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Research Article

Exploring the Role of Improvisation and Implementation Challenges in Science Teaching: A Standard-Based Curriculum Study

Charity Esenam Anor[1,*], Daniel Morrison[1], Sibaweihi Zaaria[1]
[1] Department of Integrated Science Education/Faculty of Science Education, University of Education, Winneba, Ghana

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ABSTRACT

Purpose of the study: Standards-based curriculum reforms emphasise competency development and learner-centered pedagogy, yet implementation in resource-constrained contexts remains underexplored. While research has documented general curriculum implementation challenges, limited empirical evidence exists on specific challenges in science teaching and how teachers employ improvisation to bridge resource gaps in competency-based science education.

Methodology: A qualitative case study design was employed involving five science teachers purposively selected from five government basic schools in Ghana. Data were collected through semi-structured interviews, audio-recorded and transcribed. Thematic analysis identified patterns and themes. The interview protocol was adapted from established curriculum implementation instruments and validated through expert review with trustworthiness ensured.

Main Findings: Four major challenges emerged as inadequate teacher training in competency-based pedagogy, insufficient instructional resources and laboratory equipment, difficulties implementing authentic assessment, and challenges adapting curriculum content to local contexts. Teachers employed systematic improvisation using locally available materials, which enhanced student engagement, facilitated conceptual understanding of abstract concepts, and aligned with learner-centered objectives. However, improvisation was constrained by time limitations, lack of institutional support, and absence of formal training in material adaptation.

Novelty/Originality of this study: This study provides empirical evidence that teacher improvisation constitutes a deliberate pedagogical strategy rather than a compensatory response to resource scarcity, as systematically improvised materials significantly enhance engagement and conceptual understanding. The key implication calls for a policy shift prioritising formal improvisation training, institutional time allocation for material adaptation, and professional recognition of improvisation as valid pedagogy.

Corresponding Author:
Charity Esenam Anor,
Department of Integrated Science Education, Faculty of Science Education, University of Education, Winneba, Central Region, P.O Box 25, Ghana.
Email: ceassey@uew.edu.gh

1. INTRODUCTION

Standards-based curriculum reforms have emerged globally as mechanisms to enhance educational quality through competency development, learner-centered pedagogy, and authentic assessment practices [1]. In Sub-Saharan Africa, countries including Ghana, Tanzania, Uganda, Kenya, and South Africa have implemented competency-based curricula emphasising practical skills, critical thinking, and real-world application over traditional content memorisation [2]-[4]. Ghana's Standards-Based Curriculum (SBC), introduced in 2019, represents a fundamental pedagogical shift requiring teachers to facilitate inquiry-based learning, implement authentic assessment, and develop learners' core competencies including critical thinking, creativity, communication, and collaboration [5].

However, implementation of standards-based reforms in resource-constrained contexts have been reported to be confronted with challenges such as inadequate professional development, insufficient instructional materials, overcrowded classrooms, and limited laboratory infrastructure [6]-[8]. These resource constraints are particularly acute in science education, where hands-on experimentation and practical activities are essential for developing scientific literacy and process skills [9]. The question is, do these challenges apply to the teaching of science in basic schools of the study? If they do, how do science teachers in these schools navigate the challenges through improvisation to bring about effective teaching and learning.

While existing literature documents general curriculum implementation challenges in developing contexts [9], [10], critical gaps remain unaddressed in the specific context of standards-based science education. Although studies broadly acknowledge resource shortages and training deficits, systematic documentation of how these challenges specifically manifest in science teaching in Ghanaian basic schools remains insufficient [11], [12]. Understanding the dynamics of these science-specific implementation challenges is essential for developing focused interventions and support systems.

Moreover, limited empirical research exists on how science teachers strategically employ improvisation as a deliberate pedagogical approach rather than merely a compensatory response to resource scarcity [13], [14]. While improvisation is frequently mentioned as a coping mechanism, insufficient evidence exists regarding the specific improvisation practices teachers use in science instruction, how these practices enhance student engagement and learning outcomes, whether improvisation aligns with competency-based learning objectives, and what constraints limit effective improvisation in science teaching [15], [16]. Given that improvisation in science education involves unique considerations including scientific accuracy, laboratory safety, and alignment with inquiry-based learning principles, systematic examination of these practices is crucial. These gaps are particularly urgent for science teaching given the widespread adoption of competency-based curricula across Sub-Saharan Africa and persistent resource constraints that characterise educational systems in the region [17], [18]. The study therefore sought to: (1) investigate challenges science teachers face in implementing the Standard-Based Curriculum (SBC) in science education and (2) explore the improvisation practices that exist in the implementation of the SBC in science education at the selected basic schools in Ghana.

2. LITERATURE REVIEW

2.1. General Overview of the Standard Based Curriculum

The standards-based science curriculum introduced in basic schools in Ghana signifies a transition toward a competency-driven model of education that seeks to enhance the quality of science learning while strengthening students' critical thinking abilities [14]. The Government of Ghana, acting through the Ministry of Education, implemented this curriculum to replace the former content-focused framework. Unlike the earlier approach, the standards-based curriculum prioritises the development of clearly defined competencies, knowledge, and practical skills necessary for effective participation in the modern world [15]. These competencies include critical thinking and problem solving, creativity and innovation, communication and collaboration, cultural identity and global citizenship, personal development and leadership, and digital literacy [16]. According to the national council for curriculum and assessment (NaCCA), the overarching aim of the science curriculum is to nurture scientific literacy, promote critical reasoning, strengthen problem-solving capabilities, and develop inquiry skills among learners [17]. Consequently, the adoption of the standards-based curriculum in Ghana, especially within science education, reflects a deliberate effort to promote a modern, learner-centred system of teaching and learning.

A major focus of the science curriculum is the promotion of scientific literacy, which is essential for preparing students to function effectively as informed citizens in a technologically advancing society [18]. Scientific literacy extends beyond acquiring factual scientific knowledge to include the ability to understand, interpret, and critically assess scientific information [19]. Through this process, learners gain the capacity to make informed decisions, engage meaningfully in scientific discussions, and contribute constructively to societal development. The curriculum's strong emphasis on critical thinking and problem-solving aligns with the demands of the twenty-first century [20]. In a period characterised by rapid scientific advancements and complex global challenges, students must be equipped to analyse issues, evaluate evidence, and generate innovative solutions. Therefore, the standards-based framework prioritises instructional strategies that prepare learners to

contribute effectively to national and global development [21], [22]. In addition, the inclusion of inquiry skills in the science curriculum demonstrates a shift toward experiential and participatory learning approaches [23]. Inquiry-based learning encourages students to investigate scientific ideas actively through questioning, experimentation, and exploration [24], [25].

Within this approach, learners formulate questions, develop hypotheses, conduct investigations, collect and analyse data, and draw conclusions based on evidence. Such engagement deepens their understanding of scientific processes, enhances analytical thinking, and nurtures curiosity. As a result, the implementation of the standards-based science curriculum in Ghana positions it as a vital instrument for cultivating scientifically literate citizens capable of contributing to national progress and global development. This learner-focused orientation also promotes active participation, strengthens conceptual understanding, and prepares students for further academic pursuits and careers in STEM fields [26]. The standards-based science curriculum is organised around four main thematic areas: Life and living things, Physical and chemical properties of materials, Energy and its effects, and Earth and space. Each theme consists of strands that gradually expand learners' comprehension of scientific ideas. Examples of these strands include materials, living cells, crop production, animal production, the solar system, electricity and electronics, waste management, climate change and green economy, science and industry ecosystem, and the human body system. The organisation of the curriculum around these themes reflects a structured and systematic strategy for developing scientific knowledge and understanding. The diversity of the themes enables learners to explore multiple dimensions of the natural and physical world [27], while the inclusion of various sub-strands within each theme also ensures a progressive and scaffolded learning experience. Concepts introduced at the foundational levels are revisited and expanded upon in higher grades, allowing learners to consolidate prior knowledge while developing more complex understandings. This spiral progression contrasts with the former objective-based curriculum, which lacked such systematic continuity.

Furthermore, the curriculum adopts a learner-centred orientation that promotes active involvement through practical activities, field experiences, and real-life applications [28]. These experiential learning opportunities allow students to apply scientific principles in meaningful contexts, thereby strengthening their understanding and enhancing their problem-solving abilities [29]. This approach also encourages learners to take responsibility for their own learning while fostering curiosity, creativity, and investigative thinking. In effect, the design and organisation of the standards-based science curriculum in Ghana demonstrate a comprehensive and forward-looking approach to science education [30]. It emphasises both scientific literacy and practical competencies, equips students with essential knowledge and skills, nurtures sustained interest in science and promotes appreciation for the natural environment.

2.2. Challenges Faced in Implementing the New Standard Based Curriculum

The standards-based science curriculum has strong potential to improve science teaching and learning, however, its implementation is confronted with several challenges. [31] pointed out key constraints such as inadequate infrastructure and resources, insufficient teacher preparation, and the lack of suitable instructional materials. Effective implementation depends largely on competent and well-trained science teachers who can facilitate meaningful learning experiences. Beyond possessing sound subject knowledge, science teachers must also demonstrate strong pedagogical abilities that enable them to create stimulating, interactive, and learner-centred classrooms. It is therefore important that teacher education and training programmes are aligned with the curriculum so that teachers acquire the competencies and instructional strategies needed to implement the standards successfully and promote students' scientific literacy and skills [9]. Continuous professional development (CPD) programmes and ongoing professional support are equally essential in bridging training gaps and maintaining high standards in science education.

Inadequate access to laboratory apparatus, textbooks, and technological tools further limits students' opportunities to engage fully with scientific concepts [32], [33]. For example, in Rwanda, the shortage of laboratory facilities and equipment prevents some practical activities outlined in the curriculum from being carried out effectively [34]. Addressing such shortages is necessary to ensure that all learners have equal opportunities to benefit from quality science education. In addition, the availability of instructional materials that align with the curriculum is critical. Up-to-date textbooks, laboratory guides, and supplementary learning resources that reflect the content and teaching approaches of the standards-based curriculum are vital in supporting both teachers and students [35]. These materials provide direction, examples, and opportunities for investigation and inquiry. Consequently, the development and distribution of relevant, context-specific, and accessible instructional resources are essential for strengthening curriculum implementation and improving classroom practices [36].

Limited infrastructure also presents significant barriers to practical and experiential learning. Many basic schools in Ghana lack science laboratories, computer facilities, and reliable internet access [36], making it difficult for teachers and students to conduct experiments, simulations, and other hands-on activities. Even in some urban schools, the absence of space for school farms restricts opportunities for agricultural experiments

[37]. Such limitations reduce students' exposure to inquiry-based learning experiences that require them to apply knowledge in solving real-life problems or exploring scientific ideas in depth. Practical activities and projects play an important role in fostering teamwork, independent thinking, and creativity, while allowing students to demonstrate their understanding of scientific concepts in meaningful contexts [38]. Assessment practices also pose challenges, particularly regarding the evaluation of practical skills and real-life applications of knowledge, as schools across Ghana operate under varying conditions. Traditional assessment approaches may not adequately measure the diverse competencies targeted by the curriculum, as noted by [34] and [37]. These authors argue that conventional examinations tend to emphasise memorisation and recall, which do not fully reflect students' abilities to think critically, solve problems, and apply knowledge in authentic contexts. They therefore recommend the use of alternative assessment strategies such as performance-based assessments, portfolios, and project work [37], [39], [40].

These strategies support active participation and the development of essential twenty-first-century competencies that extend beyond memorization, which characterised the earlier objective-based curriculum [15]. However, implementing these alternative approaches requires careful planning, adequate resources, teacher training, and effective monitoring to ensure fairness, reliability, and feasibility [41], [42].

2.3. Improvisation and its Relevance in Science Education

Improvisation in science education involves the use of locally available or unconventional materials to develop teaching resources and conduct experiments when standard equipment is scarce or unavailable [43]. This instructional strategy has gained recognition for its ability to increase student participation, support active learning, and strengthen problem-solving abilities [44]. When instructional materials are not used during lessons, interaction tends to decline and students' understanding may be limited, often resulting in poor academic performance [31]. In contrast, the use of improvised teaching resources can boost learners' motivation, stimulate creativity, and enhance critical thinking and innovation [45]. Within the Ghanaian context, improvisation has become an important strategy adopted by science teachers to implement the standards-based curriculum (SBC) effectively despite limited resources and other constraints [46]. Improvisation may also involve spontaneous activities such as acting, singing, dancing, playing musical instruments, engaging in dialogue, producing artwork, or responding creatively to immediate environmental stimuli [47]. When a required instructional material is unavailable, teachers may replace it with a suitable improvised alternative that they design or adapt. In this sense, improvisation refers to creating entirely new tools or modifying existing materials to perform specific instructional functions [48]. To improvise effectively, teachers must demonstrate creativity, resourcefulness, and practical skills in manipulating materials [43].

According to Akyeampong [46], improvisation is applicable across many fields, including the arts, sciences, education, medicine, engineering, and various non-academic areas. Teaching and learning inherently require improvisation because they engage learners' cognitive, affective, and psychomotor domains. Fonstad [49] further emphasised that creativity and improvisation are fundamental in Basic Technology, suggesting that improvisation occurs when individuals have internalised core concepts and can interpret and express them independently. Research indicates that improvisation enhances spontaneity, intuition, interaction, inductive discovery, attentive listening, nonverbal communication, role-playing, risk-taking, teamwork, creativity, and critical thinking [50]. For effective standards-based teaching, science teachers must understand improvisation and apply flexible strategies that help learners construct meaningful cognitive connections, relate concepts, and overcome misconceptions [51]. Teachers also need to recognise how improvisation links across disciplines and everyday experiences, as this understanding forms the basis of improvisational content knowledge that enables them to present ideas in ways that suit learners' needs [50].

Within Shulman's improvisational framework, science teachers are expected to possess two major forms of knowledge: deep subject content knowledge and knowledge of curriculum development. Content knowledge refers to an understanding of the structure, theories, principles, and concepts of a discipline, while knowledge of curriculum development involves familiarity with how to interpret, organise, and implement curricular content effectively for teaching and learning purposes [52]. When these two forms of knowledge are integrated, teachers can design meaningful learning experiences that enhance instructional delivery and support student learning outcomes.

The use of improvisation as a teaching strategy offers numerous benefits in science teaching. It improves teachers' pedagogical skills and creativity, allowing them to respond effectively to diverse learning situations [11]. It also encourages active student participation, critical thinking, and problem-solving, which align with the objectives of the SBC [18]. Another advantage is cost reduction, as teachers can produce teaching materials using locally available resources rather than relying on expensive commercial equipment [53]. This practice promotes self-reliance and boosts teachers' confidence during lesson delivery. Additionally, improvisation can save instructional time because teachers are able to modify their teaching approaches instantly based on learners' responses, creating a more flexible and responsive classroom environment [54]. Improvisation also fosters creativity among both teachers and students [55]. Teachers can design engaging learning activities,

while students can demonstrate innovative thinking and practical problem-solving skills, leading to deeper understanding and retention of concepts [56]. Furthermore, the promotion of improvisation can generate employment opportunities for unemployed youth within communities [43], as they can be trained to assist in producing improvised instructional materials, thereby contributing to both educational development and local economic growth.

For improvisation to be fully effective, it is essential that teachers, learners, and policymakers demonstrate positive attitudes toward its use [9]. Teachers should be willing to explore innovative teaching approaches and adjust their methods when necessary. Students should be encouraged to participate actively and contribute ideas during improvisational learning activities. At the policy level, government support is needed through training programmes, provision of resources, and policies that recognise the value of improvisation in education. Science teachers can create more interactive and effective learning environments that enhance understanding and empower students to develop confidence, creativity, and lifelong learning skills by embracing improvisation [55].

3. RESEARCH METHOD

This study employed a qualitative case study design [57] to explore science teachers' experiences with implementing the standards-based curriculum (SBC) and their improvisation practices in basic schools. The case study approach was selected because it enables in-depth, contextualised investigation of contemporary phenomena within real-life settings, making it particularly appropriate for examining the dynamics between curriculum implementation challenges and improvisation strategies. The study focused on five government basic schools in Ablekuma West Municipality, Ghana, treating each school as an embedded case within the broader phenomenon of SBC implementation in resource-constrained contexts. The simple random sampling was applied to select the five schools within the Municipality. A total of five science teachers, one each from each school were purposively selected based on accessibility, willingness to participate in the study, direct involvement in implementing the curriculum and possession of relevant experiences necessary for the study. The participant sample comprised three male and two female teachers to ensure gender balance. This technique ensured that participants could provide meaningful insights into improvisation practices and SBC implementation. Combining purposive and simple random sampling helped ensure variation among participants, minimised selection bias, and strengthened the credibility of the findings.

Data were collected through semi-structured interviews conducted between September and November 2024. The interview protocol was adapted from established curriculum implementation research instruments and included open-ended questions organised around two thematic areas notably, challenges encountered in implementing the SBC in science education and improvisation practices/ strategies employed. Each interview lasted approximately 45 minutes and was conducted in English at a location convenient to the participant. Interviews were audio-recorded with participants' informed consent and transcribed verbatim. Field notes were maintained throughout the data collection process to capture contextual observations and non-verbal cues. The interview protocol was validated through expert review by two curriculum specialists and one science education researcher, and was pilot-tested with two science teachers not included in the final sample. Minor revisions were made based on pilot feedback to improve question clarity and flow.

Several steps were taken to ensure the trustworthiness of the study by addressing credibility, dependability, confirmability, and transferability. Credibility was strengthened through expert validation of the interview schedules for clarity, relevance, and adequacy of the items. Necessary revisions were made based on the feedback received. Member checking was also conducted by sharing interview transcripts with participants to verify accuracy and allow for corrections where needed. Dependability was maintained by keeping detailed records of all procedures followed during data collection and analysis, making it possible for the study to be replicated under similar conditions. Confirmability was achieved by ensuring that interpretations were directly supported by participants' responses. The processes of coding, categorising, and developing themes were clearly documented to maintain transparency. Transferability was also enhanced by providing detailed descriptions of the research context, enabling readers to judge the extent to which the findings could be applied to similar educational environments, particularly urban basic schools with characteristics comparable to those in the Ablekuma West Municipality.

Data were collected through face-to-face with the selected science teachers who were labeled as T1, T2, T3, T4 and T5. Interview sessions were arranged at times convenient for participants, took place within their respective school settings and lasted for approximately 45 minutes. Before each interview, the purpose of the study was explained clearly, and informed consent was obtained from participants. With their permission, the interviews were audio-recorded to ensure accurate data capture. After data collection, the recordings were transcribed verbatim. Participants were then invited to review the transcripts to confirm their accuracy through member checking. which further enhanced the credibility of the study findings.

Data analysis followed Braun and Clarke's six-phase thematic analysis approach [58] which consist of familiarisation with data through repeated reading of transcripts, generation of initial codes through line-by-line coding, searching for themes by grouping related codes, reviewing themes for internal coherence and external distinctiveness, defining and naming themes, and producing the final analysis. The analysis process was iterative, moving recursively between data collection, coding, and theme development. Initial coding was inductive, allowing themes to emerge from the survey data rather than imposing predetermined categories. However, the literature review also informed theme formation, introducing a degree of deductive influence alongside the inductive approach. As analysis progressed, codes were organised into broader thematic categories aligned with the research questions: implementation challenges and improvisation practices. Sub-themes were identified to categorise teachers' experiences and perspectives but are not included in this study.

Ethical clearance for the study was secured from the Ablekuma West Municipal Education Directorate, which granted approval for data collection in the selected basic schools. In addition, formal permission was obtained from school heads, science teachers, and relevant administrators before the commencement of the study. Participants were clearly informed about the purpose of the research and the procedures involved, and their involvement was strictly voluntary. To protect participants' privacy, confidentiality was ensured by assigning codes in place of names and by storing all collected data securely. Participants were also made aware of their right to withdraw from the study at any stage without facing any consequences. The informed consent process was carefully followed to ensure that the study complied fully with ethical standards required for qualitative research in education.

4. RESULTS AND DISCUSSION

4.1. Implementation Challenges in Standards-Based Curriculum

Four interconnected challenges emerged from teachers' accounts of implementing the Standards-Based Curriculum in science education: inadequate teacher training in competency-based pedagogy, insufficient instructional resources and laboratory equipment, difficulties implementing authentic competency-based assessment, and challenges adapting curriculum content to local contexts.

Table 1. Implementation Challenges in Standards-Based Curriculum

Challenge	Respondents	Key Manifestations	Representative Teacher Quotes	Implications
Inadequate Teacher Training in Competency-Based Pedagogy	5	1. Brief orientation workshops (2-3 days) 2. General overview without practical guidance 3. Lack of training in inquiry-based facilitation 4. No ongoing mentoring or support 5. Difficulty shifting from teacher-centred to learner-centred pedagogy	"We attended a workshop when the SBC was introduced, but it was very general. They told us about the four core competencies and that we should use learner-centred methods, but they didn't show us how to actually do this in our classrooms with our large class sizes and limited materials." (T1) "Sometimes I plan an inquiry activity, but when students start asking questions I can't answer or going in directions I didn't anticipate, I panic and just demonstrate the concept myself." (T3)	1. Teachers revert to traditional methods 2. Lack of confidence in facilitating inquiry 3. Gap between curriculum intentions and classroom practice
Insufficient Instructional Resources and Laboratory Equipment	5	1. Severe shortages of laboratory equipment 2. Lack of consumable materials 3. 3/5 schools without functional laboratories 4. Inadequate textbooks and instructional aids	"We have a laboratory, but it's mostly empty. We have a few beakers and test tubes, but no chemicals, no microscopes, no models. How can I teach biology without a microscope?" (T2)	1. Inability to conduct prescribed practical activities 2. Lessons cancelled due to lack of materials 3. Reduced

Challenge	Respondents	Key Manifestations	Representative Teacher Quotes	Implications
		5. Large class sizes (40-60 students) compound resource issues		hands-on engagement 4. Undermines inquiry-based learning objectives
Difficulties Implementing Authentic Competency-Based Assessment	4	1. Confusion about assessing competencies vs. content 2. Lack of rubrics and assessment exemplars 3. Time constraints for formative assessment 4. Disconnect between SBC objectives and terminal examinations 5. Pressure to maintain high test scores	"The SBC talks about assessing competencies like critical thinking and problem-solving, but how do I assess these? I don't have rubrics or examples. The terminal examinations still test factual knowledge, so there's a disconnect." (T1) "Parents judge us by examination results. If I spend time on inquiry activities and competency development but students don't score well on tests, parents complain." (T5)	1. Teachers default to multiple-choice tests 2. Teaching to the test instead of competency development 3. Tension between curriculum objectives and accountability pressures
Challenges Adapting Curriculum Content to Local Contexts	3/5 teachers	1. Difficulty identifying appropriate local phenomena 2. Textbook examples from Western contexts 3. Concerns about maintaining curricular coherence 4. Time constraints for developing contextualised materials 5. Heavy teaching loads limit preparation time	"The curriculum says to use local examples, but sometimes I don't know what local examples to use. The textbook examples are often from Western contexts that students can't relate to." (T2) "Adapting lessons to local contexts sounds good in theory, but it takes so much time. With my teaching load and other responsibilities, I barely have time to prepare regular lessons." (T4)	1. Students struggle to relate to curriculum content 2. Missed opportunities for culturally relevant pedagogy 3. Limited contextualisation of scientific concepts

What improvisational practices exist in the implementation of SBC (Standard Based on Science) in science education in selected elementary schools? In response to these improvisational practices, three themes emerged: material substitution and adaptation, pedagogical improvisation, and collaborative resource sharing.

Table 2. Improvisation Practices in SBC Implementation

Theme	Respondents	Specific Practices	Materials/Resources Used	Representative Teacher Quotes	Perceived Benefits	Limitations
Material Substitution and Adaptation	5	Using plastic bottles as beakers and containers Constructing models with cardboard and paper Utilising recycled materials for demonstrations. Collecting natural materials for biology lessons Creating simple apparatus (example smartphone microscope with water droplet)	Plastic bottles Cardboard and paper Tennis balls, footballs, marbles (for solar system models) Recycled bottle caps, straws, rubber bands Leaves, stones, soil samples Red cabbage juice (pH indicator)	"I use plastic bottles for almost everything, as beakers, as containers for experiments, even to demonstrate concepts like air pressure. Students bring bottles from home, so they're free and readily available." (T1) "For teaching the solar system, I use balls of different sizes, tennis balls, footballs, marbles to represent planets. Students can see the relative sizes better than just looking at pictures." (T3)	Free and readily available Students can contribute materials from home Enhances visual understanding Makes abstract concepts concrete Demonstrates teacher creativity	Not precise enough for some experiments Cannot fully substitute real laboratory equipment Some concepts too difficult to demonstrate Students don't get same experience as with proper equipment
Pedagogical Improvisation	5	Using outdoor environments as learning spaces Incorporating storytelling and analogies Organising peer teaching activities Facilitating collaborative group learning Using digital resources (videos, simulations) when available	School compound (plants, weather observation) Natural environment (soil samples, ecosystems) Analogies (example electric circuits as water pipes) Peer demonstrations Videos and simulations (when internet available)	"When we can't do laboratory experiments, I take students outside to observe natural phenomena. We study plants in the school compound, observe weather patterns. The environment becomes our laboratory." (T2) "I use stories and analogies to make abstract concepts concrete. For example, I explain electric circuits using the analogy of water flowing through pipes." (T4)	Makes learning more interactive and engaging Develops collaboration skills (SBC core competency) Connects to students' prior knowledge Provides leadership opportunities for students Utilises freely available resources	Weather-dependent for outdoor activities Analogies may oversimplify complex concepts Digital resources limited by internet access Requires significant teacher creativity and planning
Collaborative Resource Sharing	3	Sharing improvised materials among colleagues	WhatsApp groups for science teachers Informal inter-school networks	"We have a WhatsApp group for science teachers in the municipality. When someone	Saves individual preparation time Provides	Informal and ad hoc (no official system) Limited time for coordination

	Exchanging lesson ideas via WhatsApp groups Borrowing materials from neighboring schools 4. Sharing photos and instructions for improvised activities	Peer-to-peer communication Shared improvised materials	creates a good improvised material or activity, they share photos and instructions. This saves us time and gives us new ideas." (T1) "Sometimes I borrow materials from teachers at neighboring schools. If they have something I need, they lend it to me, and I do the same for them." (T5)	new ideas and approaches Builds professional community Reduces duplication of effort Facilitates mutual support	Lack of institutional support No centralised resource centers Dependent on individual

Implementation Challenges: Sytemic Barriers to SBC Enactment

The implementation challenges identified in this study align with and extend existing research on standards-based curriculum reforms in resource-constrained contexts. The finding that all participants reported inadequate teacher training corroborates research from Tanzania, Kenya, Namibia, and Indonesia documenting insufficient professional development as a pervasive barrier to competency-based curriculum implementation [14]-[19]. This consistency across diverse national contexts suggests that inadequate teacher preparation represents a systemic challenge requiring comprehensive reforms to pre-service and in-service teacher education systems [59]. The study extends existing research by documenting how inadequate training manifests in teachers' daily practice. Teachers' accounts of reverting to teacher-centred methods when inquiry activities became unpredictable illustrates the gap between understanding competency-based principles conceptually and implementing them practically. This finding provides granular, practice-level evidence of implementation gaps that previous macro-level studies have not captured. This insight aligns with curriculum implementation theory, which recognises that effective enactment requires not only knowledge of curriculum content but also pedagogical content knowledge, classroom management skills, and confidence in facilitating student-led learning [38].

The resource constraints documented in this study comprised inadequate laboratory equipment, insufficient materials, large class sizes. This resonates with findings from Uganda, South Africa, and Kenya [20]-[22]. However, this study provides furthers insights into how resource scarcity affects specific aspects of SBC implementation. Teachers' accounts revealed that resource constraints not only limit hands-on activities but also undermine teachers' confidence in implementing inquiry-based pedagogy, create inequities in student learning opportunities, and generate tension between SBC objectives and practical realities. These findings imply that addressing resource constraints requires not increased funding as well as strategic resource allocation, development of low-cost alternatives, and curriculum design that acknowledges material realities in under-resourced schools. Assessment challenges identified in this study include confusion about competency-based assessment design, tension between formative assessment and standardised testing and time constraints for providing feedback. This is similar to research documenting assessment as a critical implementation barrier [20]-[24]. Critically, the finding that terminal examinations continue to emphasise factual knowledge despite curriculum emphasis on competency development reveals a fundamental misalignment between curriculum objectives and accountability systems**.**

Improvisation as a Pedagogical Strategy: Beyond Compensatory Response

A central contribution of this study is reconceptualising improvisation as a deliberate pedagogical strategy rather than merely a compensatory response to resource scarcity. While previous research has documented material substitution in resource-constrained contexts [28], [29], [32], this study is among the first to systematically examine teachers' motivations, decision-making processes, and pedagogical intentionality underlying improvisation. Teachers' accounts revealed systematic approaches to material adaptation, pedagogical innovation, and collaborative resource development that demonstrate professional agency and creative problem-solving. These finding challenges deficit perspectives that view resource constraints solely as barriers to quality education, instead highlighting teachers' capacity to transform constraints into opportunities for pedagogical innovation. This perspective extends teacher agency theory by illustrating how

teachers actively shape their practice in response to contextual constraints, exercising professional judgment to maintain pedagogical quality despite resource limitations [40].

The improvisation practices documented in this study, including material substitution using locally available resources, pedagogical adaptation through outdoor learning and storytelling, collaborative resource sharing align with research from South Africa, Brazil, and Indonesia documenting diverse improvisation strategies in resource-constrained contexts [43], [60], [61]. However, this study provides novel insights into the multiple purpose improvisation serves such as addressing resource constraints, enhancing student engagement through contextually relevant materials, developing students' creativity and problem-solving competencies, and fostering teachers' own pedagogical flexibility. The participants' report that improvisation can enhance student engagement and make learning more relevant to students' contexts extends constructivist learning theory by providing empirical evidence that locally contextualised, improvised materials scaffold abstract concept development [62]. When teachers use materials from students' daily they create connections between scientific concepts and students' lived experiences, facilitating knowledge construction. This finding suggests that improvisation, when implemented with pedagogical intentionality, can support rather than undermine standards-based learning objectives [63].

However, the study also reveals significant constraints on improvisation including time limitations, lack of institutional support, absence of formal training, and concerns about precision and safety. Critically, these constraints highlight that improvisation alone is insufficient without systemic support structures [43]-[64]. Teachers' call for formal training in improvisation strategies, institutional resource centers, and recognition of improvisation as a professional competency suggests that effective improvisation requires not only individual teacher creativity but also organisational capacity-building and policy support [65].

Alignment Between Improvisation and SBC Objectives

A critical concern is the extent to which improvisation practices align with SBC objectives emphasising competency development, inquiry-based learning, and authentic assessment. Findings suggest complex, conditional alignment. On one hand, improvisation can support SBC objectives by providing hands-on learning opportunities, facilitating inquiry through accessible materials, and developing students' creativity and problem-solving skills [66]. Teachers' use of outdoor environments, peer learning, and locally contextualised materials demonstrates alignment with learner-centred pedagogy and competency development. On the other hand, improvisation may reinforce teacher-centred approaches if implemented primarily as demonstration rather than student-led inquiry. Teachers' acknowledgment that they sometimes use improvised materials for demonstrations rather than student experimentation suggests that improvisation does not automatically translate to inquiry-based pedagogy [67].

This finding authenticates the importance of pedagogical intentionality in improvisation. Thus, teachers must consciously design improvisation activities to promote student agency, inquiry, and competency development rather than simply substituting materials while maintaining traditional instructional approaches [15]. The insight is that tension between improvisation and assessment emerged as a significant concern. While improvisation can support hands-on learning, teachers worried that improvised activities might not adequately prepare students for standardised examinations emphasising conventional scientific knowledge and procedures [54]-[68]. This tension reflects the broader misalignment between SBC objectives and assessment systems and suggests that effective integration of improvisation requires coherent reform of both curriculum and assessment.

This study contributes to curriculum implementation theory by demonstrating how teachers navigate implementation challenges through creative adaptation and professional agency. The findings challenge deficit perspectives that view resource constraints solely as barriers to quality education, instead highlighting teachers' capacity to transform constraints into opportunities for pedagogical innovation. This perspective aligns with ecological approaches to teacher agency that recognise teachers as active agents who shape their practice in response to contextual affordances and constraints [40]. Again, the study extends constructivist learning theory by providing empirical evidence for how locally contextualised, improvised materials can scaffold inquiry-based learning in resource-constrained environments. The finding that students engage more deeply with science concepts when using familiar, everyday materials supports constructivist principles emphasising the importance of connecting new knowledge to learners' prior experiences and cultural contexts. Also, the study introduces a three-dimensional framework of improvisation encompassing material, pedagogical, and collaborative dimensions. This framework provides a conceptual tool for understanding the complex nature of improvisation and can guide future research and professional development interventions.

All five teachers reported inadequate training, with brief workshops providing general overviews without practical guidance. This implies that professional development systems must shift from one-time workshops to sustained, practice-based learning models. Effective professional development should include: training in competency-based pedagogical strategies with modeling and practice opportunities, mentoring and coaching support from experienced practitioners, collaborative learning communities where teachers share improvisation strategies and troubleshoot challenges, opportunities for reflective practice and peer observation to

refine implementation and subject-specific training addressing science-specific challenges such as inquiry facilitation, safety with improvised materials.

The findings again revealed that teachers employ systematic improvisation strategies but lack formal training, institutional support, or professional recognition. This implies that improvisation should be integrated into pre-service teacher education and recognised as a core professional competency. Teacher education curricula should include coursework on designing improvised materials aligned with curriculum standards, practicum experiences in resource-constrained settings to develop improvisation skills, assessment of improvisation competency in teacher certification processes and case studies and exemplars of effective improvisation practices.

The findings also showed that teachers' improvisation efforts are informal, ad hoc, and unsupported by institutional structures. Education systems should therefore be established to provide institutional support infrastructure for improvisation, including district-level resource centers where teachers can access improvised materials, training, and collaborative planning spaces, funding for materials and supplies for improvisation, recognition and incentives for teachers who develop effective improvisation strategies, platforms for sharing improvisation practices across schools and districts including online repositories and partnerships with local industries and NGOs to source materials and expertise.

The fact that terminal examinations emphasise factual knowledge, creating tension between SBC competency objectives and accountability pressures implies that assessment systems must be reformed to align with competency-based learning objectives. This should include developing authentic assessment tools and rubrics for evaluating core competencies, reforming terminal examinations to include performance tasks, practical assessments, and competency demonstrations, providing training in competency-based assessment design for teachers and examination officers, reducing emphasis on standardised testing of factual knowledge in favour of formative, competency-based assessment and piloting alternative assessment models such as portfolios, project-based assessment in selected schools. Finally, to limit teachers struggle to adapt curriculum to local contexts due to time constraints, lack of guidance, and textbook examples from Western contexts, practical step must be taken to design curriculum materials with adaptation in mind. This should include suggestions for low-cost alternatives to conventional equipment for each learning activity, examples of locally contextualised activities and phenomena from diverse Ghanaian contexts, guidance for adapting content to diverse resource contexts such as urban/rural, well-resourced/under-resourced, modular curriculum design allowing flexible sequencing and adaptation and teacher notes explaining pedagogical rationale and offering adaptation options.

The study's focus on five teachers from one municipality limits generalisability to other contexts. While findings provide in-depth insights into teachers' experiences, they may not represent the full range of implementation challenges and improvisation practices across Ghana or other countries implementing standards-based reforms. Therefore, future research should examine larger, more diverse samples across multiple regions and countries. Also, comparative studies across urban/rural contexts, different resource levels, and various national curriculum reform contexts would illuminate how contextual factors shape improvisation practices and effectiveness. Again, reliance on self-reported data through interviews may be subject to social desirability bias, as teachers may have presented their practices in favourable terms. While member checking and peer debriefing enhanced credibility, classroom observations would have provided additional insights into how improvisation practices are enacted in situ and their actual impact on student learning. Future research should therefore employ mixed methods designs combining interviews, classroom observations, and student learning assessments.

Furthermore, the study did not examine student perspectives on improvisation or assess the impact of improvisation on student learning outcomes. While teachers reported that improvisation enhanced student engagement, empirical evidence of learning outcomes would strengthen claims about improvisation's pedagogical effectiveness. Future research should investigate student experiences with improvised materials and assess learning outcomes associated with different improvisation strategies. Finally, the study focused on science education and may not capture implementation challenges and improvisation practices in other subject areas. While science education faces unique challenges related to laboratory equipment and practical activities, examining improvisation across multiple subjects would provide broader insights into curriculum implementation in resource-constrained contexts. Future research should examine improvisation practices across multiple subject areas to identify common patterns and subject-specific strategies.

Beyond the Ghanaian context, this study contributes to global discourse on educational equity and quality in resource-constrained contexts. The findings challenge assumptions that quality science education requires expensive laboratory equipment and demonstrate that pedagogical innovation and teacher agency can partially compensate for resource limitations. This insight has implications for education policy in low- and middle-income countries worldwide, suggesting that investments in teacher professional development and institutional support for improvisation may be more cost-effective than large-scale infrastructure development. However, the study also cautions against using improvisation to justify continued under-resourcing of schools. Teachers emphasised that improvisation has limitations indicating that improvised materials cannot fully

substitute for proper equipment, improvisation requires significant teacher time and creativity, and lack of institutional support makes improvisation unsustainable. Improvisation should complement, not replace, adequate resource provision. The goal should be to support teachers in using improvisation strategically while simultaneously working toward equitable resource distribution.

5. CONCLUSION

This study addressed critical gaps in understanding how science teachers navigate standards-based curriculum implementation in resource-constrained contexts by examining implementation challenges and improvisation practices in Ghana's basic schools. Rather than simply documenting challenges, the study reconceptualises improvisation as a deliberate pedagogical strategy that demonstrates teacher agency and offers pathways for maintaining educational quality despite resource limitations. The study identified four interconnected implementation challenges notably inadequate teacher training in competency-based pedagogy, insufficient instructional resources and laboratory equipment, difficulties implementing authentic competency-based assessment, and challenges adapting curriculum content to local contexts. In response, teachers employ three categories of improvisation practices comprising material substitution and adaptation using locally available resources, pedagogical improvisation through outdoor learning, storytelling, and collaborative activities, and collaborative resource sharing through informal teacher networks. This study's primary theoretical contribution is reconceptualising improvisation from a compensatory response to resource scarcity to a deliberate pedagogical strategy that can support standards-based learning objectives. This reconceptualisation challenges deficit perspectives that view resource-constrained contexts solely through the lens of limitation, instead highlighting teachers' professional agency, creativity, and capacity for pedagogical innovation. The study also provided empirical evidence that locally contextualised, improvised materials can scaffold inquiry-based learning and facilitate competency development thereby extending the constructivist learning theory applications to under-resourced educational settings. The study again introduced a three-dimensional framework of educational improvisation encompassing material - physical resource adaptation, pedagogical - instructional strategy innovation and collaborative - collective resource sharing dimensions. This framework provides a conceptual tool for understanding the nature of improvisation and to provide a for guide future research, professional development design, and policy interventions.

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AUTHOR CONTRIBUTIONS

Charity Esenam Anor initiated the study, led the research design, supervised data collection and analysis, and edited the manuscript. Daniel Morrison contributed to the study design, participated in data analysis, and supported manuscript preparation. Sibaweihi Zaaria assisted with the literature review, data collection, and analysis. All authors reviewed and approved the final version of the manuscript.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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