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Exploring the Multimodal Approach in Pre-Service Chemistry Teacher Education: Perspective from Students and Lecturers

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ABSTRACT: This study aims to investigate the implementation of a multimodal approach in the learning process and the summative tests of pre-service chemistry teacher education. Data were collected through Google Forms using semi-structured questions. Data were compared with analysis handbooks and summative test documents. The results show that most pre-service chemistry teachers have a multimodal learning style. However, the application of the multimodal approach in chemistry courses has not been extensively implemented due to several challenges. For instance, the time required for preparation can be a significant barrier, as creating and organizing multiple modes of communication can be time-consuming. The complexity of creating media is another challenge, as it requires technical skills and resources. Additionally, the characteristics of students who do not support independent learning can hinder the implementation of a multimodal approach. The most commonly used media in applying the multimodal approach are videos and PowerPoint presentations, supplemented by direct explanations from lecturers. Most of the test techniques used by lecturers were in written form, owing to the difficulties in developing multimodal tests. This study implies an urgent need for the development of multimodal test instruments to accommodate differences in students' learning styles.

Keywords: chemistry, learning style, multimodal, test, pre-service education, instructional media.

I. INTRODUCTION

Digital technology and diversity present significant challenges for pre-service chemistry teacher education (PCTE). Digital technology provides opportunities for the training process to become more personalized [1]. Moreover, it can enhance student engagement and boost academic achievement through customized learning [2]. Addressing these challenges involves integrating a multimodal approach into learning.

The multimodal approach bridges pedagogy, democracy, and social justice amid classroom diversity [3]. It accommodates diverse student resources and ensures equitable access to content, formal curricula, and assessment methods [4]. In Indonesia, students' multicultural and multiethnic backgrounds influence their habits, communication styles, and learning methods. Therefore, recognizing students' communication styles during classroom interactions is essential for effectively delivering educational information. Besides addressing diversity, the multimodal approach is vital for developing new literacy theories, including digital literacy. It equips students to understand and create meaning using non-textual elements in various digital spaces, such as images, sound, and video [5]. Learning processes incorporating multimodal elements can prepare students to adapt to emerging technologies, fostering flexible, ethical thinking habits and encouraging creative problem-solving [6]. Students need the skills to succeed in studying science disciplines, particularly chemistry.

In chemistry education, multimodality is not a novelty. Teachers cannot rely solely on one mode, such as verbal or written explanations when explaining chemical concepts. Due to chemistry's abstract nature and symbolic complexity, teachers employ various modes, including visual, gestural, and tactile, to clarify symbols and chemical equations [7]. Students need to integrate multiple semiotic modes simultaneously in one learning activity to interpret and contextualize chemical information, typically presented in written form, into other formats like visual representations [8].

Multimodality serves as a form of external representation in chemistry learning. Understanding these representations is crucial for grasping chemical concepts and positively correlates with students' academic success [9]. However, this success also depends on the teacher's ability to select and combine external representations of unseen concepts [10]. Therefore, incorporating a multimodal approach in PCTE is crucial, as it prepares students or pre-service chemistry teachers (PCTs) to use diverse communication modes and appropriate representations, better equipping them for their future roles as chemistry teachers.

Despite its importance, there is a significant research gap concerning the multimodal approach in chemistry education, particularly for PCTs. While this approach is extensively explored in language teaching and applied sciences [11-13], this study focuses primarily on investigating the implementation of a multimodal approach in PCTE at Indonesian universities, considering the moderating role of students' learning styles. This study aims to explore the implementation of the multimodal approach in both the learning process and summative test, from the perspectives of PCTs and lecturers. The following three research questions were formulated: (1) What is the learning style of PCTs? (2) To what extent are PCTs' and lecturers' perspectives for implementing multimodality in the lecturing process? (3) To what extent are PCTs' and lecturers' perspectives for implementing multimodality in the summative test?

II. LITERATURE REVIEW

The advent of digital technology has transformed the learning paradigm from a text-dominated model to one that embraces multimodality. Multimodality involves a representation, communication, and interaction approach that utilizes various semiotic sources and modes, such as images, writing, movement, gaze, speech, or posture, within a product or activity [8]. It can contribute to meaning-making in the science learning approach.

The multimodal approach is grounded in the theory that the simultaneous processing of multiple modes text, image, sound, and motion in visual, media, or digital texts functions differently than print-based texts' linear and sequential reading [14]. This theory posits that communication and interaction occur through writing (a single mode) and the convergence of speech, gestures, gazes, and visual forms [15]. Multimodal communication, particularly effective for digital devices, leverages visual design aspects, intertextual links, and collaborative interactivity [8, 16].

The Cognitive Theory of Multimedia Learning supports the utilization of multimodality [17] and the Cognitive Load Theory [18]. The multimedia learning theory is based on three core assumptions: multiple channels, limited capacity, and active processing. It identifies five cognitive processes: selecting relevant words from text or narrative, selecting relevant images from graphics, organizing selected words into coherent verbal representations, organizing chosen images into coherent pictorial representations, and integrating these representations with prior knowledge. The cognitive load theory explains how the information processing load of learning tasks can impact students' ability to assimilate new information and build knowledge for long-term memory [19]. Presenting information multimodally benefits students who actively process information [20,21].

Multimodal communication extends beyond social sciences in the classroom [22]. It employs real illustrations, images, gestures, dummies, and models to support reading and writing activities. Scientific ideas are conveyed through various representation modes such as mathematics, pictures, tables, graphs, gestures, and written/verbal language [23]. Educators use images, symbols, and physical models alongside teaching materials like textbooks, which incorporate photos and texts in multiple modes to aid students in meaning-making [7]. Furthermore, technological advances have led to the use of animations, simulations, videos, virtual reality, and augmented reality to enhance science learning.

In higher education, multimodal assignments have become increasingly prevalent. Educators aim to develop students' potential and engagement with social, visual, and interactive information outside traditional classroom settings, fostering creativity and critical thinking in formal learning contexts [24]. When combined with other modes, writing tasks can serve as effective assessment tools [7]. The integration of writing with various modes, such as animations or videos, aids students in engaging with macroscopic, symbolic, and sub-microscopic aspects of phenomena, facilitating a more comprehensive understanding and explanation of these phenomena.

Furthermore, studies show that the multimodal approach is starting to be developed in science learning. It is focused on topics related to humanity and digital technology [24]. The use of virtual labs accommodating visual, auditory, and kinesthetic modalities increases students' understanding and performance [25]. While, multimodal assessment can provide an independent and complementary measurement of the student learning process [26], improve students' gain, and prepare university graduates for their future careers [27]. Considering the positive impact of using multimodality, more extensive research is needed on this topic, specifically in chemistry learning. Before conducting further research, it is necessary to map the extent of implementing the multimodal approach so that aspects that need to be developed or improved can be determined.

III. MATERIAL AND METHOD

This study employed quantitative approaches to provide a comprehensive understanding of the use of the multimodal approach in the learning process and test within pre-service chemistry teacher education (PCTE). Primary data were collected using semi-structured questionnaires, supplemented by document analysis to gain deeper insights.

1. PARTICIPANT

The participants in this study were PCTs and lecturers from the chemistry education departments of Indonesian universities. The sample included six public universities across eastern and western Indonesia, all of which have achieved at least "good" accreditation. There were 214 students and 17 lecturers participating in the study. The lecturers involved in the study were grouped into areas of expertise according to the subdiscipline of chemistry which is the main topic of their research or teaching field. Participant demographics are detailed in Table 1.

Table 1. Demographic data of the participants.

Item	Frequency (f)	Proportion (%)
Participant responsible		
Students		
Male	22	
Female	192	10.28
Total	214	89.72
Lecturer		
Male	7	41.18
Female	10	58.82
Total	17	
Lecturers' expertise		
Inorganic	1	5.88
Physical Chemistry	2	11.76
Analytic	3	17.65
Biochemistry	3	17.65
Chemistry education	8	47.06
Students' years		
1st	91	42.52
2nd	64	29.91
3rd	35	16.36
4th	24	11.21

2. DATA COLLECTION

Two questionnaires were employed in this study: a student's learning style questionnaire and a multimodal implementation questionnaire. The learning style instrument, which adopts the VARK 8.01 model [28], consists of 16 questions and categorizes students' learning preferences into four types: visual (V), auditory (A), read/written (R), and kinesthetic (K). The multimodal approach was assessed through various question formats, including close-ended, open-ended, and Likert-scale inquiries. Supplementary data included handbooks and summative exam sheets from the sampled universities. Research instruments were created using Google Forms and distributed via a social media platform. To ensure data accuracy, the questionnaires were initially given to the department heads of PCTE, who then forwarded them to students and lecturers under their authority.

3. DATA ANALYSIS

The research data was analyzed using both descriptive and qualitative methods. Descriptive analysis was conducted using SPSS, a software package utilized for quantitative analysis. It involves determining frequencies, means, and standard deviations to summarize the data quantitatively. For qualitative analysis, RStudio was employed to interpret textual data. Rstudio is open-source software for statistical analysis which makes it possible to perform qualitative analysis. Additionally, statistical and graphical analyses were executed using Excel to visualize the results and identify trends.

IV. RESULTS AND DISCUSSION

The integration of the multimodality approach in PCT education is discussed under three themes: PCTs' learning styles, the profile of multimodality in the lecturing process, and the profile of multimodality in summative assessments.

1. PCT's LEARNING STYLES

Observations on student learning styles were conducted to explore how multimodality accommodates students' diverse modal preferences when studying chemistry. Individual differences in the learning process are often due to variations in cognitive functions. The preference profile of student learning styles, illustrated in Figure 1, shows that the kinesthetic style is most prevalent among students. However, there is a noticeable trend towards using multiple learning methods simultaneously.

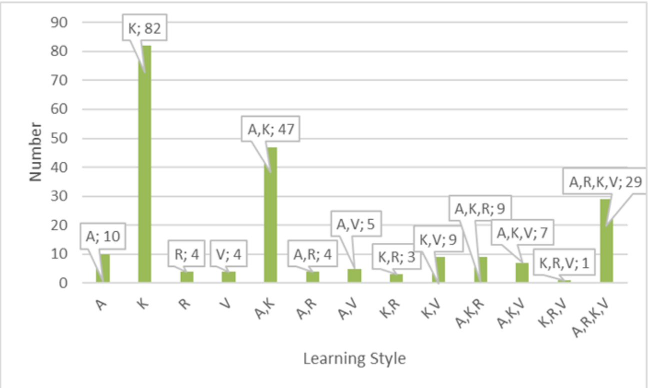

FIGURE 1. The preference of PCT's learning styles.

Further analysis of PCT students' learning styles was conducted by grouping those who showed similar scores across two or more learning style categories as multimodal learners. Table 2 reveals that a significant portion of the students, including both males and females, exhibit multimodal learning styles. Among these, the preference for bimodal learning is most common, where students favor learning through two equally significant methods, such as audio-kinesthetic, kinesthetic-visual, or audio-visual.

Table 2. Profile of PCT's learning style by modality.

Gender	Learning Styles				
	Unimodal	**Bimodal**	**Trimodal**	**Tetramodal**	**Total**
Male	9	8	1	4	22
	4.21%	3.74%	0.47%	1.87%	
Female	91	60	16	25	192
	42.52%	28.04%	7.48%	11.68%	
Total	100	68	17	29	214
	46.72%	31.78%	7.94%	13.55%	
		Total Multimodal		53.27%	

2. THE PROFILE OF MULTIMODALITY IN THE LECTURING PROCESS

The study examined the modes utilized by lecturers in their classes. Figure 2 presents data on the modes most frequently used by PCT lecturers; 97.66% of lecturers predominantly used oral modes, followed closely by written modes at 96.26%. Tactile modes were the least selected. Additionally, the data indicate that 90.65% of lecturers also apply a multimodal approach in their teaching.

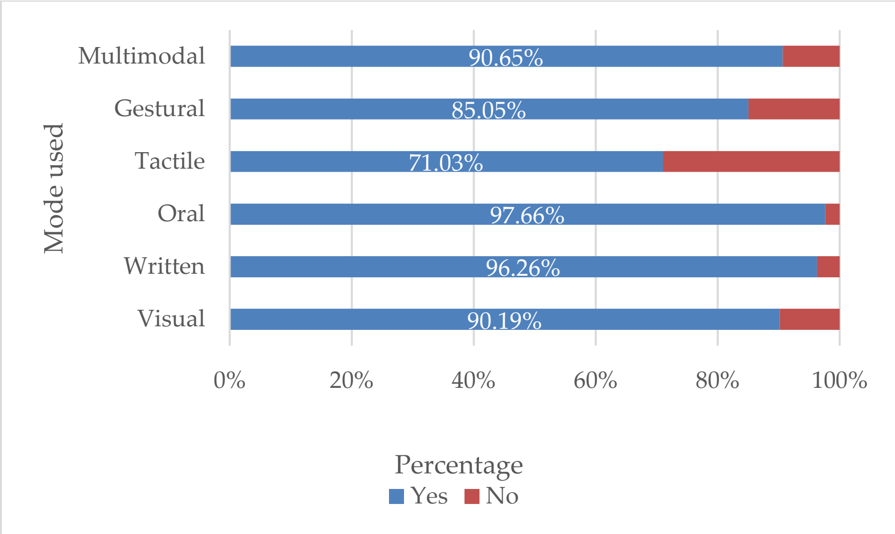

FIGURE 2. Modes used in class.

When examined in detail, most lecturers implemented multimodal frequently, while only 11.76% never implemented a multimodal approach, as shown in Figure 3.

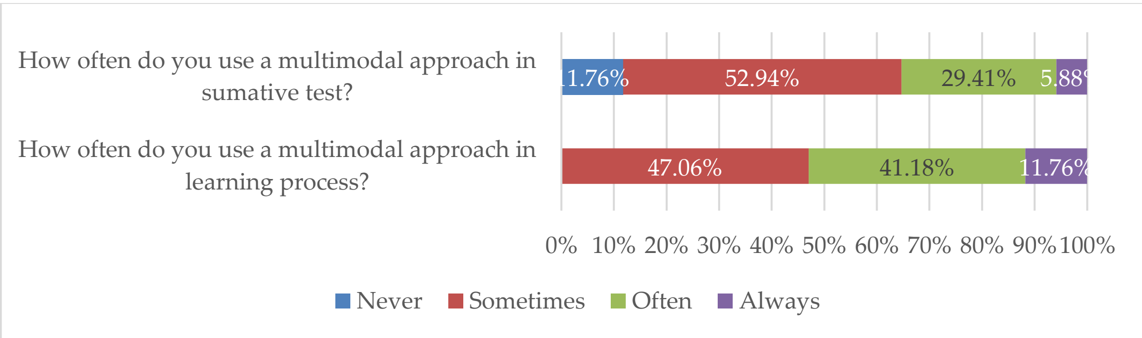

FIGURE 3. Lecturer intensity in applying multimodal approach.

Next, participants indicated that PowerPoint offers a wide range of media to support multimodality in their classes. Figure 4 shows that video and animation were chosen by a minority of respondents, 13.5% and 6.0% respectively. Other media utilized include diagrams, textual content, and tangible objects from the environment. This corresponds with the findings from handbook analyses, where multimodality is depicted through videos and student presentations, supplemented by direct teacher explanations using PowerPoint.

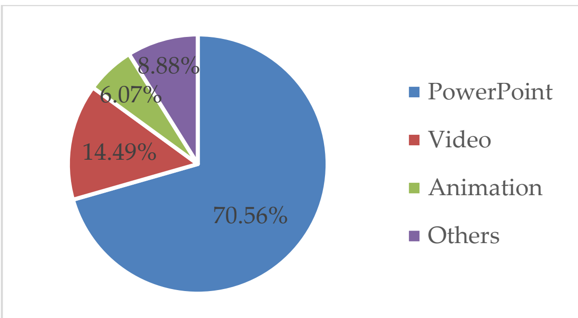

FIGURE 4. Media supported multimodality.

Regarding the advantages of implementing multimodal approaches, both students and lecturers perceive that multimodal applications enhance comprehension of learning materials, as supported by Figure 5. Through multimodality, students find it easier to visualize and grasp abstract chemical concepts.

FIGURE 5. The benefits of implementing a multimodal approach.

In terms of students' viewpoints on modes utilized in classroom learning activities, all students unanimously agree that multimodal applications enhance their understanding of learning materials, as indicated in Table 3. Furthermore, visual and tactile modes receive particularly high mean ratings among students, suggesting these are their preferred choices. Intriguingly, only kinesthetic learners give a high rating to the written mode, while others tend to express uncertainty. Upon further exploration of students' opinions, it became evident that they find the written mode time-consuming, complex, and prone to plagiarism.

Table 3. PCT's perspective on mode use.

Moda preference	**Learning Style**	**Mean**	**Std. Dev.**
Visual	Visual	4.27	0.50
	Audio	4.05	0.50
	Read	4.75	0.50
	Kinesthetics	4.63	0.48
	Multimodal	4.16	0.48
Written	Visual	3.71	0.76
	Audio	3.60	0.84
	Read	3.00	1.15
	Kinesthetics	4.00	1.15
	Multimodal	3.61	0.76
Aural	Visual	3.54	0.67
	Audio	3.35	0.67
	Read	4.38	0.75
	Kinesthetics	4.25	0.65
	Multimodal	3.80	0.63
Gestural	Visual	3.87	0.58
	Audio	3.50	0.58
	Read	4.13	0.63
	Kinesthetics	4.00	0.71
	Multimodal	3.77	0.67

Tactile	Visual	4.35	0.42
	Audio	4.20	0.58
	Read	4.50	0.58
	Kinesthetics	4.50	0.58
	Multimodal	4.29	0.65
Multimodal	Visual	4.16	0.62
	Audio	4.0	0.67
	Read	4.50	0.58
	Kinesthetics	4.25	0.96
	Multimodal	4.22	0.56

3. THE PROFILE OF MULTIMODALITY IN THE SUMMATIVE TEST

In contrast to its integration into the learning process, multimodality has not been extensively incorporated into summative assessments. Examination of final exam documents reveals that writing remains the predominant mode, a finding supported by the experiences of both students and lecturers, as depicted in Figure 6. Nearly 56% of students reported that the assessment method primarily relied on written tasks, while 39.8% utilized a combination of two modes, with only 2.3% involving spoken communication. Among the various combinations of modes, written and visual modalities are the most commonly used.

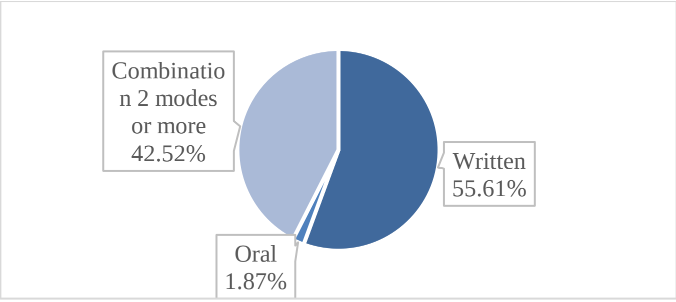

FIGURE 6. Modes used in assessment.

The students' perceptions and the results of the analysis of summative test documents present a slight contradiction with the lecturer's statements. While more than half of the lecturers claimed to have integrated multimodality in summative tests (as shown in Figure 3), this is primarily because the lecturers included the practicum report as part of the summative assessment, whereas students categorized it as a formative test. A deeper exploration of the challenges lecturers face in implementing multimodality in assessments reveals that time constraints, both in preparation and assessment after the exam, are significant obstacles, as evidenced by qualitative data in Figure 7. Additionally, lecturers expressed difficulties in developing scoring rubrics for student work.

FIGURE 7. Obstacles to multimodal implementation in tests.

Regarding the modes that PCTs were expected to utilize in the test, apart from writing, students' opinions were not definitively expressed, as outlined in Table 4. Only auditory and visual learners indicated agreement with oral and visual testing modes. Furthermore, the gestural mode was perceived as the least appealing to students. The readiness factor emerged as a significant determinant in selecting these modes. Students mentioned their lack of readiness to participate in oral and gestural testing due to factors such as limited vocabulary, nervousness, and shyness, which they believed could lead to forgetting the material learned and hinder optimal assessment results. Interestingly, some students mentioned that employing both modes in the test would prevent cheating.

Table 4. PCT preferences for modes in the test.

		Expected modes		
Learning style	**Value**	**Oral**	**Visual**	**Gestural**
Audio	Mean	3.40	3.80	3.30
	Std dev	0.16	0.20	0.21
Kinetics	Mean	3.53	3.90	3.49
	Std dev	0.11	0.93	0.11
Multimodal	Mean	3.60	3.73	3.41
	Std dev	0.09	0.79	0.09
Read	Mean	4.33	4.33	3.33
	Std dev	0.03	0.33	0.33
Visual	Mean	4.00	4.67	3.67
	Std dev	0.58	0.33	0.67

This study explored three aspects related to the profile of a multimodality approach in PCT education: student characteristics in terms of learning styles, learning activities in class, and the summative test form. Learning styles and multimodal are closely related. Learning styles theories underline encoding information employing a specific modality, while multimodal practice encompasses transcribing information using multiple modes [29].

PCT's learning style refers to the personal way of assimilating and processing information received in a learning context [30]. Each student has a particular learning style; they have a specific pattern of choosing methods, techniques, and media for learning [31]. Visual learners prefer using symbolic devices such as charts, graphs, flowcharts, and models representing printed information. Auditory learners prefer "heard" statements, so effective learners learn through discussions, lectures, and tutorials. Read/written learners prefer printed text to acquire new information, such as textbooks and lecture notes. Kinesthetic learners use a combination of sensory functions; when learning, they must feel or live the experience to remember, prefer practical simulations and authentic experiences. However, some students do not have strict preferences for the four learning styles. They have multiple choices when understanding information and are called multimodal learners [32].

Related to students' learning styles, the finding revealed that more than half of PCT preferred a multimodal learning style. These results are based on a study conducted by Khanal et al. [33] that compared some research related to the learning styles of undergraduate and postgraduate students, resulting in most students being multimodal learners. This implies that lecturers should design learning programs that involve activities that stimulate visual, auditory, read-write, and kinesthetic sensory modalities. The multimodality approach helps bridge differences in student learning styles, as it accommodates instructional elements to be presented in various sensory modes (visual, aural, written, gestural, and spatial). In addition, multimodality can also help students improve their understanding of lecture material and their ability to think creatively and discover new things [25].

Related to the implementation of a multimodal approach in the learning process of PCTE, the overall finding displays that while the multimodality approach has been implemented, it is still used sporadically. Several obstacles hinder its implementation in chemistry courses. These obstacles include time issues in planning and implementing, such as preparing teaching materials and selecting appropriate media. Additionally, the low level of students' self-regulation poses an inhibiting factor.

A plethora of media, including PowerPoint and video, are utilized to support multimodality. PowerPoint allows for combining text, images, design, etc., integrating various semiotic signs to analyze as a form of multimodal discourse [34]. It can also be incorporated with verbal explanations and gestures. PowerPoint significantly improves students' understanding immediately and in the long run [35]. Video is a highly effective multimodal medium easily accessible for communicating complex scientific ideas, explaining scientific concepts, and conveying science to interested individuals [36]. Merging different modes contributes to various semiotic sources useful for re-contextualizing knowledge for students.

PCTs revealed that they benefit from learning through multimodality. It accommodates different learning styles, enhancing their understanding of the learning material. Students experience enjoyable and meaningful learning. From a visualization standpoint, students are more engaged when the learning material is presented in pictures, graphics, and designs. Moreover, visualization, known as visual representation, is integral to learning chemistry and relates to the macroscopic, symbolic, and submicroscopic dimensions. It fosters a fun learning experience and significantly impacts long-term conceptual understanding [37].

Regarding the gestural mode, students consider this mode helpful in recognizing abstract objects more realistically. Additionally, gestures can emphasize essential parts of explanations and reduce anxiety when presenting. The tactile or spatial mode visualizes abstract concepts in three dimensions, making chemistry concepts more accessible and encouraging student creativity.

Regarding the multimodal approach in summative tests, the study results reveal that the written mode predominates the testing technique employed by lecturers. While several courses utilize performance tests to facilitate tactile and gestural modes, such as creating concept maps visually and delivering presentations for the auditory mode, these tests do not receive sufficient emphasis to gauge the level of student success in learning. Interestingly, students express comfort with written assessments but feel unprepared when assessments integrate other modes. Examinations incorporating multimodality significantly outperform the unimodal approach because multiple modalities offer independent and complementary measures of student science learning [38].

Most lecturers experienced constraints in integrating multimodality into tests during preparation, implementation, and post-assessment. At the preparatory stage, lecturers encountered difficulties in compiling appropriate test instruments. During the implementation stage, obstacles encountered in the assessment process required significant time, and students felt burdened by multimodality-based assessments. In the post-exam stage, lecturers faced challenges in reviewing and scoring student work. Therefore, lecturers expressed continued interest in developing multimodal-based tests. They concur with expert opinions regarding multimodal tests; multimodality can provide better scientific explanations for conceptual questions [39].

Despite the significant findings obtained, some limitations of the study were noted: lecturer participants do not represent all subdisciplines in chemistry. In addition, there is no definition of the term “summative test” in the questionnaire, resulting in a difference in understanding between lecturers and students regarding the components of the summative test. Lecturers include practicum reports as a technique of the summative test, while students consider it as part of the laboratory activity assignment.

V. CONCLUSION

This study found that most PCTs are multimodal learners, effectively utilizing two or more modes, such as kinesthetic and visual, for learning. Consequently, the multimodality approach is considered suitable for both classroom lectures and testing stages as it can accommodate various sensory modes (visual, aural, written, gestural, and spatial) to present instructional content. Though not extensively, multimodality has been incorporated into the learning process. Several obstacles hinder the integration of this approach, including long preparation times, complicated media preparation, and student characteristics that do not support independent learning.

The most commonly used media in multimodal chemistry classes are video and PowerPoint, accompanied by direct lecturer explanations, both reflecting individual levels of multimodality. Unfortunately, this integration of multimodality has not been matched by appropriate testing techniques. The predominant testing mode among teachers is written, although lecturers express interest in developing multimodal-based tests. Several obstacles are experienced by lecturers when developing multimodal tests, including determining the form of the test instrument, implementing the test in the classroom, and scoring students' test results.

Future studies may focus on the development of multimodal tests that integrate various sensory modes to capture a more holistic understanding of students' comprehension of chemistry. Furthermore, multimodal tests can tailor meaningful learning experiences to each student that have a unique learning style.

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Author Contribution

All authors contributed equally to planning, data collection, data analysis, and reporting.

Conflict Of Interest

The authors declare no competing interests are still not.

Data Availability Statement

Data are available from the authors upon request.

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