Journal of Studies in Science and Mathematics Education
ISSN: 2630-662x
Published: 31.08.2026
Volume (issue): *6*(2)
Page: 25–36

Psychometric Evaluation of the Chemistry Teachers' Instructional Practices Scale using Confirmatory Factor Analysis

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Abstract

This study examined the psychometric properties of the Chemistry Teachers' Instructional Practices Scale (C-TIPS), an adapted instrument designed to assess pre-service chemistry teachers' perceptions of their teachers' instructional practices. A cross-sectional survey design was employed with 247 400-level pre-service chemistry teachers from three federal universities in Northwest Nigeria. Although C-TIPS was theoretically conceptualised across three dimensions – clarity of instruction, cognitive activation, and classroom management. The hypothesised three factor model yielded an inadmissible latent covariance matrix, with some standardised correlations exceeding 1.00, indicating that the dimensions were not empirically distinguishable in the sample. Consequently, a one-factor model was tested and demonstrated excellent fit ($\chi^2/df = 1.41$, CFI = .98, TLI = .97, RMSEA = .046, SRMR = .05). The 12-item scale also demonstrated high internal consistency ($\omega = .858$) and an approximate average variance extracted (AVE) of .53. These findings provide preliminary evidence for the factorial validity and reliability of C-TIPS as a measure of perceived chemistry teachers' instructional practices. Further validation with larger and more diverse samples and additional sources of validity evidence is recommended.

Keywords: chemistry education, teachers' instructional practices, psychometric evaluation, confirmatory factor analysis, pre-service chemistry teachers

1 Introduction

The quality of education, particularly science education, remains an important concern among educators and policymakers because of the role of science in individual development, technological advancement, and national development. Science is the systematic study of the natural world through observation, investigation, experimentation, and analysis to develop knowledge and explanations of natural phenomena (Gizaw & Sota, 2023; Lederman & Lederman, 2019). The scientific process involves understanding and interpreting observed phenomena, predicting unobserved phenomena, and evaluating the outcomes of subsequent investigations and experiments (Psillos et al., 2026; Sakliressy et al., 2021). Through observation, questioning, hypothesis formulation, prediction, data collection, and analysis, science contributes to the development of knowledge and technological advancement. Among the major branches of science, chemistry occupies a central position because it focuses on the composition, structure, properties, and transformations of matter. Its principles underpin practical applications in pharmaceuticals, agriculture, food processing, environmental management, and other sectors of national development (Adedokun & Ogungbesan, 2024; Ozoji et al., 2022).

Chemistry is therefore a pivotal science subject and plays an important role in technological and industrial development. Often described as the central science, chemistry connects disciplines such as physics, biology, and environmental science by providing fundamental principles for understanding the behaviour and transformation of matter (Andrews et al., 2022). The study of chemistry provides the scientific foundation for innovations in pharmaceuticals, agriculture, energy, manufacturing, and other areas of societal development (Organisation for Economic Co-operation and Development, 2022; UNESCO, 2022). Within education, chemistry also contributes to the development of students' analytical, reflective, critical-thinking, creativity, problem-solving, and scientific-literacy skills, which are essential for participation in Science, Technology, Engineering, and Mathematics (STEM) fields (Kusuma et al., 2026; Tartiyoso, 2025). Consequently, the quality of chemistry teaching is an important consideration in efforts to prepare learners with the knowledge and skills required to address contemporary scientific and technological challenges.

Chemistry teachers play a crucial role in shaping and facilitating students' learning experiences in chemistry classrooms. Their responsibilities include organising learning activities, explaining abstract chemical concepts, providing guidance and feedback, stimulating critical thinking and problem solving, managing classroom activities, and creating learning environments that support meaningful engagement with chemistry. The quality of these activities is particularly important because chemistry involves abstract concepts and requires learners to establish relationships between theoretical knowledge, observable phenomena, and practical applications. The ways in which teachers organise and enact these activities in the classroom are commonly discussed in the literature under the broader concept of teacher instructional practices. Depaepe and König (2018) describe teacher instructional practices as the sum total of happenings in the classroom. Similarly, instructional practices have been recognized as important mechanisms through which teachers facilitate students' understanding, engagement, and performance in science education (Zakariya & Adegoke, 2024).

The importance of teacher instructional practices has become increasingly prominent because contemporary education systems are expected to prepare learners not only to acquire disciplinary knowledge but also to develop critical thinking, problem-solving, communication, collaboration, creativity, and innovation. Research has consequently examined classroom instructional practices for their capacity to facilitate these competencies among students (Larsen & Jang, 2021; Ofem et al., 2024; Zakariya & Adegoke, 2024). The quality of teachers' instructional practices may also be influenced by teachers' internal motivation and professional dispositions, which can affect the selection and implementation of instructional approaches. When teachers employ effective instructional practices, students may be more likely to engage meaningfully with learning activities and develop the knowledge and skills required for academic and professional development. Conversely, ineffective instructional practices may constrain students' opportunities for meaningful engagement and conceptual understanding. There is growing empirical evidence that teachers' instructional practices are associated with students' cognitive and academic outcomes. Effective instructional practices have been found to improve student engagement and academic performance (Öncü & Bıchelmeyer, 2021). Similarly, Liou and Jessie Ho (2018) and Daniel et al. (2024) established relationships between instructional practices and students' approaches to learning, motivation, and academic performance. In chemistry education, these relationships are particularly important because students are required to understand complex and abstract concepts and apply scientific principles to problem-solving situations. Mukagihana et al. (2022), for example, reported that effective instructional practices positively influence the performance of pre-service chemistry teachers. These findings suggest that the quality of classroom instruction may contribute substantially to how effectively learners acquire, process, and apply chemistry knowledge.

Beyond cognitive and academic outcomes, teacher instructional practices have also been associated with students' motivational and learning-related experiences. Instructional practices influence students' engagement with learning tasks and may shape the approaches they adopt when acquiring and processing knowledge (Hajian, 2019; Singh, 2025). Approaches to learning generally refer to the strategies and orientations students adopt in acquiring, processing, and applying knowledge and are commonly discussed in terms of deep and surface approaches (Asikainen & Gijbels, 2017; Biggs, 2012; Dejene et al., 2018; Zakariya et al., 2020). Students who adopt deep approaches seek meaningful understanding, make connections between concepts, and actively engage with learning tasks (Zakariya, 2023), whereas surface approaches are associated more strongly with memorisation and limited conceptual engagement (Lindblom-Ylänne et al., 2019). In chemistry, students adopting deeper approaches to learning have been reported to perform better because they actively engage with subject matter and establish connections between theoretical concepts and real-world applications (Negash et al., 2022). These findings reinforce the importance of instructional practices that promote meaningful engagement, conceptual understanding, and active participation in chemistry learning.

Despite the recognised importance of teachers' instructional practices, a significant concern relates to how these practices should be conceptualised and measured across different subject contexts. One perspective treats instructional practices as general classroom processes that can be assessed across different subjects and educational settings. From this perspective, dimensions such as instructional clarity, cognitive activation, and classroom management represent broad characteristics of effective teaching that are relevant regardless of the discipline being taught (Chen, 2023; Jerrim et al., 2025). This general approach has the advantage of facilitating comparisons of instructional practices across subjects, institutions, and educational contexts. A contrasting perspective suggests that the measurement of instructional practices should account for the specific characteristics of the subject in which teaching occurs. This position is particularly relevant to chemistry because effective chemistry teaching involves distinctive disciplinary demands. Chemistry teachers are required to facilitate students' understanding of abstract and complex concepts, support connections between theoretical principles and observable chemical phenomena, promote scientific reasoning and problem solving, and, where applicable, organise practical and laboratory-based learning experiences (Ralph et al., 2022). Consequently, although broad dimensions of instructional quality may be relevant across subjects, their classroom enactment may vary according to the disciplinary context. An instructional practice considered effective in one subject may therefore require contextual adaptation to adequately capture how it operates in another.

The hypothesised dimensions are also consistent with established frameworks of instructional quality. Research on the Three Basic Dimensions framework identifies classroom management and cognitive activation as core dimensions of instructional quality, while the broader teaching-quality literature distinguishes clarity of instruction as a related practice dimension. In the TALIS framework, clarity of instruction, cognitive activation, and classroom management are operationalised as distinct groups of teacher practices, including setting learning goals, connecting new and old topics, presenting cognitively challenging tasks, and maintaining an orderly classroom (Klieme et al., 2009; OECD, 2019). This framework therefore provides a theoretical and empirical rationale for initially testing the three-dimensional structure of the adapted C-TIPS, while allowing the CFA to determine whether the dimensions remain empirically distinguishable in the chemistry education context.

The issue of subject specificity is particularly important when instruments developed for general educational contexts are adapted for use in chemistry education. An instrument that measures instructional practices in general terms may provide useful information about broad teaching behaviours but may not fully capture how such behaviours are manifested in chemistry classrooms. For example, cognitive activation in chemistry may involve encouraging students to reason about chemical phenomena, develop alternative solutions to chemistry problems, connect theoretical concepts with practical applications, and engage in scientific inquiry. Similarly, instructional clarity in chemistry may involve helping students understand relationships among different chemistry concepts, while effective classroom management may be particularly important when teachers organise practical activities and laboratory-based learning. Therefore, adapting a general measure to the chemistry context may enhance its contextual relevance while retaining the underlying dimensions of instructional quality. However, adapting an existing instrument to a new subject context and respondent population raises important psychometric considerations. Validity and reliability evidence established for an original instrument cannot automatically be assumed to remain applicable following adaptation. Changes in item wording, response format, subject context, and respondent perspective may influence how respondents interpret the items and how the items relate to their underlying constructs. This is particularly important when an instrument developed to capture teachers' self-reported instructional practices is adapted to assess students' perceptions of their teachers' instructional practices. Consequently, empirical evaluation is necessary to determine whether the adapted instrument adequately represents the intended dimensions of instructional practices and provides reliable measurement within the new context.

The present study therefore focuses on the adaptation and psychometric evaluation of the C-TIPS from its original mathematics form (Zakariya, 2024). The 2024 source is an unpublished conference presentation rather than a peer-reviewed journal article and is therefore treated here as the immediate documentation of the M-TIPS adaptation, not as the sole basis for the validity of the underlying instructional-practices construct. The underlying item content and three-domain operationalisation are also supported by peer-reviewed research using the same instructional-practices measure and by the OECD/TALIS framework from which the practice indicators were derived (OECD, 2019; Zakariya & Adegoke, 2024). The present adaptation contextualises the measurement of instructional practices within chemistry education while retaining the core dimensions of clarity of instruction, cognitive activation, and classroom management. Because the parent M-TIPS report is not a peer-reviewed validation article, the psychometric evidence reported in the present study is interpreted as preliminary and specific to the current sample. The study is guided by the following research questions:

1. Does the hypothesised 3-factor measurement model of the adapted C-TIPS adequately fit the observed data?
2. What is the reliability estimate of the C-TIPS?

The study contributes to research on teacher instructional practices by providing psychometric evidence for a chemistry-contextualised measure of instructional practices. By evaluating the psychometric properties of the adapted C-TIPS, this study provides evidence that may support its use in future research examining chemistry teachers' instructional practices and their relationships with learning and professional outcomes among pre-service chemistry teachers.

2 Methodology

2.1 Participants

The study employed a cross-sectional survey design in which data were collected from pre-service chemistry teachers at a single point in time. The target population comprised 400-level undergraduate pre-service chemistry teachers enrolled in Chemistry Education programmes in federal universities in Northwest Nigeria. The participants were selected because they were in the final stage of their teacher education programme and had received substantial exposure to chemistry content, pedagogical training, and classroom instructional practices. Consequently, they were considered sufficiently experienced to provide informed perceptions of the instructional practices employed by their chemistry teachers. The accessible population comprised 247 400-level pre-service chemistry teachers from three selected federal universities in Northwest Nigeria. The three institutions were selected from federal universities offering Chemistry Education programmes in the region. The participants included 157 males and 90 females, giving a total sample of 247 pre-service chemistry teachers. Participation in the study was voluntary, and only participants who provided informed consent were included in the study.

2.2 Instrument

The instrument used in this study was the Chemistry Teachers' Instructional Practices Scale (C-TIPS), adapted from the Mathematics Teachers' Instructional Practices Scale (M-TIPS) developed by Zakariya (2024). The original M-TIPS comprises three dimensions: clarity of instruction, cognitive activation, and classroom management. Each dimension consists of four items, resulting in a 12-item instrument. In the chemistry-specific adaptation, clarity of instruction refers to instructional practices through which chemistry teachers communicate learning goals, explain expected learning outcomes, summarize recently learned chemistry content, and establish connections between new and previously learned chemistry topics. Cognitive activation refers to instructional practices that engage students in cognitively challenging chemistry tasks that require critical thinking, problem solving, collaboration, and the development of independent procedures for addressing complex chemistry tasks. Classroom management encompasses practices through which chemistry teachers establish and maintain an orderly classroom environment, manage disruptive behaviour, and sustain students' attention during chemistry instruction (Zakariya, 2024).

The immediate psychometric documentation for the original M-TIPS is Zakariya (2024), an unpublished conference presentation reporting data from 288 first-year engineering students at Ahmadu Bello University, Nigeria. The conference report is not a peer-reviewed journal publication and should therefore be interpreted as preliminary documentation of the M-TIPS rather than as definitive independent validation evidence. Additional peer-reviewed evidence is available from Zakariya and Adegoke (2024), who used the same instructional-practices measure and explicitly described the three dimensions of clarity of instruction, cognitive activation, and classroom management. The measure was itself derived from the OECD/TALIS instructional-practices framework, which provides published evidence and conceptual support for these practice domains (OECD, 2019). The present study therefore extends the available evidence by examining the factorial structure and reliability of a chemistry-contextualised, student-perception version of the scale. The adaptation involved one major modification: changing the disciplinary context from mathematics to chemistry. Accordingly, references to mathematics teaching, learning, content, and tasks in the original M-TIPS were modified, where necessary, to reflect chemistry teaching and learning contexts. The adaptation was intended to preserve the original structure, dimensions, and substantive meaning of the instrument while ensuring that the items were relevant to chemistry education. Thus, the adapted C-TIPS retained the three original dimensions clarity of instruction, cognitive activation, and classroom management as well as the 12-item structure of the M-TIPS. Only subject-specific terminology and contextual references were modified to reflect chemistry rather than mathematics.

Following the adaptation, the C-TIPS underwent face and content validation by experts in Science Education and Educational Psychology. Each expert possessed a minimum qualification of a PhD and reviewed the items for clarity, relevance, appropriateness, and adequacy in representing the construct of chemistry teachers' instructional practices. The experts' comments and recommendations informed revisions to items considered ambiguous, unclear, or insufficiently aligned with the intended construct. The expert review was conducted to determine whether the adapted items adequately represented the construct while maintaining contextual relevance to chemistry education and the student-perception format.

The adapted C-TIPS comprised 12 items distributed across the three hypothesised dimensions: clarity of instruction (Items 1–4), cognitive activation (Items 5–8), and classroom management (Items 9–12). Participants indicated how frequently their chemistry teachers demonstrated each instructional practice using a five-point Likert-type frequency scale ranging from Never (1), Rarely (2), Occasionally (3), Frequently (4), to Always (5). Higher scores indicated more frequent perceptions of the specified instructional practices. The response format was modified from the original four-category scale to a five-category frequency scale by introducing the Rarely response category between Never and Occasionally. Given that this modification altered the response structure of the original instrument, the reliability and other psychometric properties of the adapted C-TIPS were re-examined using data obtained from the present study. The revised C-TIPS was subsequently administered in the main study.

Table **1**

Item Distribution and Adaptation of the Chemistry Teachers' Instructional Practices Scale (C-TIPS)

Dimension	Original instructional practice	Adapted chemistry-specific item
Clarity of instruction	They present a summary of recently learned mathematics content.	My chemistry teacher presents a summary of recently learned chemistry content before proceeding with the class.
	They set goals at the beginning of mathematics classes.	My chemistry teacher sets goals at the beginning of the chemistry class.
	They explain what they expect the students to learn in mathematics classes.	My chemistry teacher explains what they expect students to learn in the chemistry class.
	They explain how new and old mathematics topics are related.	My chemistry teacher explains how new and old chemistry topics are related.
Cognitive activation	They present mathematics tasks for which there is no obvious solution.	My chemistry teacher presents chemistry tasks for which there is no obvious solution.
	They give mathematics tasks that require students to think critically.	My chemistry teacher gives chemistry tasks that require students to think critically.
	They have students work in small groups to come up with a joint solution to a mathematics problem or task.	My chemistry teacher asks students to work in small groups and develop a joint solution to a chemistry problem or task.
	They ask students to decide on their own procedures for solving complex mathematics tasks.	My chemistry teacher asks students to decide on their own procedures for solving complex chemistry tasks.
Classroom management	They tell students to follow classroom rules.	My chemistry teacher tells students to follow classroom rules.
	They tell students to listen to what they say.	My chemistry teacher tells students to listen carefully while teaching chemistry.
	They calm students who are disruptive in mathematics classes.	My chemistry teacher calms students who are disruptive in chemistry classes.
	When the lesson begins, they tell students to be quiet quickly.	When the chemistry lesson begins, my chemistry teacher tells students to be quiet quickly.

2.3 Data Collection and Analysis

Data were collected by administering the C-TIPS to 400-level pre-service chemistry teachers in the three participating federal universities. Before data collection, permission was obtained from the relevant authorities of the selected institutions. The purpose of the study was explained to the participants, and informed consent was obtained. The participants were assured that participation was voluntary, their responses would be treated confidentially, and the information provided would be used solely for research purposes. The 247 participants who consented to participate completed the questionnaires using a paper-and-pencil format. The completed questionnaires were collected immediately, screened for completeness, coded, and entered into the statistical software for analysis. The psychometric properties of the C-TIPS were evaluated using Confirmatory Factor Analysis (CFA). A three-factor model comprising clarity of instruction, cognitive activation, and classroom management was hypothesised and evaluated using the Weighted Least Squares Mean and Variance Adjusted (WLSMV) estimator, given the ordinal categorical nature of the response options. Model fit was assessed using the Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). Following Hu and Bentler (1999) and Brown (2015), CFI and TLI values of .90 or higher, RMSEA and SRMR values below .08 were considered acceptable, while CFI and TLI values above .95 indicated excellent fit. Standardised factor loadings and residuals were also examined to assess local model fit. Finally, McDonald's omega (ω) was used to estimate the reliability of the C-TIPS.

3 Results

3.1 Three-Factor Model

To address the first and second research questions, the construct validity of the Chemistry Teachers' Instructional Practices Scale (C-TIPS) was investigated using confirmatory factor analysis (CFA). This was achieved by evaluating the consistency of the hypothesised three-factor model of C-TIPS with the observed data. Table 2 presents the global fit statistics of the hypothesised three-factor model (Model 1) and the respecified one-factor model (Model 2).

Table **2**

Goodness of fit statistics for the three-factor C-TIPS model

Global fit statistic	Model 1	Model 2
χ^2	71.87	76.15
Df	51	54
χ^2/df	1.41	1.41
SRMR	.05	.05
RMSEA	.045	.046
90% CI for RMSEA	[.015, .068]	[.017, .068]
Probability RMSEA ≤ .05	.60	.60
CFI	.98	.98
TLI	.97	.97

Note. Model 1 represents the hypothesised three-factor C-TIPS model, whereas Model 2 represents the retained one-factor C-TIPS model.

The results presented in Table 2 showed that the hypothesised three-factor model of C-TIPS (Model 1) demonstrated an excellent fit with the observed data at the global level. This is evident from the χ^2/df ratio of 1.41, which is below the recommended threshold of 2. The model also yielded an SRMR of .05 and an RMSEA estimate of .045, with a 90% confidence interval ranging from [.015, .068]. The probability of RMSEA ≤ .05 was .60, while the CFI and TLI were .98 and .97, respectively. Collectively, these global fit statistics indicate an excellent fit of the hypothesised three-factor model to the observed data.

Despite the excellent global model fit suggested by the fit indices, the latent variable covariance matrix (PSI) was not positive definite. The standardised factor correlations exceeded 1.00 for each of the three factor pairs; clarity of instruction with cognitive activation, clarity of instruction with classroom management, and cognitive activation with classroom management. These values indicate empirical linear dependency among the latent dimensions and mean that the three factors were not empirically distinguishable in the present sample. The exact pairwise correlation estimates and modification-index output were not retained in the analysis output available for this manuscript; therefore, no numerical values beyond the reported >1.00 estimates are introduced here to avoid fabricating statistics. The respecification was consequently based on the non-positive-definite PSI matrix and the principle of parsimony, rather than on post hoc freeing of cross-loadings or correlated residuals. As such, the three dimensions were collapsed into a single latent factor, and the resulting one-factor model was subjected to further evaluation. The results of this evaluation are reported as Model 2 in Table 2.

3.2 One-Factor Model

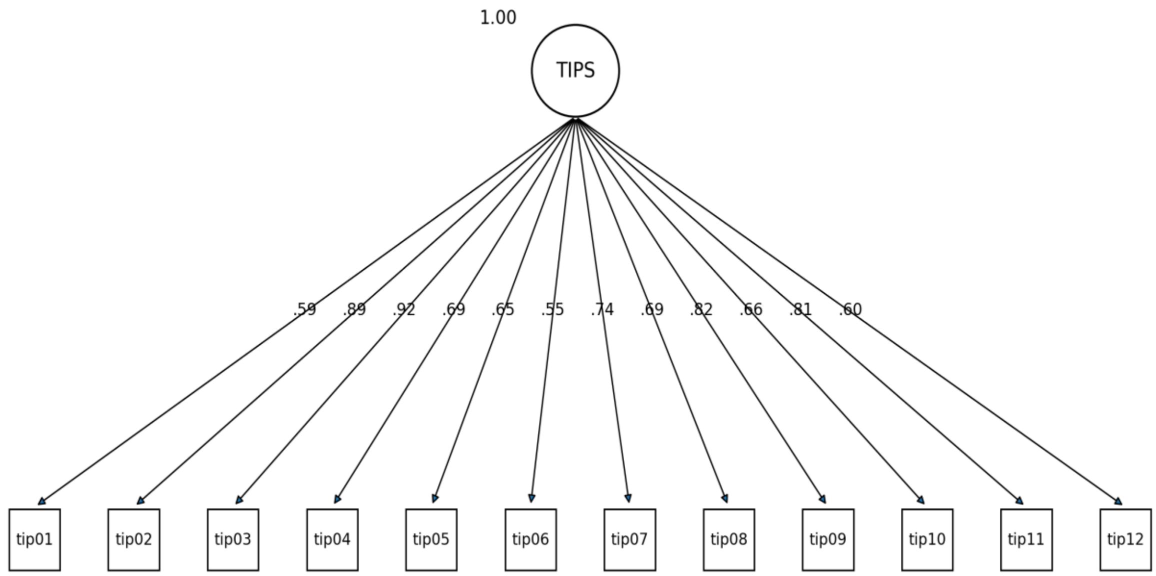
The results presented in Table 2 further showed that the respecified one-factor model of C-TIPS (Model 2) also demonstrated an excellent fit with the observed data. The model yielded a χ^2 value of 76.15 with 54 degrees of freedom, resulting in a χ^2/df ratio of 1.41. The SRMR was .05, while the RMSEA estimate was .046, with a 90% confidence interval ranging from [.017, .068]. The probability of RMSEA ≤ .05 was .60. In addition, the CFI and TLI were .98 and .97, respectively. These results indicate an excellent fit of the one-factor model to the observed data at the global level.

A comparison of Models 1 and 2 revealed that the one-factor model produced virtually identical global fit statistics to the hypothesised three-factor model. The χ^2/df ratio remained unchanged at 1.41, as did the SRMR (.05), CFI (.98), and TLI

(.97). The RMSEA increased only marginally from .045 in Model 1 to .046 in Model 2, with highly comparable 90% confidence intervals. These findings indicate that collapsing the three dimensions into a single latent factor did not result in a meaningful deterioration in the global fit of the model. Importantly, the one-factor model was empirically admissible, as the non-positive-definite latent variable covariance matrix observed in Model 1 was no longer an issue. Therefore, the one-factor model was retained as the final measurement model because it provided a more parsimonious and statistically admissible representation of the C-TIPS data while maintaining an excellent level of global model fit.

Figure **1**

Standardized parameter estimates for the one-factor C-TIPS model



The results presented in Figure 1 show that each item of the C-TIPS measures the general construct of chemistry teachers' instructional practices with moderate to high factor loadings. The lowest factor loading is .55, the highest is .92, and the average factor loading is approximately .72. Based on the standardised loadings shown in Figure 1, the average variance extracted (AVE) is approximately .53, providing preliminary evidence of convergent validity for the retained one-factor solution. Because the retained model contains only one latent factor, discriminant validity among subdimensions is not applicable to the final model. The AVE estimate should be interpreted as approximate because it is calculated from rounded standardised loadings reported in the figure. The factor loadings indicate the strength of the relationship between each item and the general construct of chemistry teachers' instructional practices, addressing the second research question.

3.3 Reliability

The reliability of the one-factor, 12-item C-TIPS was estimated using McDonald's coefficient omega (ω). The reliability coefficient was .858, indicating good internal consistency among the 12 items. This finding suggests that the items consistently measure the broader construct of teacher instructional practices and provides preliminary evidence supporting the reliability of the C-TIPS for use in the present sample.

4 Discussion

The findings of this study provide preliminary empirical evidence regarding the factorial structure and reliability of the Chemistry Teachers' Instructional Practices Scale (C-TIPS) in measuring pre-service chemistry teachers' perceptions of their teachers' instructional practices. The psychometric evidence obtained from the study indicates that C-TIPS has potential as a useful instrument for educational research, particularly for assessing chemistry teachers' instructional practices from the perspective of pre-service chemistry teachers. The confirmatory factor analysis (CFA) results, however, did not support the hypothesised three-factor model comprising clarity of instruction, cognitive activation, and classroom management as empirically distinct dimensions. The latent covariance matrix was not positive definite, and the standardised correlations among the three proposed latent dimensions exceeded unity. Consequently, a one-factor model was examined and demonstrated excellent global fit to the observed data. These findings suggest that, although the three dimensions are theoretically distinguishable and supported by the instructional-quality literature, they were not empirically differentiated by the participants in the present sample. Rather, the 12 items may be interpreted as indicators of a broader construct of perceived chemistry teachers' instructional practices. The result reinforces the importance of empirically validating adapted instruments rather than assuming that the original dimensional structure will remain unchanged across subject areas, respondent groups, and educational contexts.

The reliability analysis using McDonald's omega provided additional support for the measurement quality of the C-TIPS instrument. The omega coefficient for the 12-item scale indicated good internal consistency, suggesting that the items consistently measured the broader construct of chemistry teachers' instructional practices. The approximate AVE of .53, calculated from the reported standardised loadings, also provides preliminary evidence that the retained factor explains more than half of the average variance in the indicators. Nevertheless, this evidence should not be interpreted as comprehensive construct validation. No independent convergent, discriminant, criterion-related, or cross-validation evidence was available in the present study, and discriminant validity is not applicable to the retained one-factor model. The use of coefficient omega is appropriate for estimating reliability where items may contribute unequally to the underlying latent construct and where the assumptions required for coefficient alpha may not necessarily be satisfied (Zakariya, 2022).

The results of this study have several implications for educational practice. Firstly, the C-TIPS may provide researchers and teacher educators with preliminary empirical information about chemistry teachers' instructional practices as perceived by pre-service chemistry teachers. Given the limited and homogeneous sample used in the present validation, however, the instrument should not yet be regarded as universally validated or assumed to function identically across other populations. The importance of assessing instructional practices is underscored by evidence that teachers' classroom practices are associated with students' engagement (Christopher & Newman, 2022), motivation (Liou & Myoung, 2023), approaches to learning, and academic performance (Ajani, 2023; Tomaszewski et al., 2022). C-TIPS therefore offers a potentially useful starting point for examining instructional quality and identifying areas that may require attention in chemistry teacher preparation and professional development. Although clarity of instruction, cognitive activation, and classroom management were not empirically established as independent dimensions in the present study, these aspects remain theoretically important to effective chemistry teaching.

This study contributes to the existing literature by providing preliminary psychometric evidence for a chemistry-contextualised measure of teachers' instructional practices based on the perceptions of pre-service chemistry teachers. C-TIPS contributes to this area by adapting a general instructional-practices framework to the chemistry education context and by shifting the measurement perspective from teacher self-report to pre-service teachers' perceptions of their teachers' practices. This adaptation is particularly relevant to chemistry education because chemistry teaching involves distinctive disciplinary demands, including the interpretation of abstract concepts, the integration of macroscopic, submicroscopic, and symbolic representations, scientific reasoning, problem solving, and practical or laboratory activities. Furthermore, the emergence of a one-factor structure demonstrates that adapting an established instructional-practices framework to a new disciplinary context may result in a different empirical structure from that of the original instrument. The study therefore adds to the discussion on measurement of teacher instructional practices by demonstrating the importance of rigorous psychometric evaluation when established instruments are adapted to new populations and contexts. Within the limits of the present sample, the findings provide preliminary evidence that C-TIPS can be used to assess an overarching construct of chemistry teachers' instructional practices.

While the findings of the study are promising, several limitations should be considered. The sample comprised only 247 400-level pre-service chemistry teachers from three federal universities in Northwest Nigeria. The modest, geographically restricted, and relatively homogeneous sample limits the generalisability and stability of the factor solution and means that the findings should be treated as preliminary rather than definitive evidence of factorial validity. Future research should therefore validate C-TIPS using larger and more diverse samples across different universities, regions, programme levels, and educational contexts to determine whether the one-factor structure is stable. Additionally, the present study relied on pre-service teachers' perceptions of their chemistry teachers' instructional practices rather than direct classroom observations or teachers' self-reports. Future studies could incorporate multiple sources of evidence, including classroom observations and teacher reports, to provide a more comprehensive assessment of instructional practices. Furthermore, although C-TIPS captures three theoretically important aspects of instructional practice, other potentially relevant dimensions of chemistry teaching, such as laboratory instruction, inquiry-based teaching, formative feedback, teacher-student interactions, and the integration of practical activities, were not explicitly assessed. Expanding the scope of the instrument to incorporate additional chemistry-specific instructional practices may provide a more comprehensive measure of instructional quality. Finally, future research should further examine the factor structure of C-TIPS using independent samples and additional validity evidence to establish whether the observed unidimensional structure is specific to the present sample or represents a stable characteristic of the instrument across different populations and educational contexts.

5 Conclusion

This study examined the psychometric properties of the Chemistry Teachers' Instructional Practices Scale (C-TIPS), an adapted measure designed to assess pre-service chemistry teachers' perceptions of their chemistry teachers' instructional practices. Although the instrument was theoretically structured around three dimensions; clarity of instruction, cognitive activation, and classroom management; the hypothesised three-factor solution produced an inadmissible latent covariance structure, indicating that the dimensions were not empirically distinguishable in the present sample. An alternative one-factor model demonstrated excellent fit to the data, suggesting that the 12 items may be interpreted as indicators of a broader construct of perceived chemistry teachers' instructional practices within the population studied. The scale also demonstrated satisfactory reliability, as indicated by a McDonald's omega coefficient of .858.

The findings therefore provide preliminary evidence for the factorial structure and internal consistency of C-TIPS among 400-level pre-service chemistry teachers in three federal universities in Northwest Nigeria. Because the sample was modest, geographically restricted, and relatively homogeneous in terms of programme level and educational context, the findings should not be interpreted as definitive evidence of factorial validity across other populations. The results support the use of C-TIPS primarily as a unidimensional measure in contexts similar to the present sample and caution against interpreting the three theoretically proposed dimensions as statistically independent subscales without further evidence. Future research should replicate the one-factor structure using larger and more diverse samples, report complete factor-correlation and modification-index diagnostics where appropriate, examine measurement invariance across relevant subgroups, and investigate additional sources of validity evidence, including convergent, discriminant, criterion-related, and cross-validation evidence. Further work may also consider expanding the instrument to capture instructional practices that are more distinctive to chemistry education, including laboratory instruction, inquiry-based learning, formative assessment, and the integration of macroscopic, submicroscopic, and symbolic representations.

6 Declarations

Ethical Statements: Ethical approval was obtained from the relevant authorities of the participating federal universities before data collection. Permission was also obtained from the relevant institutional authorities. Participants were informed about the purpose and procedures of the study, and informed consent was obtained before administration of the C-TIPS. Participation was voluntary, and participants were assured that they could withdraw at any time without penalty. Confidentiality of responses was maintained throughout the study, and the data were used solely for research purposes.

Conflict of Interest: The authors declare that they have no financial or non-financial conflicts of interest.

Author Contributions: P.G. conceived and designed the study, coordinated data collection, and drafted the manuscript. Y.F.Z. analysed the dataset and contributed to the interpretation of findings and critical revision of the manuscript. U.R.E. contributed to data collection, interpretation of findings, and critical revision of the manuscript. All authors reviewed and approved the final version of the manuscript and accepted responsibility for the integrity of the work.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgments: The authors acknowledge the relevant authorities and participants of the three participating federal universities for their cooperation and participation in the study. The authors also appreciate the experts who contributed to the validation and adaptation of the research instrument.

Data Availability Statement: The dataset generated and analysed during the current study is not publicly available because it contains participant-level educational research data and is subject to confidentiality and ethical considerations. The data may, however, be made available by the corresponding author upon reasonable request, subject to appropriate ethical and institutional restrictions.

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