chemistry grade was 82.61 (SD = 4.90; range = 72–95).

Cognitive Understanding and Science Process Skills

Table 2. Descriptive Statistics for Cognitive Understanding and Science Process Skills

Variable	M	SD	Interpretation
Cognitive understanding	20.89	4.26	Developing
Science process skills	22.05	3.95	Approaching Proficiency

Table 2 shows that the mean cognitive-understanding score was 20.89 out of 30 (SD = 4.26), equivalent to 69.64%. Based on the adopted interpretation scale, this result was classified as Developing. The mean science-process-skills score was higher at 22.05 out of 30 (SD = 3.95), equivalent to 73.49%, and was classified as Approaching Proficiency. The results suggest that the students performed better in applying scientific inquiry and evidence-based reasoning than in demonstrating mastery of organic chemistry content.

Table 3. Distribution of Mastery Levels

Level	CU n	CU %	SPS n	SPS %
Advanced	8	9.5	9	10.7
Proficient	13	15.5	28	33.3
Approaching Proficiency	25	29.8	17	20.2
Developing	21	25.0	18	21.4
Beginning	17	20.2	12	14.3

The largest cognitive-understanding group was Approaching Proficiency (29.8%), followed by Developing (25.0%) and Beginning (20.2%). Only 25.0% reached the Proficient or Advanced levels. For science process skills, 44.0% reached the Proficient or Advanced levels, while 35.7% were classified as Developing or Beginning. This distribution indicates substantial variation in performance and supports differentiated instruction rather than a single remedial approach for all students.

Highest and Lowest Mastery Items

Table 4. Highest and Lowest Performing Test Items

Test	Performance	Item	% Correct
Cognitive	Highest	24	79.8
		4	78.6
		30	77.4
Cognitive	Lowest	7	57.1
		1	60.7
		25	60.7
Science process skills	Highest	30	82.1
		10	81.0
		7, 19, and 26	79.8
Science process skills	Lowest	11 and 23	64.3
		18	66.7
		17	67.9

For cognitive understanding, Item 24, which required an inference from differences in boiling range, produced the highest percentage of correct responses (79.8%). Items 4 and 30 also showed relatively high mastery. Item 7, which addressed recognition of the carboxylic acid functional group, had the lowest percentage correct (57.1%). Items 1 and 25, concerning carbon bonding and structural representation, were also among the least mastered. For science

process skills, students performed best on Item 30, which required a qualified evidence-based conclusion (82.1%), and Item 10, which involved controlling variables (81.0%). The lowest results occurred on Item 11, concerning the purpose of a blank control, and Item 23, concerning an operational definition (both 64.3%). These item-level patterns identify specific content and inquiry practices for instructional reinforcement.

Hybrid Learning Difficulties

Table 5. Hybrid-Learning Difficulties by Domain

Domain	M	SD	Extent	Rank
Laboratory and simulation	2.94	0.37	Moderate Extent	1
Integration and application	2.72	0.39	Moderate Extent	2
Access and technology	2.70	0.59	Moderate Extent	3
Resources and interaction	2.69	0.41	Moderate Extent	4
Feedback and assessment	2.54	0.38	Moderate Extent	5
Overall difficulty	2.72	0.24	Moderate Extent	—

The overall mean for hybrid-learning difficulties was 2.72 (SD = 0.24), corresponding to a Moderate Extent. Laboratory and simulation difficulties received the highest domain mean (M = 2.94, SD = 0.37), followed by integration and application (M = 2.72, SD = 0.39). Feedback and assessment received the lowest mean (M = 2.54, SD = 0.38), although it remained within the Moderate Extent category. Thus, the central instructional concern was not simply internet access; it was the reduced opportunity to connect conceptual lessons with laboratory procedures, demonstrations, and applied forensic tasks.

Table 6. Most and Least Reported Hybrid-Learning Difficulties

Group	Item	Difficulty	M	SD
Most reported	12	Limited access to laboratory materials	3.01	0.74
	9	Limited hands-on laboratory activities	2.96	0.65
	11	Difficulty connecting online lessons with classroom or laboratory activities	2.93	0.64
Least reported	14	Feedback did not clearly explain correct and incorrect answers	2.48	0.72
	13	Feedback was not provided promptly	2.51	0.75
	15	Assessment instructions and expectations were unclear	2.52	0.70

At the item level, limited access to laboratory materials was the most reported difficulty (M = 3.01, SD = 0.74). Limited hands-on laboratory opportunities (M = 2.96, SD = 0.65) and difficulty connecting online lessons with laboratory or classroom activities (M = 2.93, SD = 0.64) followed. The least reported difficulty concerned the explanatory quality of feedback (M = 2.48, SD = 0.72), which was interpreted as a Slight Extent. The pattern consistently points

to laboratory access and online-face-to-face integration as the principal areas needing improvement.

Relationship Between Cognitive Understanding and Science Process Skills

Table 7. Pearson Correlation Between Cognitive Understanding and Science Process Skills

Variables	n	r	df	p	Decision
Cognitive understanding and science process skills	84	.441	82	< .001	Reject H_0

Pearson's correlation showed a statistically significant, moderate positive relationship between cognitive understanding and science process skills, $r(82) = .441$, $p < .001$. The null hypothesis was therefore rejected. Students with higher cognitive-understanding scores tended to obtain higher science-process-skills scores. The coefficient of determination ($r^2 = .195$) indicates that the two scores shared approximately 19.5% of their variance. This result represents an association and does not establish that one variable caused the other.

DISCUSSION

Cognitive Understanding and Science Process Skills

The Developing mean for cognitive understanding indicates incomplete mastery of the organic chemistry knowledge measured by the instrument. The low-performing items involved foundational concepts such as carbon bonding, functional-group identification, and structural representation. These concepts support later reasoning about properties, reactions, and forensic identification. Weaknesses at this level may therefore limit students' ability to transfer chemistry knowledge to unfamiliar evidence-based situations. The finding supports the use of instruction that explicitly connects observable phenomena, molecular explanations, chemical symbols, and authentic applications. Wang et al. (2022) emphasized the instructional value of connecting macroscopic, molecular, and symbolic representations, while Dai et al. (2021) demonstrated that structured project-based blended learning can strengthen engagement and self-directed learning in organic chemistry.

Science process skills were relatively stronger, reaching Approaching Proficiency. The stronger performance on qualified conclusions and variable control suggests that many respondents could recognize appropriate scientific reasoning when alternatives were provided. Nevertheless, difficulty with blank controls, operational definitions, and evaluating limited evidence shows that some students still needed support in planning and judging investigations. Rusmini et al. (2021) reported that project-based chemistry learning can train science process skills, while Berg and Moon (2022) showed that carefully designed prompts can support students' data analysis and interpretations. These studies support the use of guided investigations in which students identify variables, select controls, construct operational definitions, analyze results, and justify conclusions.

Relationship of the Two Learning Outcomes

The moderate positive correlation is consistent with the conceptual framework that treated cognitive understanding and science process skills as distinct but related outcomes. Students need content knowledge to interpret evidence, but they also need process skills to examine whether evidence supports a chemical explanation. The shared variance of 19.5% shows meaningful overlap without suggesting that the two measures are interchangeable. Other influences, including prior knowledge, motivation, instructional design, laboratory exposure, and access to learning resources, may explain the remaining variability. The correlational design does not permit causal conclusions. The result should therefore guide integrated instruction, not a claim that improvement in one outcome will automatically produce improvement in the other.

Hybrid Learning Difficulties

The highest difficulty involved laboratory and simulation opportunities. Organic chemistry requires learners to connect abstract structures and reaction ideas with observable evidence. When laboratory materials, demonstrations, or simulations are limited, students may encounter concepts mainly as text and symbols. This can weaken the connection between chemical knowledge and the evidence-handling practices relevant to criminology. Recent reviews have identified inquiry, project work, digital tools, and research-oriented learning as important strategies for strengthening chemistry and biology learning (Alberto et al., 2024). Web-supported organic chemistry can also improve conceptual understanding and transferable skills when online activities are deliberately structured and supported (Iyamuremye et al., 2025).

The moderate access-and-technology difficulty also deserves attention because most respondents relied on smartphones and more than half reported unstable internet at least sometimes. Chemical structures, reaction mechanisms, and data displays are difficult to examine on small screens or under intermittent connectivity. Materials should therefore be mobile-readable, low-bandwidth, downloadable, and available before scheduled activities. However, the domain rankings suggest that providing internet access alone would not be sufficient. Students also need a coherent sequence in which online preparation leads directly to face-to-face investigation, discussion, and application.

Inputs for an Enhanced Hybrid Chemistry Instructional Plan

The findings support an instructional plan organized around four priorities. First, short diagnostic and remedial lessons should address carbon bonding, functional groups, structural formulas, and the relationship between structure and properties. Second, each online concept lesson should prepare students for a corresponding face-to-face or simulated investigation. Third, inquiry tasks should require students to identify variables and controls, define measurements operationally, organize data, and defend conclusions. Fourth, authentic criminology and forensic scenarios should be used to connect organic chemistry with evidence preservation, presumptive and confirmatory testing, volatile samples, purity, and interpretation of conflicting results.

Because performance varied substantially, the plan should include differentiated support. Students at Beginning and Developing levels may receive

scaffolded examples, guided worksheets, and short feedback cycles. Students at Proficient and Advanced levels may complete more open-ended evidence-analysis tasks. Assessment should combine brief concept checks, data-interpretation exercises, laboratory or simulation reports, and forensic case applications. This alignment would allow cognitive understanding and science process skills to develop together while directly addressing the hybrid-learning difficulties identified in the dataset.

CONCLUSIONS AND RECOMMENDATION

Based on the findings, the following conclusions were drawn:

1. The respondents represented varied age and year-level groups and relied mainly on smartphones for online learning. Although most participated in online and face-to-face activities regularly, more than half experienced unreliable internet at least sometimes. These conditions showed that access, device limitations, and connectivity remained relevant considerations in planning hybrid chemistry instruction.
2. The criminology students demonstrated a Developing level of cognitive understanding in organic chemistry. Their performance indicated partial mastery of the concepts measured by the instrument, particularly carbon bonding, functional-group identification, and structural representation. These foundational gaps could limit their ability to understand organic reactions and apply chemical concepts to forensic situations.
3. The respondents demonstrated an Approaching Proficiency level of science process skills. They performed relatively well in drawing qualified conclusions and identifying controlled variables but showed weaker performance in recognizing the purpose of blank controls and defining variables operationally. Thus, the students possessed emerging inquiry skills but still required guided practice in planning, evaluating, and explaining investigations.
4. Hybrid-learning difficulties were experienced to a Moderate Extent. Limited laboratory materials, reduced hands-on activities, and difficulty connecting online lessons with classroom or laboratory work were the most evident concerns. This indicated that the effectiveness of the hybrid class depended not only on online access but also on coherent integration of digital instruction, laboratory experiences, and applied activities.
5. Cognitive understanding and science process skills had a statistically significant moderate positive relationship. Students with higher organic chemistry understanding tended to demonstrate stronger science process skills. However, the relationship did not establish causation, and much of the variability in both outcomes could be associated with other learner and instructional factors.
6. An enhanced hybrid chemistry instructional plan should therefore combine concept remediation, inquiry-based laboratory or simulation activities, mobile-accessible learning resources, timely formative feedback, and criminology-related forensic applications. Such an approach could support the coordinated development of content knowledge and scientific reasoning.

Recommendations

In view of the conclusions, the following recommendations are offered:

1. **Organic chemistry instructors** may administer brief diagnostic assessments and provide focused remediation on carbon bonding, functional groups, structural formulas, isomerism, and structure-property relationships before introducing more complex reactions and forensic applications.
2. **Course designers and instructors** may align each online lesson with a related face-to-face activity, laboratory exercise, demonstration, or virtual simulation. The sequence should allow students to prepare online, apply the concept during class, and reflect on the evidence afterward.
3. **Science process skills development** may be strengthened through guided investigations that require students to identify variables and controls, write operational definitions, organize observations, interpret data, and justify conclusions using evidence.
4. **Laboratory and simulation support** may be improved by increasing access to essential materials, low-cost experiments, demonstration videos, virtual laboratories, and structured simulation worksheets when actual laboratory time or equipment is limited.
5. **Learning materials** may be designed for smartphone use and low-bandwidth access. Downloadable modules, concise videos, readable molecular diagrams, and offline activities may help students who experience unstable internet connections.
6. **Assessment and feedback** may include frequent low-stakes concept checks, item-specific explanations, data-interpretation tasks, laboratory or simulation reports, and forensic case analyses. Feedback should clearly explain why responses are correct or incorrect.
7. **Contextualization for criminology students** may be increased by using cases involving evidence preservation, presumptive and confirmatory testing, organic solvents, toxic substances, volatile samples, purity, and interpretation of conflicting laboratory findings.

Compliance with Ethical Standards

This study complies with the ethical standards by obtaining informed consent, informing the respondents that they can withdraw from the study should the need arise without causing any harm or conflict. Anonymity of the respondents was maintained. Data Privacy was followed. The respondents' well-being was safeguarded. No conflict of interest exists in the conduct of the study. Moreover, plagiarism was strictly avoided and there was no bias in the interpretation of data.

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