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RESEARCH PAPER

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Development and validation of laboratory assessment tools for science educators

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ABSTRACT

The study aimed to develop and validate a tool for evaluating and enhancing the practices and challenges faced by chemistry educators in laboratory instruction, grounded in Piaget's Theory of Constructivism. The instrument assesses cognitive, affective, and psychomotor domains through rigorous item generation, expert validation, and pilot testing with chemistry and science teachers. It comprises two main components: teaching practices and teaching challenges, categorized into five factors. The appropriateness of factor analysis was confirmed by Keiser–Meyer Olkin (KMO) measures of sampling adequacy (.652 for Parts II and IV, .863 for Part III) and Bartlett's test (df = 1035, p < .000 for Parts II and IV; df = 300, p < .000 for Part III). Items with factor loadings over 0.40 were retained. The Content Validity Ratio (CVR) was 1.000, and the overall Content Validity Index (CVI) was 1.000 for seven experts. The percentage of variance was 56.80% for Parts II and IV (three factors) and 64.16% for Part III (two factors). Eigenvalues for the five factors ranged from 1.172 to 21.135. Reliability analysis demonstrated strong internal consistency, with an overall Cronbach's alpha of 0.93 and subscale alphas from 0.87 to 0.96. The identified factors include Instructional Design and Delivery, Classroom Laboratory Management, Assessment and Feedback, Supervision and Safety Management, and Teaching Resources and Support. This instrument provides a valuable framework for optimizing chemistry laboratory instruction.

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INTRODUCTION

The rapidly evolving landscape of science education necessitates innovative approaches to enhance teaching and learning, particularly in chemistry laboratory instruction. Traditional instructional methods often fall short in addressing the diverse needs of students and the complex dynamics of modern classrooms. Effective science teaching requires theoretical explanations to be reinforced through practical laboratory experiences that promote observation, experimentation, and scientific inquiry. Laboratory-based instruction plays a central role in developing students' scientific knowledge and skills by providing opportunities for experiential learning (Hofstein and Lunetta *et al.*, 2004). Consequently, laboratory activities have remained an essential component of science curricula because they enhance student engagement and facilitate meaningful learning experiences (Hofstein and Lunetta, 2004; Burke *et al.*, 2006). Moreover, inquiry-based laboratory instruction encourages greater student involvement and promotes inductive learning compared with traditional instructional approaches (Abrahams, 2013).

The importance of effective laboratory instruction has been widely recognized in science education research. Previous studies have emphasized the need for laboratory experiences that foster scientific thinking while simultaneously improving instructional quality. Hofstein and Lunetta (2004) highlighted the critical role of laboratory activities in science education and stressed the importance of developing effective evaluation tools to improve instructional practices. Similarly, Abrahams *et al.* (2013) emphasized that practical laboratory work promotes scientific reasoning and requires appropriate assessment methods to evaluate instructional effectiveness. Bennett and Holman (2002) further suggested that assessment instruments are essential for evaluating context-based chemistry teaching, particularly in laboratory environments.

Additional studies have underscored the importance of evaluating teachers' instructional practices and their application of scientific models in laboratory teaching (Van Driel and Verloop, 1999). Furthermore, Burke *et al.* (2006) emphasized that effective laboratory instruction requires inquiry-oriented teaching strategies, meaningful assessment, and active student engagement. Likewise, Abrahams *et al.* (2013) highlighted that practical laboratory activities promote scientific reasoning and should be accompanied by appropriate assessment methods to improve instructional effectiveness. These findings reinforce the importance of developing comprehensive instruments capable of evaluating laboratory teaching practices and instructional quality.

Although previous studies have highlighted the importance of laboratory instruction and instructional assessment, there remains a need for a comprehensive instrument specifically designed to evaluate both the instructional practices and the challenges encountered by chemistry educators during laboratory teaching. Existing evidence supports the importance of practical laboratory instruction, effective assessment, and constructivist learning; however, there is still a need for an instrument that integrates these dimensions into a single framework capable of evaluating teaching practices, instructional challenges, and assessment practices. Furthermore, increasing concerns regarding low chemistry performance, failure rates, and student attrition in the Chemistry Education program of Jose Rizal Memorial State University (JRMSU), together with increasing enrolment following the implementation of the K–12 curriculum, highlight the need for improved instructional assessment tools that can support effective laboratory teaching.

This study is grounded in Piaget's Theory of Constructivism, which proposes that learners actively construct knowledge through processes of assimilation and accommodation based on their experiences (Muijs and Reynolds, 2011). Constructivist learning emphasizes collaboration, interaction, exploration, experimentation, and problem-solving, allowing learners to develop new ideas by integrating prior knowledge with new experiences. Guided by this theoretical perspective, the present instrument was designed to evaluate the cognitive, affective, and psychomotor dimensions of laboratory instruction while ensuring that its constructs align with constructivist principles. Accordingly, the instrument focuses on five major domains: Instructional Design and Delivery, Classroom Laboratory Management, Assessment and Feedback, Supervision and Safety Management, and Teaching Resources and Support. These domains collectively provide a comprehensive evaluation of laboratory teaching practices and challenges and are represented through a detailed Table of Specifications developed during the instrument construction process.

The study aimed to develop and validate a comprehensive Laboratory Assessment Tool for Science Educators that measures the effectiveness of laboratory-based teaching practices, identifies instructional challenges encountered by chemistry educators, and evaluates student engagement and learning outcomes. The instrument is intended for science teachers in secondary and tertiary chemistry education and is designed for use by educators, curriculum developers, and educational researchers.

Contributions of the study

The proposed instrument provides a comprehensive framework for evaluating chemistry laboratory instruction by integrating teaching practices, instructional challenges, and assessment practices within a constructivist perspective. Unlike instruments that focus primarily on theoretical understanding or basic laboratory skills, the present tool offers a holistic assessment of laboratory instruction by addressing cognitive and affective aspects of teaching and learning. By providing educators with systematic information regarding instructional practices and challenges, the instrument is expected to support evidence-based improvements in laboratory teaching, enhance student engagement and understanding, and contribute to improving educational outcomes within chemistry education.

MATERIALS AND METHODS

Research design

This study employed an instrument development and validation research design to develop and evaluate the psychometric properties of the Laboratory Assessment Tool for Science Educators (LATSE). Instrument development research is widely recognized as an appropriate approach for constructing valid and reliable measurement tools intended to assess latent educational constructs (DeVellis, 2016). The study followed a systematic process that included construct identification, item generation, expert content validation, pilot testing, and psychometric evaluation.

The development of the instrument was guided by Piaget's Theory of Constructivism, which emphasizes that learners actively construct knowledge through interaction, exploration, and experiential learning (Muijs and Reynolds, 2011). This theoretical perspective served as the conceptual foundation for identifying the major constructs and developing questionnaire items that comprehensively represent effective chemistry laboratory instruction. Accordingly, the instrument was designed to evaluate teaching practices and instructional challenges across the cognitive, affective, and psychomotor domains of laboratory learning.

The overall development process consisted of four sequential stages. First, relevant literature and theoretical concepts were reviewed to identify the constructs underpinning effective laboratory instruction. Second, questionnaire items were developed and organized according to a Table of Specifications (TOS). Third, the preliminary instrument underwent expert review to establish content validity. Finally, the revised instrument was pilot-tested among science educators to evaluate its construct validity and internal consistency before its finalization. This systematic approach ensured that the resulting instrument possessed adequate content coverage, conceptual alignment, and psychometric quality.

Instrument development

The Laboratory Assessment Tool for Science Educators (LATSE) was developed through a structured process that combined theoretical foundations with evidence from previous studies. An extensive review of the literature was first conducted to identify existing concepts, instructional models, and assessment practices related to chemistry laboratory instruction. This review facilitated the operational definition of the constructs to be measured and informed the generation of questionnaire items. The development process was further guided by the principles of constructivist learning theory, ensuring that each item reflected authentic laboratory teaching practices and challenges encountered by science educators.

Based on the identified constructs, an initial pool of questionnaire items was developed to represent three major domains: Teaching Practices in Science Education, Teaching Challenges Encountered during Laboratory Instruction, and Assessment Practices in Science Laboratory Instruction. The preliminary questionnaire consisted of 71 items, including 35 items for Teaching Practices, 25 items for Teaching Challenges, and 11 items for Assessment Practices. Responses were recorded using a five-point Likert scale. For the Teaching Practices and Assessment Practices sections, response options ranged from 1 (Strongly Disagree) to 5 (Strongly Agree), whereas the Teaching Challenges section employed a severity scale ranging from 1 (Not a Problem) to 5 (Very Serious). This response format enabled respondents to provide nuanced evaluations of their instructional practices and perceived laboratory challenges.

To ensure that the instrument adequately represented the intended constructs, each item was written to measure a single observable behaviour or instructional characteristic. Particular attention was given to item clarity, relevance, and consistency with constructivist principles. The preliminary instrument was subsequently subjected to expert review, during which specialists in science education and chemistry evaluated the appropriateness, comprehensibility, and relevance of each item before pilot testing. This iterative development process is consistent with established recommendations for educational instrument construction and validation (DeVellis, 2016).

Table of specifications

A Table of Specifications (TOS) was developed prior to questionnaire construction to ensure comprehensive representation of the intended constructs and balanced distribution of questionnaire items. The TOS served as the blueprint for instrument development by systematically linking the theoretical framework with the specific domains and indicators measured by the LATSE. Its primary purpose was to ensure that all essential aspects of chemistry laboratory instruction were adequately represented while minimizing construct underrepresentation and item redundancy.

The TOS was organized around five core dimensions of effective laboratory instruction: Instructional Design and Delivery, Classroom Laboratory Management, Assessment and Feedback, Supervision and Safety Management, and Teaching Resources and Support. These dimensions collectively encompass curriculum planning, instructional implementation, classroom and laboratory management, assessment practices, laboratory safety, supervision, and resource availability. The selection of these domains was informed by the literature on effective science teaching and laboratory instruction and aligned with the principles of constructivist learning adopted in this study. Each construct was represented by multiple measurable indicators to ensure adequate content coverage throughout the instrument.

The Table of Specifications also guided the proportional allocation of questionnaire items across the identified constructs, ensuring that each domain was represented according to its conceptual importance. This systematic mapping strengthened the content validity of the instrument by maintaining alignment between the theoretical framework, research objectives, and questionnaire items.

Furthermore, the TOS provided a transparent framework for subsequent expert validation and psychometric evaluation, thereby supporting the development of a comprehensive and balanced instrument for assessing laboratory teaching practices and instructional challenges among science educators.

Expert validation

The preliminary version of the Laboratory Assessment Tool for Science Educators (LATSE) was subjected to expert validation to establish its content validity before pilot testing. Content validation is a critical stage in instrument development because it determines whether the questionnaire adequately represents the intended constructs and whether individual items are relevant, clear, and appropriate for the target population (DeVellis, 2016). Accordingly, the initial instrument was reviewed by seven subject-matter experts with expertise in science education, chemistry education, and educational measurement.

The experts were asked to evaluate every questionnaire item with respect to its relevance, clarity, comprehensibility, appropriateness of language, plausibility, construct representation, and overall suitability for assessing laboratory instruction among science educators. In addition, they examined the logical alignment between each item and its corresponding construct, as well as the overall organization of the instrument. Their qualitative comments and recommendations were carefully reviewed and incorporated into the revised version of the questionnaire to improve wording, eliminate ambiguity, and strengthen construct representation before empirical testing. This iterative review process enhanced both the content coverage and face validity of the instrument.

To quantitatively assess content validity, the Content Validity Ratio (CVR) proposed by Lawshe (1975) was calculated for each questionnaire item, while the Content Validity Index (CVI) was computed to evaluate the overall content validity of the instrument. The CVR measures the degree of agreement among experts regarding the essentiality of each item, whereas the CVI provides an overall estimate of the instrument's content validity (Lawshe, 1975). For a panel of seven experts, a CVR value greater than 0.99 indicates unanimous agreement that an item is essential according to the revised critical values proposed by Ayre and Scally (2014). In the present study, all questionnaire items achieved a CVR of 1.000, indicating complete agreement among the experts regarding their essentiality. Similarly, the overall CVI was 1.000, demonstrating excellent content validity for the entire instrument. Consequently, all 71 questionnaire items were retained for subsequent pilot testing.

Table 1 presents the Content Validity Ratio (CVR), Content Validity Index (CVI), and expert decisions for all questionnaire items. As shown, every item received a CVR of 1.000 and was retained without deletion, reflecting unanimous expert consensus regarding the relevance and appropriateness of the instrument for assessing laboratory teaching practices, instructional challenges, and assessment practices among science educators. These findings provide strong evidence that the LATSE possesses excellent content validity and adequately represents the theoretical constructs identified during the instrument development process.

The unanimous agreement among the expert panel indicates that the questionnaire items comprehensively capture the intended domains of laboratory instruction while maintaining conceptual clarity and practical relevance. The high CVR and CVI values further demonstrate that the instrument is well aligned with the underlying constructivist framework and adequately covers the essential dimensions of effective chemistry laboratory instruction. Establishing strong content validity before pilot testing increases confidence that subsequent analyses of construct validity and reliability will reflect the psychometric properties of a theoretically sound measurement instrument (DeVellis, 2016).

Table 1. Content Validity Ratios (CVR), Content Validity Index (CVI), and expert decisions for the Laboratory Assessment Tool for Science Educators (LATSE)

Sl	Statement	CVR	CVI (Mean)	Decision
1.	I provide a foundation of factual knowledge and conceptual understanding.	1.00	1.00	Retained
2.	I develop activities that will foster scientific reasoning ability.	1.00	1.00	Retained
3.	I employ strategies to help students control their learning.	1.00	1.00	Retained
4.	I encourage students to learn together.	1.00	1.00	Retained
5.	I adopt an empirical approach to teaching.	1.00	1.00	Retained
6.	I regularly employ active learning strategies.	1.00	1.00	Retained
7.	I integrate discussion about the nature of science in teaching.	1.00	1.00	Retained
8.	I give learning activities that enhance student engagement.	1.00	1.00	Retained
9.	I provide an active approach to learning that includes a strong emphasis on student interaction with phenomena.	1.00	1.00	Retained
10.	I can clearly and explicitly connect representations and phenomena.	1.00	1.00	Retained
11.	I strive to balance the emotional and cognitive aspects of learning.	1.00	1.00	Retained
12.	I link scientific concepts and processes with prior learning in science and other disciplines.	1.00	1.00	Retained
13.	I use a constructivist approach in teaching and learning.	1.00	1.00	Retained
14.	I maintain a balance between the depth and breadth of the lessons I cover.	1.00	1.00	Retained
15.	I assign manageable tasks (respecting the Zone of Proximal Development).	1.00	1.00	Retained
16.	I provide feedback to students.	1.00	1.00	Retained
17.	I include real-world applications in the learning process.	1.00	1.00	Retained
18.	I give activities that will develop problem-solving and analytical thinking skills.	1.00	1.00	Retained
19.	I align objectives, instruction, and assessments all the time.	1.00	1.00	Retained
20.	I promote critical thinking in varied science activities.	1.00	1.00	Retained
21.	I employ learner-centered classroom activities.	1.00	1.00	Retained
22.	I use an inquiry laboratory in my work.	1.00	1.00	Retained
23.	I engage students in challenging, authentic, and interdisciplinary tasks.	1.00	1.00	Retained
24.	I provide opportunities for students to observe, explore, and test hypotheses.	1.00	1.00	Retained
25.	I transcend disciplinary boundaries when it is natural, logical, and appropriate.	1.00	1.00	Retained
26.	I nurture students' imagination, logic, and open-mindedness.	1.00	1.00	Retained
27.	I incorporate the content and processes of science giving due regard to science teaching standards.	1.00	1.00	Retained
28.	I set high expectations for my students' outputs.	1.00	1.00	Retained
29.	I provide the learners with the opportunity to practice the skills they learned in class.	1.00	1.00	Retained
30.	I employ learning cycles - observation, generalization, verification, and application.	1.00	1.00	Retained
31.	I base my approach to teaching on multiple intelligences.	1.00	1.00	Retained
32.	I establish conducive learning environments.	1.00	1.00	Retained
33.	I make sure that all students have access to laboratory activities.	1.00	1.00	Retained
34.	I incorporate peer assessment or collaborative evaluations into laboratory activities to encourage student engagement and reflection.	1.00	1.00	Retained
35.	I assess the difficulty level of evaluating students' critical thinking and problem-solving	1.00	1.00	Retained
	skills displayed during laboratory experiments.			
36.	I engage students in self-assessment or reflection activities to encourage metacognitive	1.00	1.00	Retained
	awareness and ownership of learning in the laboratory.			
37.	I always begin a lesson by assessing the students' initial understanding and preconceptions.	1.00	1.00	Retained
38.	I create, share, and use scoring rubrics.	1.00	1.00	Retained
39.	I utilize pre-laboratory quizzes or assessments to gauge students' understanding before conducting experiments.	1.00	1.00	Retained
40.	I use current methods for assessing students' procedural skills during laboratory experiments.	1.00	1.00	Retained
41.	I provide opportunities for experiential learning through trial and error, which contributes to a deeper understanding.	1.00	1.00	Retained
42.	I foster learners' development of critical and independent reasoning through practical	1.00	1.00	Retained
	training in hypothesis testing, data collection, and analysis.			
43.	I employ formative assessments during laboratory sessions to monitor student progress	1.00	1.00	Retained
	and provide timely feedback.			

44.	I use laboratory reports or write-ups as a means of assessing students' understanding of scientific concepts and experimental procedures.	1.00	1.00	Retained
45.	I use rubrics or grading criteria to ensure consistency and transparency in laboratory assessment practices.	1.00	1.00	Retained
46.	I provide meaningful and constructive feedback to students on their laboratory performance.	1.00	1.00	Retained
47.	I observe that students lack the necessary practical skills to effectively carry out their laboratory activities.	1.00	1.00	Retained
48.	I notice that students lack clear learning goals.	1.00	1.00	Retained
49.	I find it difficult to manage large groups of students in the laboratory.	1.00	1.00	Retained
50.	I provide limited access to laboratory equipment, supplies, and space to students.	1.00	1.00	Retained
51.	I provide limited opportunities to gain practical, hands-on experience to students.	1.00	1.00	Retained
52.	I have limited experience in using laboratory equipment properly.	1.00	1.00	Retained
53.	I have difficulty managing my time effectively during laboratory sessions.	1.00	1.00	Retained
54.	I lack training courses in practical laboratory work.	1.00	1.00	Retained
55.	I use the scaffolding technique for students who need assistance and guidance.	1.00	1.00	Retained
56.	I was challenged by budgetary constraints and resource limitations that impact laboratory instruction.	1.00	1.00	Retained
57.	I encounter challenges in fostering student engagement and participation during laboratory experiments.	1.00	1.00	Retained
58.	I have low ecological validity in the teaching laboratory.	1.00	1.00	Retained
59.	I find it difficult to adapt experiments to accommodate diverse student needs and abilities.	1.00	1.00	Retained
60.	I struggle with managing group dynamics and promoting collaboration among students during laboratory work.	1.00	1.00	Retained
61.	I encounter difficulties in incorporating technology and digital resources into my laboratory instruction.	1.00	1.00	Retained
62.	I face difficulties in aligning the laboratory activities with the curriculum standards and learning objectives.	1.00	1.00	Retained
63.	I had difficulty in providing supervision and support to students during laboratory experiments.	1.00	1.00	Retained
64.	I was challenged to manage and mitigate risks associated with experimental procedures in the laboratory.	1.00	1.00	Retained
65.	I evaluate the effectiveness of strategies employed in promoting a culture of inquiry and critical thinking in science labs.	1.00	1.00	Retained
66.	I find it difficult to assess student learning and performance in the laboratory.	1.00	1.00	Retained
67.	I frequently encounter difficulties in laboratory instruction due to language barriers or communication challenges.	1.00	1.00	Retained
68.	I find difficulty in staying current with advancements in laboratory techniques and technologies.	1.00	1.00	Retained
69.	I have noticed that obtaining high levels of student engagement can be challenging during science instruction.	1.00	1.00	Retained
70.	I use different teaching methods to cater to various learning styles in science education.	1.00	1.00	Retained
71.	I was challenged in assessing student understanding and mastery of scientific principles.	1.00	1.00	Retained

Pilot testing

Following expert validation, the revised Laboratory Assessment Tool for Science Educators (LATSE) was pilot-tested to examine its construct validity and internal consistency before its application in the main study. Pilot testing is an essential stage in instrument development because it enables researchers to evaluate the performance of questionnaire items, identify potential ambiguities, and determine the preliminary psychometric properties of the instrument (DeVellis, 2016).

The pilot study involved 56 prospective science and chemistry teachers, who served as the initial respondents for evaluating the instrument. Although larger sample sizes are generally recommended for exploratory factor analysis, the number of participants was constrained by the limited availability of science major teachers within the study area and the timeframe allocated for data collection. Nevertheless, the pilot sample was considered appropriate for the preliminary evaluation of the instrument before large-scale implementation.

The questionnaire was administered electronically using Google Forms, allowing respondents to complete the survey remotely within a one-week period. Prior to administration, participants were informed of the purpose of the study, and their responses were treated with strict confidentiality. The electronic mode of data collection facilitated efficient distribution of the instrument while ensuring that all respondents received identical instructions and response formats.

The pilot data were subsequently used to examine the instrument's construct validity through exploratory factor analysis (EFA) and to evaluate its internal consistency using Cronbach's alpha reliability coefficients. Findings from the pilot testing provided empirical evidence regarding the adequacy of the questionnaire items and informed the final refinement of the LATSE before its use as a validated instrument for assessing laboratory teaching practices and instructional challenges among science educators.

Statistical analysis

The psychometric properties of the Laboratory Assessment Tool for Science Educators (LATSE) were evaluated using established statistical procedures for instrument validation. Data obtained from the pilot study were analyzed using IBM SPSS Statistics version 24. The analysis focused on assessing the instrument's content validity, construct validity, and internal consistency reliability.

Content validity was established through expert evaluation using the Content Validity Ratio (CVR) and the Content Validity Index (CVI). The CVR for each questionnaire item was calculated following the method proposed by Lawshe (1975), while the overall CVI was computed to determine the degree to which the instrument adequately represented the intended constructs. Items meeting the recommended CVR criterion were retained for subsequent analyses.

Construct validity was examined using Exploratory Factor Analysis (EFA) with Principal Component Analysis (PCA) as the extraction method, followed by Varimax rotation with Kaiser normalization to obtain a simpler and more interpretable factor structure. Before factor extraction, the suitability of the data for factor analysis was assessed using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. KMO values greater than 0.60 and a statistically significant Bartlett's test indicate that the correlation matrix is appropriate for factor analysis (Kaiser, 1974; Field, 2018). Factor retention was further evaluated using eigenvalues, the percentage of explained variance, and rotated factor loadings. Consistent with recommendations in psychometric literature, questionnaire items with factor loadings of 0.40 or greater were considered acceptable and retained in the final instrument (Kline, 2016).

The internal consistency of the LATSE and its underlying dimensions was evaluated using Cronbach's alpha coefficient, one of the most widely used measures of reliability for multi-item scales. Cronbach's alpha values of 0.70 or higher were considered indicative of acceptable reliability, while higher values reflected stronger internal consistency among questionnaire items (Cronbach, 1951; DeVellis, 2016). Overall, these statistical procedures provided comprehensive evidence regarding the validity and reliability of the developed instrument and supported its use for assessing laboratory teaching practices and instructional challenges in chemistry education.

RESULTS

Exploratory factor analysis

The construct validity of the Laboratory Assessment Tool for Science Educators (LATSE) was examined using exploratory factor analysis. The analysis was conducted using IBM SPSS Statistics version 24, with principal component analysis as the extraction method and Varimax rotation with Kaiser normalization to obtain a more interpretable factor structure. Questionnaire items with factor loadings of 0.40 or higher were retained for interpretation. All items included in the final instrument met this minimum loading criterion.

Table 2. Factors loading, eigen values and percentage of variance Explained of LATSE

Item no.	Factor loadings		
	1	2	3
Part II and IV TP 1			.432
TP 2	.701		
TP 3	.563		
TP 4	.572		
TP 5	.602	.562	
TP 6			
TP 7	.644		
TP 8	.731		
TP 9		.547	
TP 10	.494		
TP 11	.578		
TP 12	.560		
TP 13	.539	.529	
TP 14			
TP 15		.680	
TP 16		.620	
TP 17		.640	
TP 18		.625	
TP 19	.587		
TP 20	.710		
TP 21	.521		
TP 22	.761		
TP 23	.665	.539	
TP 24			
TP 25	.452		
TP 26	.606	.638	
TP 27			
TP 28		.631	
TP 29		.688	
TP 30		.558	
TP 31	.572		
TP 32		.629	
TP 33			
TP 34	.615	.586	
TP 35	.664		.653
AP 1			
AP 2			.904
AP 3			.567
AP 4			.749
AP 5			.760
AP 6		.666	.610
AP 7			
AP 8		.519	
AP 9			.438
AP 10			.559
AP 11		.592	
Part III TC 1		.683	
TC 2		.621	
TC 3		.666	
TC 4		.765	
TC 5		.727	
TC 6		.674	
TC 7		.559	
TC 8		.663	
TC 9	.679	.585	
TC 10			
TC 11	.669		
TC 12	.723		
TC 13	.681		
TC 14	.637		
TC 15	.684	.478	
TC 16			
TC 17	.669		
TC 18	.816		
TC 19	.783		
TC 20	.640		
TC 21	.736		
TC 22	.730		
TC 23	.847		
TC 24	.797		
TC 25	.826		
Eigen values Part II and IV	21.135	2.939	2.053
Part III % variance	13.975	2.064	
Part II and IV	22.444%	44.219%	56.796%
Part III	37.670%	64.155%	

The suitability of the data for factor analysis was assessed using the Kaiser–Meyer–Olkin measure of sampling adequacy and Bartlett's test of sphericity. For Parts II and IV, the KMO value was 0.652, whereas Part III yielded a KMO value of 0.863. Bartlett's test of sphericity was statistically significant for both analyses (df= 1035, $p < 0.001$ for Parts II and IV; df= 300, $p < 0.001$ for Part III), confirming that the correlation matrices were suitable for factor extraction.

The analysis identified three factors for Parts II and IV, accounting for 56.796% of the cumulative variance. Two factors were extracted for Part III, explaining 64.155% of the total variance. Across the five retained factors, the eigenvalues ranged from 1.172 to 21.135. The factor loadings, eigenvalues, and percentages of explained variance for the retained questionnaire items are presented in Table 2.

Table 3. Reliability values of laboratory assessment tool for science educators

Factors	Reliability coefficient (Cronbach's Alpha)	Number of items
1	.952	20
2	.945	17
3	.874	9
4	.964	15
5	.903	10

The retained items had factor loadings ranging from 0.432 to 0.904. All items exceeded the predetermined cut-off value of 0.40. Although several items showed cross-loadings, each retained item had a satisfactory loading on its primary factor.

Reliability analysis

The internal consistency of the Laboratory Assessment Tool for Science Educators was evaluated using Cronbach's alpha coefficient. The reliability estimates for the five factors are presented in Table 3.

Factor 1 obtained a Cronbach's alpha coefficient of 0.952 based on 20 items, while Factor 2 yielded a coefficient of 0.945 based on 17 items. Factor 3, consisting of nine items, produced a Cronbach's alpha coefficient of 0.874. Factor 4 achieved a coefficient of 0.964 across 15 items, whereas Factor 5 obtained a coefficient of 0.903 based on 10 items.

The final instrument retained 71 questionnaire items and achieved an overall reliability coefficient of α = 0.930. Parts II and IV retained three factors consisting of 20, 17, and 9 items, respectively, while Part III retained two factors consisting of 15 and 10 items, respectively. The reliability coefficients for all five factors ranged from 0.874 to 0.964.

DISCUSSION

The present study aimed to develop and validate the Laboratory Assessment Tool for Science Educators (LATSE) as a comprehensive instrument for assessing the instructional practices and challenges encountered by chemistry educators in laboratory settings. The findings provide strong evidence that the LATSE possesses satisfactory content validity, construct validity, and internal consistency reliability. Collectively, these psychometric properties indicate that the instrument is appropriate for evaluating multiple dimensions of laboratory instruction and can serve as a useful resource for educational practice and research.

One of the major findings of this study is the successful development of a multidimensional instrument that extends beyond the initial conceptual framework. Although the questionnaire was originally developed around three broad domains-teaching practices, teaching challenges, and assessment practices-the exploratory factor analysis identified a more refined five-factor structure consisting of Instructional Design and Delivery, Classroom and Laboratory Management, Assessment and Feedback, Teaching Resources and Support, and Supervision and Safety Management. This finding suggests that laboratory instruction is a multidimensional construct that cannot be fully explained by only a few broad categories. Instead, effective laboratory teaching involves several interconnected aspects of instructional practice, classroom organization, assessment, safety, and resource management. Similar observations have been reported in instrument development studies, where empirical factor analysis often reveals a more nuanced structure than the original theoretical model, thereby improving the interpretability and usefulness of educational measurement instruments.

The construct validity of the LATSE was further supported by the exploratory factor analysis. The acceptable KMO values, statistically significant Bartlett's tests of sphericity, satisfactory cumulative percentages of explained variance, and factor loadings exceeding the recommended threshold of 0.40 demonstrate that the retained items adequately represented their respective latent constructs. These findings are consistent with established psychometric recommendations that emphasize the importance of examining structural validity before interpreting instrument scores (DeVellis, 2016; Kline, 1994). Recent chemistry education research has similarly emphasized that evidence of structural validity is fundamental to ensuring that questionnaire scores meaningfully represent the intended educational constructs (Stains *et al.*, 2018).

Another important finding is the excellent internal consistency demonstrated by the LATSE. The overall Cronbach's alpha coefficient (α= 0.930) and the subscale coefficients ranging from 0.874 to 0.964 indicate that the questionnaire items consistently measure their respective constructs. These reliability estimates exceed the minimum values generally recommended for educational research and instrument development, suggesting that the LATSE can produce stable and dependable measurements across its different dimensions. Although Cronbach's alpha remains one of the most widely reported indices of internal consistency, recent psychometric literature recommends interpreting alpha alongside evidence of construct validity rather than relying on reliability coefficients alone. The present study follows this recommendation by integrating content validation, exploratory factor analysis, and reliability assessment into the instrument development process.

The findings also provide empirical support for the constructivist perspective that underpinned the development of the instrument. Piaget's Theory of Constructivism emphasizes that meaningful learning occurs through active engagement, exploration, collaboration, and reflection (Muijs and Reynolds, 2011). The five factors identified through the exploratory factor analysis closely reflect these principles. For example, Instructional Design and Delivery and Assessment and Feedback emphasize inquiry-oriented teaching and formative assessment, whereas Classroom and Laboratory Management and Supervision and Safety Management address the supportive learning environments necessary for effective laboratory experiences. This alignment between the theoretical framework and the empirically derived factor structure strengthens the conceptual foundation of the LATSE and suggests that the instrument adequately captures key characteristics of constructivist laboratory instruction.

The present findings are also consistent with previous research highlighting the central role of laboratory instruction in science education. Hofstein and Lunetta (2004) argued that well-designed laboratory experiences promote conceptual understanding, scientific reasoning, and inquiry skills when supported by effective instructional practices. Similarly, Burke *et al.* (2006) emphasized that meaningful laboratory learning depends not only on experimental activities but also on instructional design, assessment, and student engagement. The dimensions identified in the LATSE correspond closely with these essential elements, suggesting that the instrument captures practices recognized in the literature as critical to successful laboratory teaching. Furthermore, recent studies in chemistry education continue to emphasize the importance of developing psychometrically sound instruments for evaluating laboratory learning environments and instructional effectiveness.

From a practical perspective, the LATSE offers several potential applications for chemistry education. First, it provides educators with a structured means of reflecting on their instructional practices and identifying areas requiring improvement. Second, school administrators and curriculum developers may use the instrument to evaluate professional development needs related to laboratory instruction, assessment practices, laboratory management, and safety. Third, the instrument may serve as an evaluation tool for teacher education programs by providing systematic evidence of laboratory teaching competencies among pre-service and in-service science educators. Because the questionnaire addresses both instructional practices and instructional challenges, it also enables institutions to identify contextual factors that may hinder effective laboratory teaching, thereby supporting evidence-based educational planning and resource allocation.

Despite these encouraging findings, several considerations should be acknowledged when interpreting the results. The pilot testing was conducted with a relatively limited sample of prospective science and chemistry teachers, primarily because of constraints in participant availability and the study period. Although the exploratory factor analysis produced an interpretable and theoretically meaningful factor structure, larger and more diverse samples would provide stronger evidence regarding the stability and generalizability of the identified dimensions. Contemporary guidelines for educational measurement recommend that newly developed instruments undergo additional validation in independent populations and educational contexts before widespread implementation. Such cross-validation would help determine whether the five-factor structure identified in the present study remains consistent across different institutions and respondent groups.

Future research should therefore focus on extending the validation of the LATSE through larger multicenter samples and confirmatory factor analysis (CFA) to verify the stability of the five-factor model identified in this study. Additional evidence regarding convergent validity, discriminant validity, criterion-related validity, and measurement invariance across different educational settings would further strengthen the psychometric foundation of the instrument. Such investigations would enhance confidence in the LATSE as a standardized assessment tool for evaluating laboratory instruction in science education.

Overall, the findings demonstrate that the Laboratory Assessment Tool for Science Educators (LATSE) is a psychometrically sound instrument with strong evidence of content validity, construct validity, and internal consistency. The identified five-factor structure provides a comprehensive representation of laboratory teaching practices and instructional challenges, while the high reliability coefficients indicate consistent measurement across all dimensions. These results support the use of the LATSE as a practical and evidence-based instrument for evaluating and improving chemistry laboratory instruction in both secondary and tertiary educational settings.

CONCLUSION

The Laboratory Assessment Tool for Science Educators (LATSE) was successfully developed and validated as a reliable and valid instrument for assessing laboratory teaching practices and instructional challenges in chemistry education. The findings demonstrated strong content validity, a stable five-factor structure, and high internal consistency, indicating that the instrument effectively measures key dimensions of laboratory instruction.

The LATSE provides educators, researchers, and curriculum developers with a practical tool for evaluating instructional practices, identifying areas for improvement, and supporting evidence-based professional development. Future studies involving larger and more diverse samples are recommended to further validate the instrument and enhance its applicability across different educational settings.

Recommendations

Future studies should validate the Laboratory Assessment Tool for Science Educators (LATSE) using larger and more diverse samples across different educational settings. Further psychometric evaluation, including confirmatory factor analysis and additional validity testing, is recommended to strengthen the instrument's generalizability and applicability in science education research.

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