Journal of Studies in Science and Mathematics Education
ISSN: 2630-662x
Published: 31.08.2026
Volume (issue): *6*(2)
Page: 37–46

Culturally Responsive Pedagogy in Chemistry Education: An Investigation into Its Effect on Performance among Pre-service Teachers

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Abstract

This study investigated the effect of culturally responsive pedagogy integrating indigenous knowledge on the academic performance of pre-service teachers in chemistry. A pretest–posttest quasi-experimental research design was employed. Eighty-seven pre-service teachers participated in the study and were exposed to chemistry instruction that incorporated culturally responsive teaching strategies and relevant indigenous knowledge practices. Data were collected using the Indigenous Knowledge Systems Performance Test (IKSPT) administered before and after the instructional intervention. Descriptive statistics, paired sample t-test, and analysis of covariance (ANCOVA) were used to analyse the data. The findings suggest a significant improvement in students' academic performance following exposure to culturally responsive pedagogy integrating indigenous knowledge, $t(86)=13.932$, $p<.001$. The results also indicated that there was no statistically significant difference in the academic performance of male ($M=13.29$, $SD=2.18$) and female ($M=14.13$, $SD=2.63$) students, $F(1, 84) = 2.67$, $p = .106$. This suggests that the instructional approach benefits students irrespective of gender. The study concludes that integrating indigenous knowledge through culturally responsive pedagogy enhances students' conceptual understanding and engagement in chemistry learning. It is therefore recommended that chemistry educators incorporate culturally relevant knowledge systems into instructional practices to promote meaningful, inclusive, and effective science education.

Keywords: culturally responsive pedagogy, indigenous knowledge, ethnochemistry, academic performance, gender

1 Introduction

The introduction should be succinct and contain no subheadings. This section should present background for the study, Nigeria is widely recognized as one of the most culturally diverse nations in Africa, with hundreds of ethnic groups and rich traditions of indigenous knowledge systems that have evolved through centuries of interaction with the natural environment. Particularly in northern Nigeria, indigenous knowledge manifests in everyday practices such as traditional medicine preparation, soap making, food preservation, fermentation, crop storage, dye production, and environmental management. These practices embody empirical knowledge accumulated through observation, experimentation, and generational transmission within communities. Indigenous knowledge systems represent locally generated bodies of knowledge that guide communities in solving practical problems related to health, agriculture, environmental conservation, and household production. Scholars have increasingly acknowledged that such knowledge systems are not merely cultural artifacts but constitute valuable intellectual resources for scientific understanding and education (Govender et al., 2025; Singh-Pillay & Madlala, 2026). This recognition suggests that indigenous knowledge can serve as a powerful contextual foundation for teaching scientific concepts, including those in chemistry.

Despite the rich reservoir of indigenous chemical knowledge available in African societies, its potential contribution to chemistry education remains largely underexplored in formal instructional settings. Historically, science curricula in many postcolonial education systems have been heavily influenced by Western epistemologies, often marginalizing or ignoring indigenous knowledge systems. This separation has resulted in what scholars describe as a cultural disconnect between school science and community knowledge traditions (Mavuru, 2025; Lodge & Dillon, 2026). In such contexts, students are expected to learn scientific concepts presented in unfamiliar cultural frames, which may hinder their engagement and comprehension. Researchers have therefore argued that bridging the gap between indigenous knowledge and formal science education can help create culturally meaningful learning experiences and promote a deeper understanding of scientific ideas.

The need to bridge this gap has given rise to the concept of culturally responsive pedagogy, an educational approach that recognizes and incorporates students' cultural backgrounds, experiences, and community knowledge into teaching practices. Culturally responsive pedagogy emphasizes the importance of connecting academic content with learners' cultural identities in order to make learning more meaningful and accessible. In science education, this approach encourages educators to contextualize scientific concepts within culturally relevant practices and everyday experiences. Studies have demonstrated that culturally responsive teaching strategies improve student engagement, conceptual understanding, and academic achievement in science classrooms (Bonney et al., 2026; Xie & Yusuf, 2026). By drawing on indigenous knowledge systems, culturally responsive pedagogy provides a framework for transforming abstract scientific ideas into relatable, real-life problem-solving experiences.

Within the context of chemistry education, culturally responsive pedagogy holds particular promise because many chemical principles are embedded in traditional technologies and daily practices. For example, indigenous soap production reflects the principles of saponification, traditional fermentation processes demonstrate biochemical reactions, and natural dyeing techniques illustrate chemical interactions between pigments and fibers. When educators intentionally connect these culturally familiar practices to formal chemical concepts, students are better able to visualize and internalize abstract ideas. Research has also shown that integrating culturally relevant examples into science teaching helps learners develop metacognitive awareness and strengthens their ability to apply scientific knowledge in practical situations (Tawanda & Mudau, 2024). In this way, culturally responsive chemistry instruction not only improves conceptual understanding but also promotes the development of real-life problem-solving skills. Furthermore, culturally responsive approaches align closely with contemporary calls for contextualized and transformative science education in Africa. Educational scholars have emphasized the importance of decolonizing science education by recognizing indigenous knowledge systems as legitimate sources of knowledge alongside Western scientific traditions (Govender et al., 2025). Integrating these knowledge systems into teaching practices can foster a more inclusive learning environment where students see their cultural heritage reflected in academic content. This inclusive approach has been shown to improve students' attitudes toward science and enhance their academic performance. In Nigeria, where indigenous practices are deeply embedded in community life, culturally responsive chemistry instruction offers a practical strategy for transforming chemistry learning from a purely theoretical exercise into a meaningful exploration of real-world phenomena.

Despite the growing recognition of culturally responsive pedagogy in science education, empirical research examining its application in undergraduate chemistry classrooms remains limited, particularly within the Nigerian context. Most existing studies have focused on primary or secondary education, leaving a gap in understanding how culturally responsive approaches can influence learning outcomes among university students. Moreover, there is still limited evidence on how indigenous knowledge can be systematically integrated into chemistry courses that address everyday chemical applications such as medicine, soaps and detergents, polymers, preservatives, and environmental chemistry. Addressing this gap is crucial for advancing pedagogical strategies that promote meaningful chemistry learning and real-life problem solving. In response to this need, the present study, framed within the context of cultural historical activity theory, investigates the effect of culturally responsive pedagogy on undergraduate students' performance in chemistry by integrating indigenous knowledge practices into the teaching of "Chemistry in Everyday Life." The study explores how culturally contextualised examples drawn from local knowledge systems can facilitate conceptual understanding and enhance academic achievement in chemistry. In specific terms, the study aimed to address the following research questions:

1. What is the effect of culturally responsive pedagogy integrating indigenous knowledge on the mean academic performance score of pre-service teachers taught chemistry?
2. What is the effect of culturally responsive pedagogy integrating indigenous knowledge on the mean academic performance score of male and female pre-service teachers taught chemistry?

By examining the intersection between indigenous knowledge, culturally responsive pedagogy, and chemistry education, this research contributes to ongoing efforts to make science education more relevant, inclusive, and effective. Ultimately, the study seeks to demonstrate that transforming indigenous knowledge into structured classroom learning experiences can serve as a powerful strategy for promoting real-life chemical problem-solving, thereby aligning chemistry education with the broader goals of societal development and sustainable knowledge systems.

2 Theoretical Framework

This study is anchored in Cultural-Historical Activity Theory (CHAT), a sociocultural and developmental framework that explains human learning and development as processes situated within social, cultural, historical, and material contexts. CHAT is particularly appropriate for the present study because the intervention involves bringing students' indigenous knowledge and culturally familiar practices into the formal chemistry classroom and using them as resources for understanding chemical concepts and solving everyday problems. Rather than viewing learning as an exclusively individual cognitive process, CHAT conceptualizes learning as mediated activity involving learners, cultural tools, other people, institutional rules, and historically developed practices. This perspective provides a basis for understanding how culturally responsive chemistry instruction can transform the relationship between students and chemistry knowledge and potentially improve academic performance. The intellectual foundations of CHAT can be traced to the cultural-historical psychology of Lev Vygotsky, whose work challenged explanations of human learning that separated cognition from social and cultural contexts. Vygotsky (1978) argued that higher mental functions develop through socially mediated activity and that human action is mediated by cultural tools, language, signs, and interaction with others. From this perspective, learning is not simply the acquisition of information by an isolated learner; rather, learners develop through participation in culturally organized activities. The second generation of activity theory was substantially developed by Alexei Leont'ev (1978), who extended Vygotsky's focus from individual mediated action to collective activity. Leont'ev distinguished between motives, activities, actions, and operations and emphasized that human actions acquire meaning through participation in collective activities directed toward objects. This development shifted the unit of analysis from the individual to the broader activity in which the individual participates.

Yrjö Engeström (2014) subsequently expanded activity theory into a third-generation CHAT framework by representing activity through an activity-system model. The model incorporates the subject, object, mediating tools, rules, community, division of labour, and outcome. It therefore enables researchers to examine learning as a complex relationship among individuals, cultural artefacts, social groups, institutional expectations, and the objects of activity. Contemporary educational research continues to apply CHAT to complex learning environments, including science teaching, teacher learning, practical laboratory work, and curriculum transformation (Rutt & Mumba, 2023; Hennah et al., 2022). The central assumption of CHAT is that human learning and development are socially mediated, culturally situated, historically formed, and object-oriented. Human beings do not interact directly with the world in isolation; their activities are mediated by cultural artefacts, language, knowledge systems, technologies, social relationships, and institutional practices. Consequently, what students learn and how they learn it are influenced by the cultural and historical environments in which learning occurs.

A second important assumption is that learning occurs through collective activity. The learner is therefore not treated as an isolated recipient of knowledge but as a participant in an activity system involving teachers, peers, cultural resources, rules, and shared objectives. CHAT also assumes that activity systems are dynamic rather than static. They contain different perspectives, interests, expectations, and historically accumulated practices. These may produce contradictions, which CHAT views not merely as problems but as potential sources of learning, transformation, and development (Engeström, 2014). A further assumption is mediation. Cultural tools mediate the relationship between the learner and the object of learning. In science education, such tools may include laboratory equipment, language, textbooks, digital technologies, representations, classroom discourse, practical activities, and culturally derived knowledge. Thus, indigenous knowledge can function as a mediating cultural resource through which students connect familiar experiences with formal scientific concepts. CHAT has considerable relevance to science education because science learning occurs within complex social and cultural environments. Science classrooms involve interactions among learners, teachers, curricula, instructional materials, assessment systems, scientific concepts, and broader community expectations. Consequently, examining only students' individual cognition may provide an incomplete explanation of learning outcomes. CHAT allows researchers to examine how these interacting elements collectively shape learning. Studies have demonstrated the usefulness of CHAT for analyzing science teaching and learning. For example, CHAT has been used to investigate pre-service science teachers' instructional practices and the interaction between language, literacy, classroom communities, and science teaching (Rutt & Mumba, 2023). Similarly, Hennah et al. (2022) applied CHAT to chemistry practical work and demonstrated how instructional tools, social interaction, dialogue, and the organization of classroom roles can influence learning outcomes. CHAT has also been applied to science argumentation, educational technology, teacher learning, and curriculum change (Camillo & Mattos, 2014; Lazarou, 2011). These applications demonstrate that science learning is influenced not only by what is taught but also by the tools, social relationships, practices, and contexts through which scientific knowledge is constructed.

CHAT provides a particularly strong theoretical foundation for integrating indigenous knowledge into science education. Indigenous knowledge is historically and culturally developed through communities' interactions with their environments. When students enter formal educational settings, they do not arrive without prior knowledge; they bring experiences, practices, language, beliefs, explanations, and knowledge developed through participation in their communities. From a CHAT perspective, these forms of knowledge can become mediating resources for learning. De Beer (2015) specifically argued that CHAT provides a useful lens for incorporating indigenous knowledge into science classrooms because learners enter the classroom with embodied and situated knowledge that can be used as an entry point for making abstract science concepts more accessible and relevant. Similarly, de Beer and Kriek (2021) demonstrated the potential of indigenous knowledge within CHAT for curriculum transformation and the decolonisation of science education. Their argument is particularly relevant to the present study because indigenous knowledge is not treated merely as an illustrative addition to the curriculum; rather, it becomes part of the activity through which students encounter, interpret, discuss, and apply scientific knowledge. In the present study, practices such as traditional soap making, fermentation, food preservation, natural dyeing, medicinal preparation, and other locally familiar activities can serve as mediating artefacts. For example, students may connect traditional soap production with saponification, fermentation with chemical and biochemical transformations, and preservation practices with chemical principles underlying food stability. Such connections can enable students to move from familiar practical experiences toward formal chemical explanations. In this way, culturally responsive pedagogy transforms the chemistry classroom into an activity system in which students' community knowledge and formal chemistry knowledge interact.

Despite its usefulness, CHAT has been criticised for its conceptual complexity and broad scope. Nussbaumer (2012), for example, noted difficulties in the consistent application of CHAT constructs in educational research. Because the framework encompasses numerous interacting elements, researchers may find it difficult to operationalise the entire activity system without producing overly complex analyses. Another criticism concerns the tendency to emphasise contradictions, which may cause researchers to overlook processes characterised by cooperation, stability, or congruence (Kerosuo, 2014). Langemeyer and Roth (2006) further questioned some interpretations of contradictions within Engeström's formulation and argued for greater attention to broader social relations and power structures. CHAT may also be challenging when researchers attempt to establish straightforward causal relationships between particular elements of an activity system and learning outcomes. Unlike theories designed primarily to predict behaviour, CHAT is principally an interpretive and explanatory framework for understanding complex human activity. Nevertheless, CHAT remains highly promising for contemporary science education because it provides a holistic account of learning that accommodates culture, social interaction, material tools, institutional structures, and historical development. Its emphasis on mediation and collective activity makes it particularly suitable for culturally responsive and context-based science education. More recent applications demonstrate its continuing usefulness for educational transformation and for understanding complex interactions among learners, teachers, tools, and learning environments (Engeström, 2026; Rutt & Mumba, 2023). For the present study, CHAT offers a coherent explanation of why indigenous knowledge may influence undergraduate chemistry learning. When students' culturally familiar experiences are deliberately incorporated as mediating resources, the object of chemistry learning becomes connected to meaningful everyday activity. Students can therefore move between community-based knowledge and formal chemical explanations, while classroom interaction provides opportunities for discussion, interpretation, and problem-solving. Consequently, CHAT supports the proposition that culturally responsive pedagogy integrating indigenous knowledge can create a more meaningful activity system for chemistry learning, thereby improving students' academic performance and their capacity to apply chemistry to real-life problems. The theory therefore provides an appropriate conceptual foundation for investigating the effect of culturally responsive pedagogy integrating indigenous knowledge on undergraduate students' chemistry performance.

3 Methodology

This study adopted a one-group pretest–posttest quasi-experimental design to investigate the effect of culturally responsive pedagogy on undergraduate students' performance in chemistry. This design is appropriate when a researcher seeks to determine the effect of an instructional intervention on a single group by measuring learning outcomes before and after exposure to the treatment (Creswell & Creswell, 2017). The participants consisted of 300-level undergraduate Integrated Science students enrolled in the teacher education programme and taking SEIT315: Chemistry in Everyday Life, a first-semester course in the 2023/2024 academic session. A purposive sampling technique was employed to select the class because the students were already registered for the course in which the culturally responsive pedagogy intervention was implemented. The intervention lasted for 12 weeks of the semester, during which culturally responsive instructional strategies incorporating indigenous chemical practices were integrated into the delivery of 12 instructional topics, with each topic taught for two hours. Lessons employed guided discussions, collaborative activities, and real-life applications, using structured lesson plans to ensure consistency and fidelity of implementation. Data were collected using an Indigenous Knowledge Systems Performance Test (IKSPT) consisting of 20 multiple-choice questions and five short-answer questions administered as both a pretest and posttest. The IKSPT was validated by experts in Chemistry Education and Indigenous Knowledge Systems for relevance, clarity, and alignment with the study objectives. Its reliability was established through a test–retest procedure, yielding a reliability coefficient of 0.72, indicating acceptable stability of the instrument. To minimise testing effects and recall bias, the posttest items were reshuffled and partially reframed while maintaining the same learning constructs. The collected data were analyzed using a paired-sample t-test to determine whether there was a statistically significant difference between students' pretest and posttest scores following the instructional intervention, and an ANCOVA for significant difference between males' and females' posttest scores using pretest scores as a covariate.

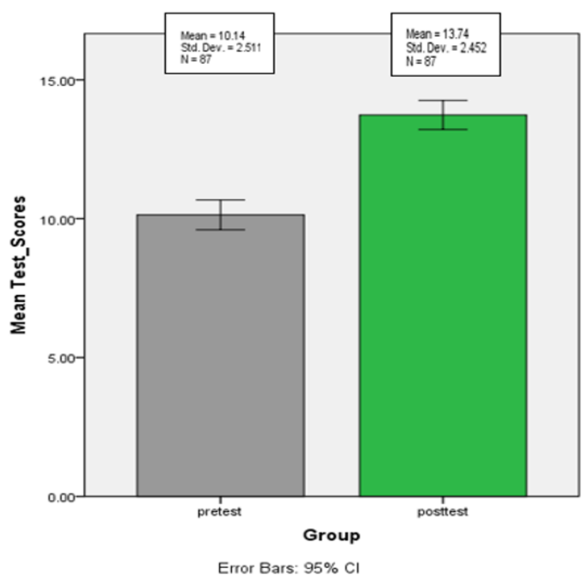
4 Results

4.1 Addressing Research Question One

To address the first research question, I compare the mean pretest scores with the mean posttest scores of students taught using culturally responsive pedagogy that integrates indigenous knowledge. The descriptive statistics are presented in Figure 1.

Figure **1**

Descriptive statistics of pretest and posttest performance scores



The results presented in Figure 1 show a noticeable increase in students' mean scores after the instructional intervention. The mean pretest score was 10.14 (SD = 2.51), whereas the posttest mean score increased to 13.74 (SD = 2.45) among the 87 students who participated in the study. This represents a mean difference of 3.60 points, indicating an upward trend in students' academic performance following the implementation of culturally responsive pedagogy. To determine whether the observed difference between the pretest and posttest scores was statistically significant, a paired-samples t-test was conducted. Table 1 presents the summary statistics of this analysis.

Table **1**

Paired samples t-test statistics

	Mean	N	Std. Deviation	MD	df	t-value	p-value
Posttest	13.7356	87	2.45167	3.59770	86	13.932	<.001

Pretest	10.1379	87	2.51124

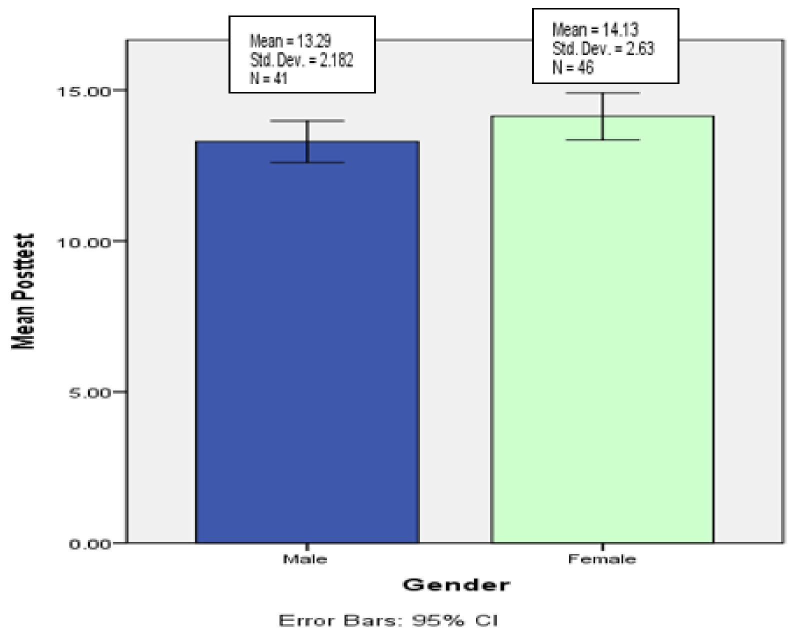
The results presented in Table 1 revealed a statistically significant difference between the pretest and posttest scores, $t(86) = 13.93$, $p < .001$. The bar chart corresponding to this result illustrates a clear increase in the posttest performance compared with the pretest performance, indicating improved academic outcomes after the semester's instructional intervention.

4.2 Addressing Research Question Two

To address the second research question, I compare the mean posttest scores of male and female students taught using culturally responsive pedagogy that integrates indigenous knowledge. The descriptive statistics are presented in Figure 2.

Figure **2**

Descriptive statistics of male and female posttest scores



The results presented in Figure 2 indicate that both male and female students recorded comparable academic performance after the instructional intervention. The analysis shows that male students achieved an overall posttest mean score of 13.74 (SD = 2.45) compared to female students mean score of 14.13 (SD = 2.63). To further determine whether gender influenced students' academic performance after the intervention, an analysis of covariance (ANCOVA) was conducted while controlling pretest scores as a covariate. Table 2 presents the summary statistics of this analysis.

Table **2**

Summary statistics of ANCOVA for the performance of male and female students

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	156.209[a]	2	78.104	18.188	<.001
Intercept	362.634	1	362.634	84.448	<.001
Pretest	140.994	1	140.994	32.834	<.001
Gender	11.473	1	11.473	2.672	.106
Error	360.711	84	4.294		
Total	16931.000	87			
Corrected Total	516.920	86			

a. *R Squared = .302 (Adjusted R Squared = .286)*

The results presented in Table 2 revealed that the effect of gender on students' posttest performance was not statistically significant, $F(1, 84) = 2.67$, $p = .106$, after controlling for the initial differences before the experiment. This result indicates that both male and female students benefited similarly from the instructional approach.

5 Discussion

The findings of this study provide empirical evidence for the pedagogical value of culturally responsive pedagogy (CRP) that integrates indigenous knowledge in undergraduate chemistry instruction. The first research question examined whether the approach improved students' academic performance, while the second considered whether the effect differed according to gender. Overall, the results indicate that integrating indigenous knowledge into the teaching of Chemistry in Everyday Life produced a significant improvement in students' performance, while the improvement did not differ significantly between male and female students. These findings are important because they provide evidence that culturally contextualised chemistry instruction can move learning beyond the transmission of abstract concepts towards meaningful engagement with chemical phenomena encountered in students' everyday environments. With respect to the first research question, students' mean performance increased from 10.14 (SD = 2.51) in the pretest to 13.74 (SD = 2.45) in the posttest, representing a mean gain of 3.60 points. The paired-samples t-test confirmed that this improvement was statistically significant, $t(86) = 13.93$, $p < .001$. Thus, the observed increase in performance cannot reasonably be attributed to a mere descriptive difference between the two assessments. Rather, it provides evidence that the instructional experience was associated with substantial improvement in students' chemistry performance.
The finding is consistent with the argument advanced in the introduction that indigenous knowledge can provide meaningful contexts for understanding chemistry. Traditional practices such as soap making, fermentation, preservation, dyeing, and medicinal preparation contain observable processes that can be connected to formal chemical principles. When these practices are brought into classroom discourse, students can begin with phenomena that are already familiar and progressively connect them with scientific concepts. This interpretation is consistent with Rahmawati et al. (2019), who found that integrating ethnochemistry with culturally responsive teaching supported students' critical thinking in chemistry. It is also consistent with Chibuye and Singh (2024), who demonstrated the value of integrating local knowledge and examples of ethnochemistry into chemistry curricula. Similarly, Abumchukwu et al. (2021) reported improved chemistry achievement among students exposed to an ethnochemistry instructional strategy, while Ahmad and Halliru (2022) found that ethnochemistry-based instruction produced better achievement and retention than conventional instruction. The present finding therefore extends the evidence from predominantly school-level contexts by demonstrating a similar potential among pre-service teachers.

The improvement can also be interpreted through the lens of Cultural-Historical Activity Theory (CHAT). From this perspective, students' learning does not occur independently of their social and cultural environment; rather, learning is mediated by culturally developed tools and participation in meaningful activities (Vygotsky, 1978; Leont'ev, 1978). In the present study, indigenous knowledge functioned as a mediating cultural resource through which students encountered chemistry. Instead of approaching chemical concepts only through conventional textbook explanations, students were exposed to knowledge and practices connected to their everyday experiences. This may have reduced the psychological distance between students and the formal chemistry curriculum and enabled them to reconstruct abstract concepts through familiar contexts. The finding is particularly consistent with de Beer (2015), who argued that CHAT provides a useful basis for incorporating indigenous knowledge into science classrooms because learners enter formal education with culturally and historically developed knowledge. From an activity-system perspective, the indigenous practices used during instruction can be understood as mediating artefacts connecting the students, as subjects, with the object of learning. The lecturer's role was not simply to transmit information but to facilitate connections between indigenous practices and formal chemical explanations. This is consistent with Engeström's (2014) view that learning occurs through mediated, collective, and object-oriented activity. The significant performance improvement therefore suggests that changing the mediating tools and learning context may have transformed students' engagement with the object of chemistry learning.

The result also supports the broader argument for culturally responsive and decolonised science education. The introduction highlighted concerns that conventional science curricula may privilege Western scientific knowledge while overlooking learners' community-based knowledge. Govender et al. (2025) and Mavuru (2025) similarly emphasise the importance of recognising indigenous knowledge within science education. The present findings suggest that acknowledging students' cultural knowledge is not only an issue of cultural representation; it can also have pedagogical consequences for learning achievement. By positioning familiar cultural practices alongside formal chemistry, the intervention may have enabled students to perceive chemistry as relevant to their own lives rather than as knowledge detached from their social and cultural experiences. The finding further resonates with Oladejo et al. (2022), whose culturo-techno-contextual approach demonstrated the potential of culturally responsive tools for meaningful chemistry learning in Africa. However, the present study differs in its emphasis on indigenous chemical practices within a university-level Chemistry in Everyday Life course. This is significant because much of the evidence cited in the introduction concerns secondary education. The present study consequently contributes to filling the identified empirical gap concerning the application of culturally responsive approaches and indigenous knowledge in undergraduate chemistry education. Regarding the second research question, male and female students recorded comparable posttest performance, with mean scores of 13.74 (SD = 2.45) and 14.13 (SD = 2.63), respectively. After controlling pretest scores, ANCOVA showed that gender did not have a statistically significant effect on posttest performance, $F(1, 84) = 2.67, p = .106$. This suggests that the instructional approach supported comparable learning outcomes among male and female students rather than favouring one gender. This finding agrees with Oladejo et al. (2022), who emphasised the capacity of culturally responsive approaches to support meaningful and inclusive chemistry learning. It also reinforces the argument that culturally contextualised instruction can provide common experiential entry points for learners. When instructional activities draw on practices that students recognise from their communities, participation may become less dependent on prior exposure to highly abstract or decontextualised forms of scientific learning. The absence of a significant gender effect therefore suggests that the intervention had broad applicability across the participating students.

From the CHAT perspective, the comparable outcomes may be understood as evidence that the activity system created by the intervention provided both male and female students with access to similar mediating resources, classroom participation, and opportunities to engage with the object of learning. Rather than treating gender as the primary determinant of learning, CHAT directs attention towards the social organization of activity, the tools available to learners, and the interactions through which knowledge is constructed. Thus, the finding supports the theoretical proposition that transforming the conditions and mediating resources of learning can influence students' engagement with scientific knowledge. Nevertheless, the findings should be interpreted with caution. The one-group pretest–posttest design does not provide a control group against which the observed improvement can be compared. Consequently, factors such as maturation, exposure to other learning experiences, or testing effects cannot be completely excluded. The study nevertheless provides useful empirical evidence that culturally responsive pedagogy integrating indigenous knowledge is associated with improved undergraduate chemistry performance. Future studies employing control or comparison groups and larger samples could provide stronger evidence concerning causality. Overall, the findings support both the empirical literature and the CHAT framework underpinning the study. Integrating indigenous knowledge transformed familiar cultural practices into mediating resources for learning chemistry, while the significant improvement in students' performance indicates that this contextualization can support meaningful chemistry learning. The absence of significant gender difference further suggests that the approach can promote relatively equitable learning outcomes. Thus, culturally responsive pedagogy that deliberately connects indigenous knowledge with formal chemistry offers a promising pathway for making undergraduate chemistry more meaningful, relevant, inclusive, and oriented towards real-life chemical problem-solving.

6 Conclusion

This study examined the effect of culturally responsive pedagogy integrating indigenous knowledge on the academic performance of pre-service teachers in chemistry and explored whether gender influenced the outcomes of the instructional approach. The findings demonstrate that incorporating indigenous knowledge into chemistry instruction through culturally responsive pedagogy can significantly enhance students’ understanding and academic performance. By connecting abstract chemical concepts with culturally familiar practices and real-life experiences, the instructional approach makes learning more meaningful and accessible to students. The results further indicate that the strategy benefits both male and female students equally, suggesting that culturally responsive pedagogy provides an inclusive learning environment that promotes equitable participation and achievement. These findings underscore the importance of contextualizing chemistry instruction within students’ cultural backgrounds and community knowledge systems. Integrating indigenous knowledge into science education, therefore, represents a valuable pedagogical strategy for improving chemistry learning outcomes and fostering more relevant, inclusive, and engaging science education.

7 Limitation of the Study

The study was limited by its one-group pretest-posttest design, which lacked a comparison group and therefore limits causal interpretation of the observed gains. In addition, the relatively small sample of 87 students from a single intact class and one institution may limit the generalizability of the findings to other students and settings.

8 Declarations

Conflict of Interest: The author declares neither financial nor non-financial conflict of interest.

Author Contributions: R. E. conceptualised the study, carried out the research, conducted the analyses, and wrote the manuscript.

Funding: The research reported in this article received no funding.

Data Availability Statement: The dataset used for this study is available upon request from the corresponding author.

9 References

Abumchukwu, A. A., Eke, J. A., & Achugbu, C. N. J. (2021). Effects of ethnochemistry instructional strategy on secondary school students' achievement in chemistry in Onitsha education zone. *African Journal of Science, Technology and Mathematical Education*, *6*(1), 121-128.

Ahmad, S. S., & Halliru, A. (2022). Effects of Ethnochemistry Based Approach on Chemistry Students' Academic Achievement and Retention in Malumfashi Educational Zone, Katsina State, Nigeria. *African Journal of Science, Technology and Mathematics Education*, *8*, 658-670.

Bonney, E. A., Akosah, E. F., Tawiah-Mensah, J. E., Tetteh, A. A., & Kafu, G. Y. (2026). Culturally Responsive Pedagogy: Leveraging Ethno-Cultural Approaches to Enhance Mathematics and Science Teaching in Ghana's Early Childhood Development Programs. *Early Childhood Education Journal*, 1-18.

Camillo, J., & Mattos, C. (2014). Science education and the cultural-historical activity theory: Contributions for reflection on educational practice. *Ensaio Pesquisa em Educação em Ciências, 16*(1), 211–230. https://doi.org/10.1590/1983-21172014160113

Chibuye, B., & Singh, I. S. (2024). Integration of local knowledge in the secondary school chemistry curriculum-A few examples of ethno-chemistry from Zambia. *Heliyon*, *10*(7).

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Sage.

de Beer, J. J. (2015). The inclusion of indigenous knowledge in the science classroom: A substantiation from cultural-historical activity theory. *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie, 34*(1), Article 1344. https://doi.org/10.4102/satnt.v34i1.1344

de Beer, J. J., & Kriek, J. (2021). Insights provided into the decolonisation of the science curriculum, and teaching and learning of indigenous knowledge, using Cultural-Historical Activity Theory. *South African Journal of Higher Education, 35*(6), 1–20. https://doi.org/10.20853/35-6-4217

Engeström, Y. (2014). *Learning by expanding: An activity-theoretical approach to developmental research*. Cambridge University Press.

Engeström, Y. (2026). Cultural–Historical Activity Theory and Educational Change: Formative Interventions Toward a Zone of Proximal Development. In: Goodwin, A.L., Hargreaves, A., Showunmi, V., Stone-Johnson, C., Weiner, J. (eds) Third International Handbook of Educational Change. Springer International Handbooks of Education. Springer, Cham. https://doi.org/10.1007/978-3-031-88898-4_20-1

Govender, N., Moheeput, K., Singh-Pillay, A., Cyparsade, M., James, A., Mabaso, B., & Kolobe, L. (2025). Cultural decolonization and implications for pedagogy in integrating STEM-IKS education in the Global South. *Cultural Studies of Science Education*, 1-25.

Hennah, N., Newton, S., & Seery, M. K. (2022). A holistic framework for developing purposeful practical work. *Chemistry Education Research and Practice*, *23*(3), 582-598. https://doi.org/10.1039/D1RP00168J

Kerosuo, H. (2014). Kollektiivinen muutoslaboratorio toiminnan teorian kehittämisen välineenä [Collective Change Laboratory as a tool for developing activity theory]. *Aikuiskasvatus, 34*(3), 178-191.

Langemeyer, I., & Roth, W. M. (2006). Is cultural-historical activity theory threatened to fall short of its own principles and possibilities as a dialectical social science?. *Outlines. Critical Practice Studies*, *8*(2), 20-42. https://doi.org/10.7146/ocps.v8i2.2090

Lazarou, D. (2011). Using Cultural-Historical Activity Theory to design and evaluate an educational game in science education. *Journal of Computer Assisted Learning*, *27*(5), 424-439. https://doi.org/10.1111/j.1365-2729.2011.00410.x

Leont'ev, A. N. (1978). *Activity, consciousness, and personality*. Prentice-Hall.

Lodge, W., & Dillon, J. (2026). Culturally Responsive Pedagogy in Science Education: Insights, Challenges and. *Culture and Science Education: Towards More Inclusive Practice*, 7.

Mavuru, L. (2025). Reimagining indigenous knowledge in a multicultural science classroom. *International Journal of Inclusive Education*, *29*(3), 344-360.

Nussbaumer, D. (2012). An overview of cultural historical activity theory (CHAT) use in classroom research 2000 to 2009. *Educational Review*, *64*(1), 37-55. https://doi.org/10.1080/00131911.2011.553947

Oladejo, A. I., Okebukola, P. A., Olateju, T. T., Akinola, V. O., Ebisin, A., & Dansu, T. V. (2022). In search of culturally responsive tools for meaningful learning of chemistry in Africa: We stumbled on the culturo-techno-contextual approach. *Journal of Chemical Education*, *99*(8), 2919-2931.

Rahmawati, Y., Baeti, H. R., Ridwan, A., Suhartono, S., & Rafiuddin, R. (2019). A culturally responsive teaching approach and ethnochemistry integration of Tegal culture for developing chemistry students' critical thinking skills in acid-based learning. In *Journal of Physics: Conference Series* (Vol. 1402, No. 5, p. 055050). IOP Publishing.

Rutt, A. A., & Mumba, F. (2023). Examining preservice science teachers' implementation of language-and literacy-integrated science through a cultural historical activity theory lens. *Science education*, *107*(3), 773-809. https://doi.org/10.1002/sce.21775

Singh-Pillay, A., & Madlala, A. (2026). Legitimising Indigenous knowledge systems as a pathway to sustainable development. *Discover Education*, *5*(1), 87.

Tawanda, T., & Mudau, A. V. (2024). The influence of indigenous knowledge on chemistry metacognition. *F1000Research*, *12*, 589.

Vygotsky, L. S., & Cole, M. (1978). *Mind in society: Development of higher psychological processes*. Harvard University Press.

Xie, Y., & Yusuf, A. (2026). Advancing scientific literacy: A systematic review of trends, pedagogies and challenges in the 21st century. *Review of Education*, *14*(1), e70140.

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