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Original Research

Enhancing how to practice writing chemical symbols and formulae through a competency-based curriculum approach among environmental science trainees at Oromia State University, Chiro Education Campus, Ethiopia

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Abstract

This study investigated the effects of competency-based curriculum strategies on first-year environmental science trainees at Oromia State University, Chiro Education Campus, in writing chemical symbols and constructing chemical formulas. Using an explanatory design with pre- and post-tests, the study compared trainees receiving competency-based curriculum-based instruction with those taught traditionally. Pre-test results showed strong recognition of familiar elements (Cl, Ca, H, Fe) but difficulty with less familiar ones (Ag, B, Hg). The experimental group showed significant gains: recognition of Ag increased from 33.33% to 78.70% and Hg from 27.27% to 96.90%, while correct formula construction for Cu_2O, Fe_2S, *and* $Cu_3(PO_4)_2$ *rose from 33.33%, 15.15%, and 18.18% to 93.94%, 90.90%, and 87.87%, respectively. The control group showed minimal improvement. Findings confirm that teaching methods and strategies effectively enhance chemical literacy by addressing misconceptions in oxidation states, charge balancing, and polyatomic ion identification, emphasizing the value of scaffold and concept-driven instruction. These findings demonstrate the importance of purposeful, scaffolded, and conceptually driven instruction in enhancing trainees' chemical literacy. To address particular learning gaps and customize instruction, teachers should identify students' preexisting misconceptions early on.*

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INTRODUCTION

Learning is not just about going to and from school; it's also about changing behavior and knowledge within the grade level (Negassa, 2014). Understanding what students are learning is critical in today's educational environment since it is a key tool for enhancing their interests. Holding students accountable is critical for effective education (Kasa, 2016).

In chemistry education, it is important to be able to write and understand chemical symbols, formulas, and how to balance chemical equations. One important thing to learn in order to get better at chemistry is how to write chemical formulas (Baah et al., 2012). These skills are vital for learning chemistry basics and advancing in the field. But even though they are important, a lot of students have a hard time learning how to write chemical symbols and make chemical formulas. People often say that these problems are caused by misunderstandings, bad teaching methods, and not having a deep understanding of the chemical principles that underlie them. At first, it seems easy to write chemical symbols, but you need to know a lot about atomic structure, like atomic number, mass number, and charge (Tro, 2017). But a lot of students have trouble with the simple task of matching the right symbol to the right element, especially when the element has more than one isotope or when they are learning about the periodic table (Barke & Temechegne, 2009). Also, mistakes in showing ions or isotopes can make it even harder for students to write chemical formulas. According to a study by Kautz & Watts (2014), students' problem-solving skills in writing chemical symbols for elements, formulae, and balancing chemical equations were also improved by giving them frequent formative assessments followed by focused feedback.

Given this, the researcher feels appreciative to conduct research in order to help first-year environmental science trainees at Oromia State University, Chiro Education Campus, Ethiopia, with their writing of chemical symbols and formulas and balancing chemical equations.

Statement of the Problem

In my experience teaching chemistry, the most common issues that trainees face are recognizing the names of common elements and formulas, balancing chemical equations, and lacking confidence when writing chemical symbols and formulas. I had trouble putting the course objectives into practice when I was given oral questions and class assignments. This issue was particularly bothersome for first-year environmental science trainees in their second semester. In recent instances, researchers have faced challenges from trainees in the form of various oral questions, class work, individual and group assignments, and general chemistry tests. It is challenging to determine whether or not the course objectives were met when such issues arise in chemistry classes.

Numerous pedagogical approaches have been investigated in recent research to address these issues. Through conceptual engagement and deep learning, active learning strategies like inquiry-based learning, problem-solving exercises, and hands-on activities have been demonstrated to enhance students' comprehension of chemical symbols and equations (Huddle & Sanger, 2009). In particular, novice trainees encountered difficulties when writing formulas, stoichiometric calculations, chemical equations, and element symbols. According to action research done in Nekemte CTE by Dula (2018), trainees learn chemistry more easily when they are taught different chemical languages, such as the distinctions between ions, atoms, and molecules, and the symbol and formula of a compound.

Danili and Reid (2004) investigated how field dependency and working memory space affected Greek students' chemistry learning. Students may encounter linguistic, contextual, or cultural challenges when studying chemistry in a language other than their mother tongue. According to Baah et al. (2012), students' ability to succeed in chemistry depends on their familiarity with a few fundamental concepts, norms, and techniques that serve as the foundation for subsequent research. Yideg (2022) suggested specialized tutorials and counseling interventions to help trainees who were having trouble understanding the symbolic aspects of chemistry. Similarly, tutorial classes greatly improved students' self-confidence and decision-making skills in science learning, according to Melaku (2021) at Wachamo University and Bedada (2022) at Qillisoo Primary School.

Since our trainees were college students, it was extremely difficult to teach the course effectively, particularly for those trainees who had a critical issue. Chemistry courses they were taking included not only writing formulas and chemical symbols for elements but also balancing chemical equations, as well as chemical reactions, chemical bonds, compound properties, and other topics. The researcher noticed a general lack of focus in the classroom for those trainees who were having serious issues. I was inspired to carry out this action research to close the gap based on my observations of the class and their exam results. Thus, by posing the following research questions, the researcher hopes to improve the issues of writing chemical symbols and formulae and balancing chemical equations through a competency-based curriculum in the Oromia state of the University of Chiro education campus.

Research Questions

1. How does trainees' prior understanding of fundamental chemistry concepts influence their ability to write chemical symbols and construct chemical formulas?
2. What is the current level of trainees' comprehension, and what difficulties do they encounter when writing chemical symbols and constructing chemical formulas?
3. To what extent do competency-based curriculum strategies improve trainees' skills in writing chemical symbols and constructing chemical formulas?

MATERIALS AND METHODS

Description of Study Area

The study was conducted in Chiro Town, located in the West Hararghe Zone of the Oromia Regional State, Ethiopia, from January 2025 to June 2025. Chiro is situated approximately 326 kilometers east of Addis Ababa, the capital city of Ethiopia. Geographically, the town lies in the Gara Jalloo Mountain region, with coordinates of 9°05′N and 40°52′E, at an altitude of 1,826 meters above sea level. Chiro serves as the administrative center of the West Hararghe Zone.

Research Design

Explanatory design is used in this study, integrating qualitative and quantitative research techniques. This method was especially appropriate since it enables the gathering of both numerical and non-numerical data, offering a thorough comprehension of the research issue. Creswell (2012) asserts that "the use of mixed methods involves the combination of both forms of data that provide a better understanding of a research problem than either quantitative or qualitative data alone."

The goal of this mixed-methods study is to obtain a comprehensive understanding of how competency-based curriculum strategies can enhance first-year environmental science trainees at Chiro College of Teacher Education's comprehension and application of important chemistry concepts. The flowchart of the pre-test, post-test quasi-experimental design framework is shown in Figure 1.

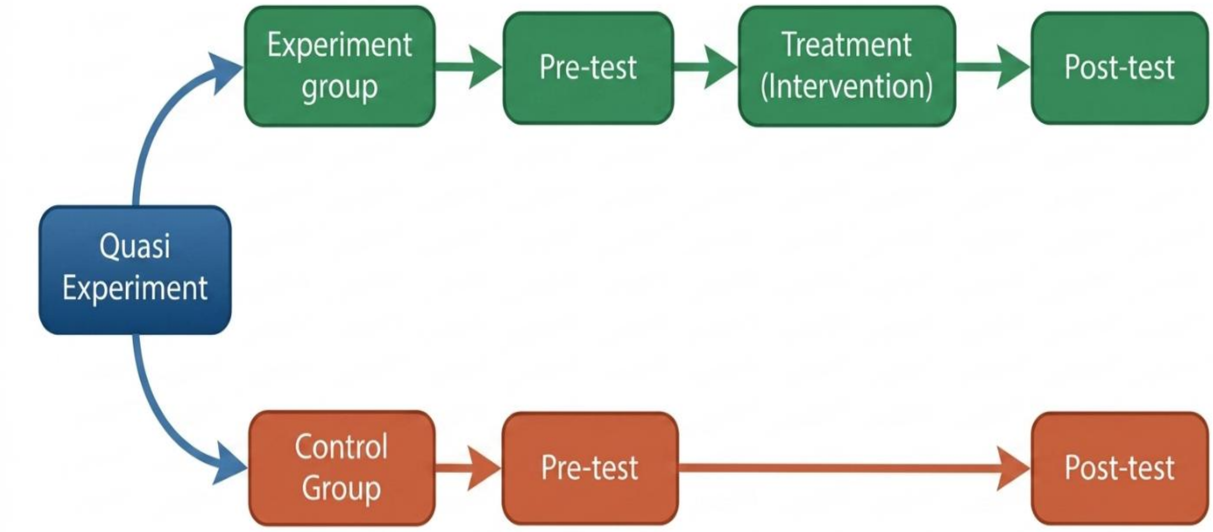

Figure 1. *Flowchart of the pre-test, post-test quasi-experimental design framework.*

Research Techniques

A pre-test and post-test nonequivalent control group was used in this quasi-experimental study to evaluate how the competency-based curriculum (CBC) affected trainees' capacity to write chemical symbols, create chemical formulae, and balance chemical equations. The researchers were able to compare learning gains and assess the efficacy of CBC implementation by having both groups complete pre-tests before the intervention and post-tests afterward. Because random assignment has practical limitations in educational settings, especially in College of Teacher Education (CTE) institutions, this design was chosen.

Study Population

All first-year, second-semester regular Environmental Science trainees at Chiro College of Teacher Education (CCTE) for the 2025 academic year make up the study's target population. The study specifically focused on the 66 trainees who were enrolled in Sections Seven and Eight combined. These trainees were presently enrolled in the Oromia State University Chiro Education Campus environmental science program. These trainees stand in for the group of students who participated in the study and were observed in order to evaluate and enhance their abilities to write chemical equations, formulas, and symbols as part of their general chemistry coursework.

The Study's Sample and Sampling Methods

The sample population for this study consists of all regular Environmental Science trainees for the 2025 academic year. To ensure that the sample reflects those who are most likely to struggle with chemical symbols, formulas, and equations, the trainees who were enrolled in the pertinent courses were specifically chosen to take part in the study. To target the group of students who are directly involved in the study and have experienced the problems being investigated, the purposive sampling technique is used. When researchers look for participants who fit particular requirements pertinent to the study, purposeful sampling works well (Creswell, 2014; Etikan et al., 2016).

Data Collection Instrument

Questionnaire

The researcher's main instrument for gathering data was a questionnaire. To collect a well-rounded combination of qualitative and quantitative data, the questionnaire contained both open-ended and closed-ended questions. This method was thought to be the most suitable for gathering a variety of answers while guaranteeing that both descriptive and numerical data could be successfully analyzed (Creswell, 2014). In this situation, a questionnaire is particularly helpful since it enables the researcher to effectively oversee the formulation of the questions and the evaluation of the answers. Additionally, by providing a structured format and anonymity, it helps minimize respondent biases, which can lessen the likelihood of social desirability bias (Dillman et al., 2014)**.**

Observation in the Classroom

Classroom observation was another important data collection method used in this study. This instrument was chosen by the researcher in order to collect first-hand, real-time data regarding the actual classroom environment while instruction was taking place. Through classroom observation, the researcher can gather data on a range of learning process elements, including student engagement, the use of active learning strategies by teachers, and other pertinent classroom dynamics (Cohen et al., 2018; Johnson & Christensen, 2019). Particularly with regard to the acquisition of chemical symbols, formulas, and equations, these observational data were found to offer important insights into how trainees interact with the material and the instructional strategies used. Additionally, it provides the chance to watch how students and teachers interact in a natural environment, which may highlight other elements affecting the students' comprehension and performance (McMillan, 2012).

Data Analysis Techniques

Three primary categories were used to group the study's findings, each of which will correspond to a particular research question that was derived from the data gathered. These categories include (1) how accurately trainees write chemical symbols, formulas, and equations; (2) obstacles to writing these fundamental components; and (3) instructional strategies that improve trainees' chemistry comprehension. Every data collection instrument is made to provide the most thorough response to these particular research questions. To provide both descriptive and quantitative insights, the information collected from the respondents was arranged and examined using tables and percentages. A clear tabulation of the responses was done, and the results will be visually represented using graphical representations (such as pie charts and bar charts). A more thorough and approachable comprehension of the data, particularly the test results, is made possible by this method.

Implementation of the Action Plan

This study was implemented in multiple phases.

Phase 1: Planning and Preparation: The researcher developed and improved competency-based curriculum strategies in this first phase to meet the unique requirements of first-year environmental science trainees. This included creating practical exercises, problem-solving activities, and group projects that were meant to improve trainees' comprehension of the fundamental ideas of chemistry. In order to facilitate the execution of these activities, the necessary teaching materials and resources will also be prepared. Active learning, inquiry-based exercises, and practical experiences that promote conceptual engagement and enhance students' comprehension of the subject matter were given priority in these strategies (Huddle & Sanger, 2009; Pavlova et al., 2020).

Phase 2: Instruction and Activity Introduction: The researcher will present the competency-based curriculum approach to the trainees during this phase. The learning objectives, the significance of the activities, and how these will advance their comprehension of chemical symbols, formulas, and equations will be the main topics of the first sessions. Initial exercises will also be given to trainees in order to assess their foundational understanding of the subjects. Following the analysis of the pre-test results and the information gleaned from additional data sources, including questionnaire responses, classroom observations, and attitude tests, the implementation of these interventions will get underway. In order to ensure that the actions are in line with the needs of the trainees, the researcher used this analysis to guide the customization of the interventions to address particular areas of difficulty found in the initial assessment. In addition to increasing trainees' accuracy when writing chemical symbols, formulas, and equations, these interventions are anticipated to promote a positive attitude toward chemistry, lessen misconceptions, and raise overall student engagement.

Phase 3: Activity Implementation: During this phase, the competency-based curriculum sessions were actually carried out. Interactive lessons led by the researcher included group discussions, practical experiments, and problem-solving exercises centered on chemical symbols, formula construction, and equation balancing. Throughout the process, feedback was given to correct misconceptions and reinforce learning, and active participation was encouraged.

Phase 4: Monitoring and Feedback: The researcher kept a close eye on the trainees' progress during the implementation phase. In order to make sure that trainees are successfully participating in the activities and improving their learning, this involved regular formative assessments, classroom observations, and informal feedback sessions. Based on observations and feedback, the teaching strategies were modified as necessary.

Phase 5: Evaluation and Reflection**:** The researcher assessed the intervention's efficacy at the end of the competency-based curriculum sessions. This included summative evaluations of the trainees' proficiency with chemical symbols, formulas, and equations, in addition to reflections on the procedure as a whole. To ascertain the degree of progress and pinpoint areas in need of additional work, the information gathered from the surveys, classroom observations, and other evaluations will be examined.

RESULTS AND DISCUSSION

Results

The general objective of this study was to examine the effectiveness of the Competency-Based Curriculum (CBC) approach in enhancing the practice of writing chemical symbols and formulae among environmental science trainees at Oromia State University, Chiro Educational Campus, Ethiopia. The results and discussion section focused on determining whether the competency-based instructional approach brought measurable improvement in trainees' ability to correctly identify, write, and apply chemical symbols and formulae before and after the intervention. The comparison of pre-test and post-test results between the control and experimental groups revealed that trainees exposed to the CBC approach demonstrated better performance and greater improvement than those taught through the conventional method.

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Table 1

Pre-Test Results for writing the chemical symbols (N=66)

Element	Symbol	Pre-test Control (%)	Pre-test Experimental (%)	Post-test Control (%)	Post-test Experimental (%)
Chlorine	Cl	30(90.91)	32(96.97)	30(90.90)	32(96.90)
Calcium	Ca	31(93.94)	30(90.91)	31(93.93)	30(90.90)
Boron	B	16(48.48)	14(42.42)	16(48.48)	23(69.60)
Hydrogen	H	25(75.76)	24(72.73)	25(75.75)	27(81.80)
Nitrogen	N	25(75.76)	23(69.70)	25(75.75)	31(93.90)
Sodium	Na	23(69.70)	25(75.76)	23(69.69)	32(96.90)
Potassium	K	24(72.73)	28(84.85)	24(72.72)	30(90.90)
Iron	Fe	29(87.88)	25(75.76)	29(87.87)	29(87.80)
Silver	Ag	17(51.52)	11(33.33)	17(51.51)	26(78.70)
Oxygen	O	11(33.33)	25(75.76)	11(33.33)	28(84.80)
Mercury	Hg	7(21.21)	9(27.27)	7(21.21)	32(96.90)

Table 1 shows the pre-test and post-test results for the control and experimental groups on writing the chemical symbols. These data provide evidence to support that the experimental group performed better than the control group after the instruction. Both groups beforehand achieved high rates of correct recognition when common elements were involved, such as Cl, Ca, H, and Fe (over 70% of accuracy). This could mean that for these signs, the participants already had quite a lot of prior knowledge.

However, there was a greater increase in the experimental group after treatment for items with a lower initial recognition rate. For example, the experiment group's correct rate of knowing boron (B) was raised from 42.4% to 69.7%, while that of the control group did not improve. The recognition rate of nitrogen (N) increased from 69.7% to

93.9% in the experimental group and showed no significant change in the control group.

However, for elements with lower initial recognition rates, more substantial improvements were observed in the experimental group following the intervention. For instance, the experimental group's correct identification of boron (B) increased from 42.4% to 69.7%, while the control group showed no improvement. Similarly, recognition of nitrogen (N) rose from 69.7% to 93.9% in the experimental group, compared to no change in the control group.

Significant improvements were also observed for elements with Latin-derived or non-phonetic symbols. Recognition of silver (Ag) increased markedly in the experimental group—from 33.3% to 78.8%, while the control group remained nearly unchanged. A similar trend occurred for oxygen (O) and mercury (Hg), where the experimental group's recognition rose from 75.8% to 84.8% and from 27.3% to 96.9%, respectively.

Table 2

Trainees' Reactions and Justifications for Incorrectly Writing the Chemical Formula of Copper (I) Oxide (N = 66)

Chemical Formula Given	Trainees' Reason for the Formula	Pre-test (Control)	Pre-test (Experimental)	Post-test (Control)	Post-test (Experimental)
Cu_2O	Copper (I) is Cu, and oxide is O.	9 (27.27%)	11 (33.33%)	10 (30.31%)	31 (93.94%)
CuO	Copper (II) is Cu; oxide is O^{2-}	10 (30.31%)	10 (30.31%)	9 (27.27%)	2 (6.06%)
CuO_2	Copper (II) is Cu; oxide is O^{-}.	13 (39.39%)	12 (36.36%)	14 (42.42%)	
CuO_2^{-}	Copper (I) is Cu; oxide is O^{2-}.	1 (3.03%)			

Table 2 presents the trainees' responses and justifications for writing the chemical formula of copper (I) oxide before and after the instructional intervention. The pre-test results reveal a wide distribution of incorrect responses across both groups, indicating confusion regarding ionic charges and oxidation states.

In the pre-test, only 9 trainees (27.3%) from the control group and 11 trainees (33.3%) from the experimental group correctly identified the formula Cu_2O. A substantial number of trainees incorrectly wrote CuO or CuO_2, demonstrating misconceptions about copper's oxidation states. For instance, 10 trainees (30.3%) from each group provided CuO, while 13 trainees (39.4%) in the control group and 12 trainees (36.4%) in the experimental group wrote CuO_2. Some even produced CuO_2^{-}, reflecting a fundamental misunderstanding of charge balance.

Following the instructional intervention, there was a notable improvement in the experimental group's performance. Correct responses for Cu_2O increased dramatically to 31 trainees (93.9%), while incorrect formulas such as CuO dropped sharply to 2 trainees (6.1%). In contrast, the control group showed minimal improvement, with correct responses increasing only slightly from 9 (27.3%) to 10 (30.3%). These results suggest that the intervention significantly enhanced the experimental group's understanding of chemical formula construction.

Table 3

Trainees' Reactions and Justifications for Erroneously Writing Iron (II) Sulphide's Chemical Formula (N = 66).

Chemical Formula Given	Trainees' Reason for the Formula Provided	Pre-test (Control)	Pre-test (Experiment)	Post-test (Control)	Post-test (Experiment)
Fe_2S	Iron (II) is 2Fe, and sulphide is S.	7(21.21%)	5 (15.15%)	12(36.36%)	30 (90.90%)
FeS_2	Iron is Fe, and sulphide is 2S.	7(21.21%)	7 (21.21%)	11 (33.33%)	3 (9.09%)
$Fe(SO_3)_2$	Iron is Fe and sulphide is SO_3, but it is multiplied by 2 because it is bonded to iron (II).	8(24.24%)	6 (18.18%)	10 (30.30%)	
$Fe(SO)_2$	Iron is Fe, and sulphide is SO, but it is multiplied by 2 because it is bonded to iron (II).	12(36.36)	14 (42.42%)		

Table 3 summarizes trainees' responses and reasoning regarding the chemical formula of iron (II) sulfide (FeS) during pre-test and post-test phases for both control and experimental groups. The pre-test results revealed widespread misconceptions about ionic bonding, oxidation states, and the correct use of chemical symbols for sulfide compounds.

In the pre-test, only a small proportion of trainees demonstrated partial understanding of the compound's composition. Five trainees (15.15%) from the experimental group and seven (21.21%) from the control group provided Fe_2S, reflecting confusion about the stoichiometric relationship between Fe^{2+} and S^{2-} ions. Similarly, seven trainees (21.21%) in both groups selected FeS_2, showing an incorrect assumption that sulfur's bonding capacity required doubling its subscript.

Errors involving polyatomic ions were also common. For example, $Fe(SO_3)_2$ was chosen by eight trainees (24.24%) in the control group and six (18.18%) in the experimental group, while $Fe(SO)_2$ appeared in twelve (36.36%) control responses and fourteen (42.42%) experimental responses. These responses demonstrate confusion between sulfide (S^{2-}), sulfite (SO_3^{2-}), and even nonexistent ions like "SO."

Following the instructional intervention, the experimental group exhibited a marked improvement. Thirty trainees (90.90%) selected Fe_2S in the post-test, a significant increase from 15.15% in the pre-test. Additionally, incorrect responses involving FeS_2, $Fe(SO_3)_2$, and $Fe(SO)_2$ declined sharply. No trainees in the experimental group used $Fe(SO)_2$ in the post-test, indicating the elimination of that misconception.

In contrast, the control group showed only modest progress. The percentage of trainees providing Fe_2S increased slightly from 21.21% to 36.36%, while misconceptions involving FeS_2 and polyatomic ions persisted. Table 4 summarizes trainees' responses and reasoning when writing the chemical formula of copper (II) phosphate ($Cu_3(PO_4)_2$) before and after the instructional intervention. The results indicate that both the control and experimental groups initially struggled to correctly apply valency and charge-balancing principles.

Table 4

Trainees' Responses and Reasons for Writing the Chemical Formula of Copper (II) Phosphate (N=66)

Chemical Formula Given	Trainees' Reason for the Formula Provided	Pre-test (Control)	Pre-test (Experiment)	Post-test (Control)	Post-test (Experiment)
$CuPO_4$	Copper (II) is Cu^{2+}, and the phosphate ion is	9 (27.28%)	10 (30.30%)	12(36.36%)	2 (6.06%)
$Cu_3(PO_4)_2$	Copper (II) is Cu^{2+}, the phosphate ion is $PO_4^{2}.^{-}$	7 (21.21%)	6 (18.18%)	9 (27.27%)	29 (87.87%)
Cu_2PO_4	Copper (II) is Cu^{2+}, phosphate is PO_4.	12(36.36%)	12 (36.36%)	7 (21.21%)	2 (6.06%)
Cu_2P_4	Copper (II) is Cu^{2+}, phosphate is P_4.	7 (21.21%)	3 (9.09%)	5 (15.15%)	

During the pre-test, only 7 trainees (21.21%) from the control group and 6 trainees (18.18%) from the experimental group provided the correct formula, $Cu_3(PO_4)_2$. The majority selected incorrect formulas such as $CuPO_4$ and Cu_2PO_4, chosen by over 60% of trainees in both groups combined. These incorrect responses suggest that while trainees recognized copper (II) as Cu^{2+} and phosphate as a related species, they failed to apply proper charge balancing between the ions. The selection of $CuPO_4$, for example, reflects the mistaken assumption that one Cu^{2+} ion can directly combine with one PO_4^{3-} ion to form a neutral compound. A similarly frequent error was Cu_2PO_4, chosen by 36.36% of both groups, implying a misunderstanding of the ratio between Cu^{2+} and PO_4^{3-} ions. Furthermore, Cu_2P_4, selected by 21.21% of the control group and 9.09% of the experimental group, reveals confusion between the polyatomic ion phosphate (PO_4^{3-}) and the molecular form of phosphorus (P_4).

After the instructional intervention, the experimental group demonstrated substantial improvement. The proportion of correct responses rose sharply to 29 trainees (87.87%), compared to only 9 trainees (27.27%) in the control group. Incorrect answers such as $CuPO_4$ and Cu_2PO_4 decreased drastically in the experimental group to 6.06% each, and Cu_2P_4 was no longer selected by any trainee. These results indicate that the intervention effectively addressed misconceptions about charge balance, oxidation states, and the proper use of polyatomic ions.

Discussion

The main objective of this research was to examine the effectiveness of the instructional intervention on students' achievement in identifying chemical elements and their symbols. Specifically, the study aimed to compare the performance of students in the control group and the experimental group during the pre-test and post-test phases.

Table 1 results indicate that the instructional intervention had a positive impact on students' ability to correctly identify and write chemical symbols, particularly for elements with less intuitive or Latin-derived abbreviations.

The high pre-test scores for Cl, Ca, H, and Fe indicate that these symbols are widely recognized, likely due to their frequent appearance in early science education and everyday contexts. This aligns with previous research suggesting that familiarity and repeated exposure lead to higher baseline knowledge (Johnson & Christensen, 2019). For elements with lower initial familiarity—such as B, Ag, O, and Hg—the experimental group's post-test improvements demonstrate the effectiveness of the targeted pedagogical approach. These findings support the notion that structured instructional interventions can bridge gaps in students' understanding of chemical notation, particularly for symbols derived from Latin or those lacking clear phonetic cues (Brown et al., 2014).

The substantial gain in recognizing Hg (Mercury), where the experimental group achieved near-perfect accuracy, underscores the potential of focused instruction in addressing conceptual difficulties and enhancing symbol literacy. Overall, the results affirm that deliberate, context-based teaching strategies can significantly improve learners' comprehension of chemical symbols, particularly for those that are not intuitively recognizable.

The results in Table 2 show that the instructional intervention had a substantial positive effect on trainees' understanding of oxidation states and the proper formulation of ionic compounds. The pre-test results highlighted widespread misconceptions, particularly surrounding the interpretation of Roman numerals in chemical nomenclature and the relationship between oxidation states and charge balance. Many trainees incorrectly assumed that CuO could represent all copper oxides or that copper (II) could pair with a monovalent oxygen ion (O^-), resulting in erroneous formulas such as CuO_2. These findings are consistent with earlier research identifying oxidation number misinterpretation as a common learning obstacle in chemistry education (Johnson & Tang, 2021). The experimental group's significant improvement—from 33.3% correct responses in the pre-test to 93.9% in the post-test—demonstrates the effectiveness of the instructional approach. The intervention likely succeeded because it explicitly addressed key conceptual gaps, including oxidation number assignment, charge balancing, and formula derivation. Such focused instruction aligns with established findings that scaffolded learning, guided practice, and visual representations can enhance comprehension of abstract chemical concepts (Kumar, 2022; Smith et al., 2022). In contrast, the control group's negligible improvement (from 27.3% to 30.3%) suggests that traditional teaching methods were insufficient to correct entrenched misconceptions. This limited progress supports prior evidence that passive learning approaches often fail to develop deep conceptual understanding in chemistry (Bretz, 2012). Overall, the findings underscore the value of explicit, concept-based instruction in improving learners' mastery of chemical formulas and oxidation principles. The success of the experimental group highlights the importance of integrating active learning strategies that promote conceptual clarity and long-term retention in chemical education.

The results in Table 3 demonstrate that the instructional intervention effectively reduced misconceptions related to ionic bonding, oxidation states, and the formulation of binary compounds. The pre-test findings revealed widespread misunderstandings about the relationship between metal cations and nonmetal anions, particularly regarding charge balancing and stoichiometric ratios. Many trainees incorrectly associated the Roman numeral "II" with the number of metal atoms rather than the oxidation state, leading to responses such as Fe_2S and FeS_2. The frequent appearance of $Fe(SO_3)_2$ and $Fe(SO)_2$ in the pre-test suggests that trainees struggled to differentiate between binary ions and polyatomic ions and sometimes invented nonexistent ion species. This confusion reflects a lack of conceptual understanding about ionic bonding rules and the distinct nature of sulfide compared to sulfate or sulfite ions, consistent with the findings of Cooper and Stieff (2011) and Bretz (2012).

After the intervention, the experimental group's performance improved dramatically, with most trainees applying oxidation state and charge-balance principles more accurately. Although the correct chemical formula for iron (II) sulfide is FeS, the strong preference for Fe_2S in the post-test indicates a near-correct conceptualization of charge balance, even if some overcompensation remained (Cooper & Stieff, 2011). The elimination of incorrect polyatomic ions further suggests that trainees developed a clearer understanding of ionic species and naming conventions (Smith et al., 2022). In contrast, the control group's limited progress highlights the inadequacy of passive or traditional instruction in addressing deep-seated misconceptions. Persistent errors such as FeS_2 and $Fe(SO_3)_2$ suggest that exposure alone does not foster conceptual change. This aligns with research emphasizing that explicit, scaffolded instruction and interactive teaching strategies are necessary to promote accurate mental models of chemical bonding (Mulford & Robinson, 2002; Jones & Wang, 2022).

Overall, the findings underscore the importance of conceptually focused instruction that integrates guided practice, discussion, and visualization to help students correctly apply oxidation rules and ionic charge balancing. By actively engaging learners in reasoning about ion formation and compound structure, educators can effectively correct misconceptions and deepen conceptual understanding in chemistry. The findings from Table 4 highlight the significant impact of conceptual, targeted instruction on trainees' ability to correctly construct the chemical formula for copper (II) phosphate. The pre-test results revealed a widespread lack of understanding regarding charge neutrality and ionic compound formulation. Many trainees applied an additive or one-to-one approach to combining ions (e.g., $CuPO_4$), without recognizing the need to use the Least Common Multiple (LCM) to balance charges between Cu^{2+} and PO_4^{3-} ions. This type of procedural error, frequently reported in the literature, reflects surface-level knowledge of ion symbols but insufficient grasp of the underlying principles of electrostatic neutrality (Stains et al., 2021). Errors such as Cu_2P_4 further revealed that some trainees confused polyatomic ions with elemental forms, treating phosphate as a cluster of phosphorus atoms rather than as an ion composed of phosphorus and oxygen. This misconception mirrors broader findings in chemical education research, where students often blur the conceptual boundaries between molecular and ionic representations (Talanquer, 2017).

After the intervention, the experimental group's strong performance—87.87% accuracy—demonstrates the effectiveness of explicit instruction emphasizing valency rules, charge balancing, and differentiation of ionic and covalent species**.** The marked decline in incorrect responses and the complete elimination of chemically implausible formulas (like Cu_2P_4) suggest that trainees developed a more coherent mental model of ionic compound formation.

These outcomes align with recent scholarship advocating for conceptually driven, scaffolder teaching strategies that engage learners in reasoning through representations rather than memorizing formulas (Cooper et al., 2021; Weinrich & Talanquer, 2016). Moreover, the results reinforce calls to shift chemistry instruction toward integrated conceptual understanding—linking symbolic, particulate, and macroscopic representations—to promote deep learning and chemical reasoning.

CONCLUSIONS

The findings of this study clearly indicate that the Competency-Based Curriculum (CBC) approach significantly enhanced the ability of environmental science trainees at Oromia State University, Chiro Education campus, to practice writing chemical symbols and formulae accurately. The pre-test results revealed that trainees entered the study with varied levels of prior knowledge and several conceptual gaps. Although commonly encountered elements such as chlorine, calcium, and hydrogen were relatively well recognized, many trainees had difficulty identifying less familiar elements such as mercury and silver. Likewise, substantial misconceptions were observed in constructing chemical formulae, particularly for compounds requiring understanding of oxidation states, valency, charge balancing, and the correct use of polyatomic ions.

Following the targeted instructional intervention based on the competency-based approach, the experimental group demonstrated remarkable improvement in both symbol recognition and formula construction compared to the control group, which showed only limited progress. The substantial gains observed in the post-test results confirm that the CBC approach was effective in improving trainees' practical chemistry competencies and conceptual understanding.

Therefore, the study concludes that a competency-based instructional approach plays a vital role in strengthening trainees' reasoning skills, problem-solving abilities, and practical application of chemistry concepts. The findings further suggest that chemistry instruction should move beyond rote memorization and emphasize active practice, conceptual clarity, and learner-centered activities to achieve meaningful learning outcomes. This approach is particularly important in teacher education institutions such as Chiro CTE, where trainees are expected to develop both subject mastery and effective teaching competencies.

Recommendations

Integrate Concept-Focused Teaching: Rather than focusing on memorization, the teacher should emphasize conceptual understanding of symbols, oxidation states, and ionic relationships.

Make Use of Diagnostic Assessments: To address particular learning gaps and customize instruction, teachers should find students' preexisting misconceptions early on.

Use Active Learning Strategies: To strengthen comprehension of chemical formulas, activities like problem-based learning, guided practice, and peer collaboration should be used.

Offer Ongoing Support and Feedback: Students can monitor their progress and quickly clear up misunderstandings with the aid of frequent formative assessments and feedback.

Additional Research: Future investigations could look at how conceptual knowledge is retained over time and how laboratory experiences or digital tools affect the ability. How To Practice Writing Chemical Symbols And Formulae Through a Competency-Based Curriculum Approach.

CRediT Authorship Contribution Statement

The author confirms sole responsibility for the entire scope of this manuscript, including study conception, methodology design, data collection, analysis, and manuscript preparation.

Declaration of Competing Interest

There was no conflict of interest.

Ethical Approval

Not applicable

Data Availability Statement

Upon reasonable request, the corresponding author will provide the data.

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