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Research Article

Validation Tool for Chemistry Teaching Innovations: Polytomous Rasch, Confirmatory Factor, and Reliability Analyses

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Abstract
The study developed and validated the Chemistry Teaching Innovations Validation (CTIV) tool to meet the changing needs of chemistry teaching and enhance student engagement and understanding. The CTIV tool, built on the ADDIE concept, has five main components: pedagogical approach, content relevance, technology integration, assessment strategies, and teacher support and professional development. Item creation, scale formulation, and scale evaluation were all part of the validation process, including thorough testing for validity and reliability. Seven experts validated the created items, fifteen in-service teachers further improved and verified the items as included in the scale, and 264 in-service teachers participated in the pilot-testing of the revised tool. The CTIV was evaluated using various statistical analyses, including the infit and outfit values, which confirmed its reliability. The robustness of the instrument was validated by strong Cronbach's alpha values and confirmatory factor analysis (CFA), which showed good internal consistency and precise measurement of the desired components. The CTIV tool offers teachers a systematic way to assess and use teaching innovations, guaranteeing conformity to curricular requirements and improving the quality of chemistry education. with the help of this comprehensive validation tool, which connects theory and practice in education, chemistry and science classrooms can become more productive and interesting places to learn.

Keywords: Chemistry, Confirmatory Factor Analysis, Rasch Analysis, Reliability, Teaching Innovations, Validation Tool

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1. INTRODUCTION

Teaching innovations in chemistry are now crucial to meeting students' varied learning needs and the changing demands of the educational landscape. Even though they are fundamental, traditional teaching approaches frequently fall short of holding students' attention and class engagement and providing a thorough understanding of complex chemistry topics (Ayittey et al., 2023; Demelash et al., 2024). As a result, teachers are exploring and adopting new ways of teaching chemistry effectively (Sanchez, 2017; Marchak et al., 2021; Ha, 2022). With the help of these innovations, chemistry teaching could become more dynamic, applicable, and relevant in this ever-changing field of science.

Designing and using innovative strategies, educational resources, and engaging activities are typical developments in chemistry teaching. Inquiry-based learning (e.g., Orosz et al., 2023), flipped classrooms (e.g., Karapinar et al., 2023), problem-based learning (e.g., Li et al., 2023), peer learning (e.g., Taborada & Sanchez, 2020), and contextualized material use (e.g., Rivera & Sanchez, 2020) are innovative strategies that promote critical thinking and active student participation. With the addition of digital tools (e.g., Uyulgan & Akkuzu Güven, 2022), simulations (e.g., Mukama & Byukusenge, 2023), and virtual laboratories (e.g., Alhaslem & Alfailakawi, 2023), instructional materials have also advanced to give students opportunities for experiential learning. Collaborative projects (Adjei et al., 2022), practical experiments (Sanchez et al., 2021; Cerna et al., 2023), multiple macro-micro-symbolic representations (Sanchez, 2018; Sanchez, 2021), and interactive multimedia content (e.g., Guion et al., 2023; Navarette et al., 2023; Cotiangco et al., 2024) are engaging activities that enhance learning and stimulate students' interest in the subject matter.

Although there is much interest in novelty and innovation, as evident in the literature above on chemistry teaching innovations, many strategies are implemented without thorough validation from peers, coordinators, or experts. This lack of validation can result in innovations that might not align with the specific requirements of the chemistry curriculum, the subject matter being taught, or the competencies that students are expected to acquire. Consequently, these unvalidated innovations might fail to meet student learning goals and leave them with gaps in their knowledge and understanding.

With this, a comprehensive tool for validating chemistry teaching innovations before implementation is needed. This instrument would guarantee that novel and innovative strategies, resources, and activities are carefully examined for their educational value and alignment with the chemistry curriculum. By offering a systematic validation approach, teachers ensure that their teaching innovations are well-founded, well-designed, and capable of improving student learning outcomes, as evident in other fields of education (Turrado-Sevilla & Cantón-Mayo, 2022; Otter & Wopereis, 2023).

This present study developed and validated a tool for validating chemistry teaching innovations that follow the iterative approach of the ADDIE model. This model highlights the significance of validation at every phase of the development process, including the stages of analysis, design, development, implementation, and evaluation (Aldoobie, 2015; Sahaat et al., 2019; Moral et al., 2023). Using the model's iterative nature, the study aimed to develop a validation tool that teachers use to thoroughly evaluate the design and development of their teaching innovations before implementing them. Assessments conducted before or after implementation could further guarantee these innovations' effectiveness and ongoing improvement.

The instrument's development and validation could significantly impact science and chemistry education. It could give teachers a dependable way to ensure that their innovative lessons align with educational standards and appropriate pedagogy. This could help improve Science education and learning outcomes and raise the caliber of chemistry instruction. The study aimed to bridge the gap between educational theory and classroom practice by building a solid framework for validating teaching innovations and facilitating the development of a more effective and engaging learning environment for students.

2. METHODS

As Boateng et al. (2018) recommended, the study followed the three phases of instrumentation: item development, scale development, and scale evaluation.

2.1. Item Development

The research process started with creating a validation instrument for innovations in chemistry teaching based on a comprehensive literature study. The pedagogical approach (PA) (Aris et al., 2024), content relevance (CR) (Üce & Ceyhan, 2019), technology integration (TI) (Yesgat et al., 2023), assessment strategies (AS) (Dolin & Evans, 2018; Opateye & Ewim, 2021), and teacher support and professional development (TSPD) (Asiyah et al., 2021) are the five critical elements that this review highlighted as being essential for validating innovations. Each component consists of five indicators that thoroughly assess the effectiveness and quality of innovative teaching strategies, guaranteeing that they meet academic requirements and significantly improve student learning opportunities.

Seven experts in professional education, chemistry education, and innovation evaluated the created items for comprehensiveness, clarity, and relevance as part of the validation process. Their input was crucial in helping to improve the tool and ensure its reliability and competence in assessing innovations in chemistry education.

2.2. Scale Development

The items created during the first item development stage were further improved and verified throughout the scale development phase. Fifteen in-service chemistry teachers were selected as a small sample and given the first set of developed items. Certain necessary rephrasing and revisions were made throughout the pilot testing phase to improve clarity and relevance, resulting in a more robust Chemistry Teaching Innovation Validation (CTIV) tool.

After the changes, 264 in-service chemistry teachers, a more extensive sample, were given the revised CTIV instrument. Clark and Watson (1995) stressed the significance of a suitably big sample to guarantee successful scale development and validation. The tool's administration to this larger group ensured it could be successfully extended across various instructional settings by providing an extensive dataset for examination later.

Polytomous Rasch analysis, an advanced statistical technique for improving and validating measuring devices, was then employed for item reduction. This investigation determined the products that match well with each CTIV tool component. Bond and Fox (2013) deem items with infit and outfit values of more than 0.40 but less than 1.60 acceptable. This standard ensured that every item accurately measured the intended criterion and added to the tool's overall validity and reliability.

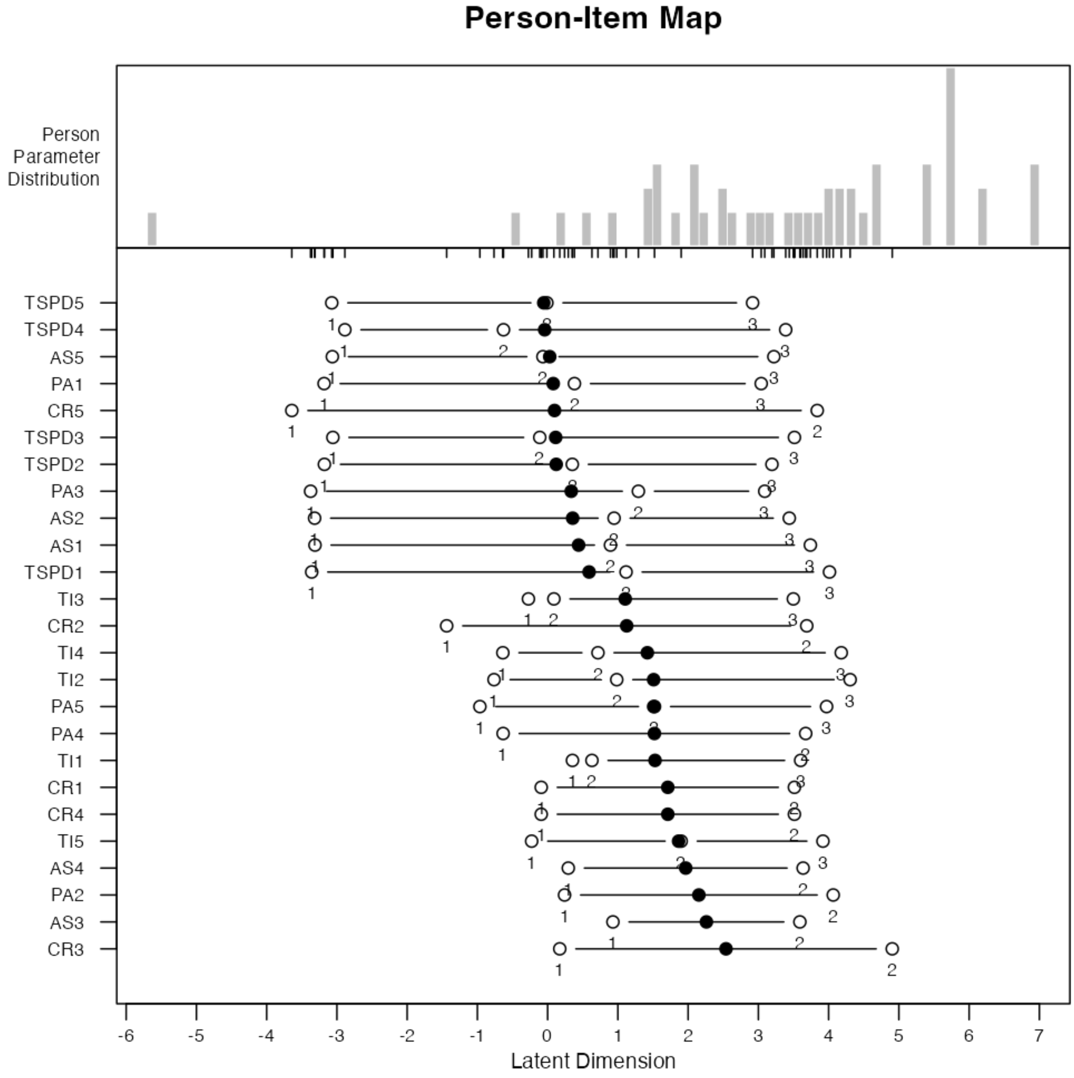

Figure 1. Pearson-Item Map of the CTIV Tool

2.3. Scale Evaluation

The CTIV tool received extensive confirmatory analysis during the scale evaluation phase to guarantee validity and reliability. Confirmatory factor analysis (CFA) confirmed the suggested scale item structure. This statistical method is essential for determining whether the data conforms to the proposed measurement model and assessing the tool's construct validity. Some significant indices were used to evaluate the model's fit. A comparative fit index (CFI) of 0.95 or higher showed an acceptable fit between the model and the observed data. Additionally, the requirement that the Tucker-Lewis index (TLI) be at least 0.95 supports the model's robustness. The root mean square error of approximation (RMSEA) of 0.06 or less indicates a close fit between the model and the degrees of freedom. By following Brown's (2014) recommendations, these standards guaranteed that the model captured the underlying structure of the data.

A further essential element of the scale evaluation process was reliability testing. The internal consistency of the scale items was evaluated using Cronbach's alpha, a measure of how well a set of items is positively linked. Cronbach (1951) states that appropriate reliability is suggested by alpha values between 0.70 and 0.80, which show that the items are sufficiently consistent in measuring the same construct. Good reliability is indicated by values between 0.80 and 0.90, suggesting high internal consistency between the items. Excellent reliability is shown by values of 0.90 and above, which denotes very high measurement consistency among the scale items.

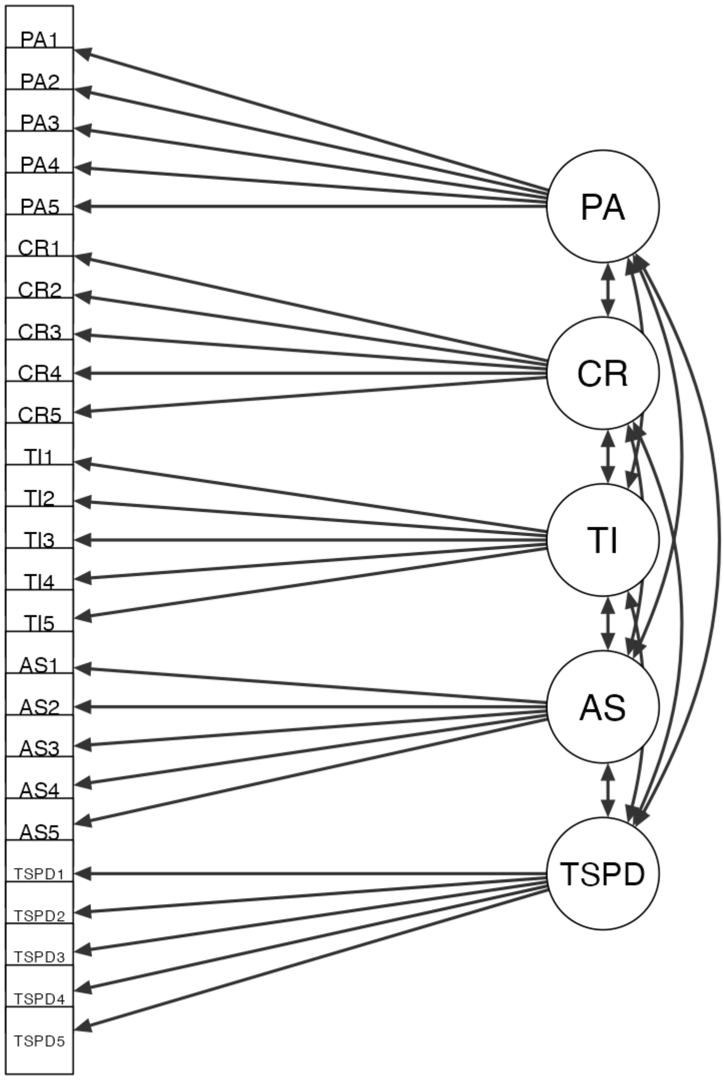

Figure 2. Path Diagram of the CTIV Items

3. RESULTS

3.1. Infit and Outfit Values

According to the results, every item in the CTIV fits within the infit and outfit values, which range from 0.40 to 1.60, as Bond and Fox (2013) suggested. As a result, every item is accepted, demonstrating the validity and reliability of the tool used to validate chemistry teaching innovations. This indicates that PA, CR, TI, AS, and TSPD can effectively measure the desired components. As supported by the Pearson-item map in Figure 1, the CTIV can effectively capture the complex features of chemistry teaching innovations.

3.2. Factor Loadings and Model Fit

According to the CFA results, all items in the CTIV show high and statistically significant factor loadings on their respective constructs, ranging from 0.434 to 0.809 ($p < .001$). The loading of the items for PA ranges from 0.434 to 0.699, while CR items load between 0.44 and 0.54; TI items load between 0.451 and 0.809; AS items load between 0.513 and 0.68; and TSPD items load between 0.564 and 0.627. With all items accurately measuring their intended dimensions in the CTIV, the CFA confirms the tool's validity, as illustrated in the path diagram in Figure 2.

The model fit indices comply with Brown's (2014) criteria, with fit indices such as RMSEA (0.019), TLI (0.979), and CFI (0.917) falling within the acceptable ranges for a good match between the observed data and the model. This indicates that while assessing chemistry innovations in education, the validation instrument successfully captures the targeted constructs of PA, CR, TI, AS, and TSPD.

3.3. Cronbach's Alpha Values

The Cronbach's alpha values of the aspects of the CTIV are presented in Table 1.

Table 1. Cronbach's Alpha Values of CTIV Aspects

Aspect	Cronbach's alpha	Interpretation
PA	0.900	Excellent
CR	0.901	Excellent
TI	0.918	Excellent
AS	0.927	Excellent
TSPD	0.945	Excellent

Every aspect obtained Cronbach's alpha values over 0.90, showing excellent reliability across all dimensions (Cronbach, 1951). This indicates good measurement consistency among the scale items and high internal consistency between the items within each aspect, as evident in other published research tools in science education (e.g., Gaylan et al., 2024). These strong reliability coefficients assure the CTIV tool's consistency and dependability since they show that each aspect's items consistently measure the same underlying concept. Based on these findings, no items of the CTIV tool seem to have reliability issues.

3.4. Finalized CTIV Tool

After a thorough three-phase instrumentation, the finalized CTIV tool with five aspects and 25 items is presented below.

3.4.1. Pedagogical Content

This aspect refers to the instructional methods and strategies teachers employ to facilitate learning in the classroom.

1. The innovation encourages student-centered learning.
2. The innovation promotes inquiry-based learning in chemistry.
3. The innovation effectively integrates hands-on activities into chemistry instruction.
4. The innovation facilitates the development of critical thinking and problem-solving skills.
5. The innovation supports differentiated instruction to meet diverse student needs.

3.4.2. Content Relevance

This aspect pertains to aligning instructional materials, activities, and assessments with the objectives of the chemistry curriculum.

6. The innovation aligns with the objectives of chemistry curriculum standards.

7. The innovation incorporates real-world applications of chemistry concepts.
8. The innovation includes interdisciplinary connections with other subjects.
9. The innovation addresses current scientific research and advancements.
10. The innovation provides opportunities for students to engage in project-based learning related to chemistry topics.

3.4.3. Technology Integration

This aspect incorporates technology tools and resources to enhance chemistry teaching and learning experiences.

11. The innovation effectively integrates technology to enhance chemistry learning.
12. The innovation utilizes digital tools for data collection and analysis.
13. The innovation facilitates collaboration and communication among students.
14. The innovation promotes the development of digital literacy skills in chemistry.
15. The innovation leverages educational apps and simulations to reinforce chemistry concepts.

3.4.4. Assessment Strategies

This aspect encompasses the methods and techniques used to evaluate student learning and progress in chemistry.

16. The innovation employs varied assessment methods to evaluate student learning in chemistry.
17. The innovation includes formative assessment practices that inform instructional decisions.
18. The innovation provides opportunities for student self-assessment and reflection.
19. The innovation aligns assessments with chemistry learning objectives and outcomes.
20. The innovation offers timely and constructive feedback to students to enhance their understanding of chemistry.

3.4.5. Teacher Support and Professional Development

This aspect involves initiatives and resources provided to teachers to enhance their knowledge, skills, and confidence in delivering effective chemistry instruction.

21. The innovation provides adequate resources and materials to support chemistry teaching.
22. The innovation offers professional development opportunities to enhance teachers' chemistry pedagogy.
23. The innovation fosters a supportive school culture that values chemistry teaching innovations.
24. The innovation encourages collaboration and knowledge sharing among chemistry educators.
25. The innovation recognizes and celebrates teachers' efforts to improve chemistry instruction.

4. DISCUSSION

The study's findings demonstrate how well the Chemistry Teaching Innovations Validation (CTIV) tool works as a valid and reliable framework for assessing teaching innovations. The CTIV tool's robustness in evaluating different aspects of chemistry teaching innovations is indicated by statistical data such as factor loadings, infit and outfit values, model fit indices, and Cronbach's alpha values. The tool's ability to measure important factors such as Pedagogical Content, Content Relevance, Technology Integration, Assessment Strategies, and Teacher Support and Professional Development is guaranteed through this validation.

The validity and reliability of the CTIV tool are established by the infit and outfit values, which show that each item works well in measuring the required components (Bond & Fox, 2013). This suggests that the instrument can be relied upon to accurately assess innovative teaching practices and determine whether or not they are appropriate for classroom use. The CFA results, which show significant factor loadings for every item, provide additional evidence that every component of the CTIV instrument is clearly defined and competent to measure the particular aspects for which it is intended (Brown, 2014). The model fit indices indicate a strong fit between the observed data and the model fit indices, which fulfill established standards. This alignment demonstrates how well the tool captures the intricacies of innovations in chemistry education. The CTIV tool's excellent reliability is shown by the high Cronbach's alpha values obtained for all of its components (Cronbach, 1951). Because of the measuring consistency, the tool can be used confidently and consistently to assess different educational innovations accurately. Its high internal consistency strengthens The tool's reliability, which indicates that all dimensions are consistently measured.

The final validated CTIV tool, with its intricate five-aspect structure and twenty-five items, offers a thorough framework for assessing innovations in chemistry education. To effectively teach Chemistry, pedagogical content emphasizes student-centeredness, inquiry-based learning, practical exercises, and developing critical thinking and problem-solving abilities (Aris et al., 2024). Content relevance guarantees that educational resources and activities have real-world applications, interdisciplinary links, and the most recent scientific developments and are in line with curricular standards. This connection improves the relevance and application of chemistry instruction to students' daily lives (Üce & Ceyhan, 2019).

In today's classroom, technology integration is essential (Mananay et al., 2023; Yesgat et al., 2023). The CTIV tool assesses how well digital tools and resources are used to improve chemistry instruction. This entails encouraging digital literacy, assisting student cooperation and communication, and using instructional simulations and applications. Assessment strategies cover a range of techniques for assessing student learning, such as opportunities for self-evaluation and reflection, timely and helpful feedback, and formative assessments that guide instructional decisions (Dolin & Evans, 2018; Opateye & Ewim, 2021). By ensuring that assessments are in line with learning objectives and outcomes, these strategies help students' learning to develop continuously. Maintaining and improving good teaching strategies requires a strong foundation in professional development and teacher support (Asiyah et al., 2021). The CTIV instrument assesses the availability of materials and resources, opportunities for professional growth, and a conducive learning environment that recognizes innovative approaches to teaching chemistry. Positive and dynamic learning environments are facilitated by acknowledging teachers' achievements and fostering collaboration and knowledge exchange.

Simply put, the validated CTIV instrument guarantees quality assurance before introducing and assessing innovative teaching methods in the classroom. Chemistry education could be improved due to the tool's ability to assist teachers in identifying and implementing innovative teaching strategies by offering a valid and reliable framework for assessment. Since proven teaching strategies can raise students' interest, comprehension, and performance in chemistry classes, this development has broader implications for Science education. The CTIV tool improves Science education by implementing only well-researched innovations and evidence-based practices, giving students a more engaging and dynamic learning in the field. This comprehensive approach to validating and implementing innovative teaching practices raises the bar for quality in education and helps teachers and students alike.

5. CONCLUSION

The study effectively developed and validated the Chemistry Teaching Innovations Validation (CTIV) tool, underscoring its importance in enhancing chemistry instruction. This tool's validation fills a crucial gap in educational research by offering a reliable and efficient way to evaluate several aspects of teaching innovations. By providing an organized framework, the CTIV tool guarantees that teachers can systematically examine educational strategies, content relevance, technological integration, assessment strategies, teacher support, and professional development. These results show the tool's potential applicability in practical educational settings and add to the larger body of knowledge in academic research. This, in turn, confirms the primary assumption that a well-validated evaluation tool may considerably improve the quality of education by ensuring that innovations are both reliable and effective. It also highlights the significance of validated tools in improving teaching methods and educational outcomes. While opinions on the generalizability of these tools differ, the CTIV tool's strong statistical validation indicates that it provides a reliable way to assess chemistry teaching innovations, resolving some concerns about its applicability.

Despite the CTIV tool's proven benefits, it is critical to recognize the study's limits to present a fair analysis. The size and demographic variety of the sample are two significant limitations. The study's results might only accurately reflect some educational environments, especially in those with notably distinct institutional or cultural features. Additionally, using self-reported data adds inherent biases that can compromise the results' objectivity. Furthermore, the study mainly concentrates on quantitative metrics, which, although reliable, may ignore qualitative subtleties that offer a more profound understanding of the efficacy of teaching innovations.

The noted limitations and biases could affect the interpretation of the results. For example, the findings may be less applicable to larger educational contexts due to the sample's low level of demographic variety. Results could be skewed by biases relating to individual experiences and views introduced by self-reported data. The focus on quantitative metrics may restrict the ability to understand the qualitative components of innovative teaching practices, which could offer a more comprehensive assessment of their efficacy. These restrictions emphasize the necessity of caution when extrapolating the results and stress the significance of considering contextual factors when using the CTIV tool.

Future studies in this area should consider enlarging the sample size and boosting demographic diversity to ensure the tool works in different educational settings. Future researchers may consider investigating different methodologies, such as mixed-method approaches, to obtain qualitative and quantitative data, offering a more thorough assessment of teaching innovations. The robustness of the results could also be improved by addressing the constraints of self-reported data through triangulation with secondary or observational data sources. Studies with a longitudinal design may evaluate the long-term effects of innovative teaching methods verified by the CTIV tool, offering insights into their long-term viability. Furthermore, examining the tool's use in various contexts may guarantee its worldwide applicability. Making specific recommendations for future research emphasizes the CTIV tool's continued applicability and encourages more academic investigation. Initiating further research and involving the educational community will help improve Science education worldwide and promote continual improvement.

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