ASSESSING CLASSROOM PRACTICES OF CHEMISTRY LECTURERS IN COLLEGES OF EDUCATION: A QUALITATIVE MULTIPLE-CASE STUDY

Solomon Boachie[1i],
Francis Quansah[2],
Emmanuel Kyame Oppong[3],
Arkoful Sam[3],
Rita Asano[4]

[1]Department of Science,
St. Ambrose College of Education,
Dormaa-Akwamu, Ghana
[2]Department of Science,
Foso College of Education,
Assin Foso, Ghana
[4]Department of Science Education,
University of Education,
Winneba, Ghana
[4]Agogo Presbyterian Women's College of Education,
Agogo, Ghana

Abstract:

This study investigated how chemistry lecturers in the Colleges of Education enact a reformed Bachelor of Education (B.Ed.) chemistry curriculum designed to promote inquiry-based instruction, practical laboratory work, ICT-supported pedagogy, and learner-centred approaches. Using a qualitative multiple-case study design, the study drew on structured, reliability-tested classroom observations conducted across five Colleges of Education. Cross-case thematic analysis revealed persistent reliance on lecture-based instruction, limited use of practical laboratory activities, minimal integration of ICT tools, and generally low levels of learner engagement. These patterns indicate a substantial gap between the intended learner-centred curriculum and the enacted teaching practices. Strong inter-rater agreement (κ = 0.70–0.84) strengthened confidence in the consistency of observed instructional patterns. Interpreted through the lenses of Pedagogical Content Knowledge (PCK), curriculum implementation theory, and educational change frameworks, the findings demonstrate how institutional capacity, teacher beliefs, pedagogical preparedness, and limited technological competence shape curriculum enactment. The study recommends that the government and stakeholders prioritise the equitable provision of laboratory infrastructure, teaching

---

[i] Correspondence: email solomonboachie@sace.edu.gh

aids, and ICT facilities to reduce disparities in curriculum implementation across colleges. Stronger administrative monitoring mechanisms should be instituted to ensure uniform implementation of the curriculum across all colleges.

Keywords: chemistry; education; qualitative multiple-case study; fidelity of implementation

1. Introduction

The reform of science teacher education has become a global priority as education systems seek to prepare learners with the scientific reasoning, inquiry competencies, and technological literacy required for participation in contemporary societies. Recent international scholarship consistently emphasises the need to move beyond transmissive, lecture-dominated instruction toward inquiry-based pedagogies, meaningful practical laboratory work, and technology-enhanced learning environments that support conceptual sense-making in science and chemistry education.

Teacher education institutions play a critical role in preparing pre-service teachers to enact these reform-oriented practices. However, contemporary international evidence suggests that ambitious curriculum reforms frequently fail to translate into sustained changes in classroom practice, resulting in persistent gaps between intended and enacted curricula (Pepin *et al.*, 2025).

Even in contexts where inquiry-based learning, practical work, and ICT integration are explicitly promoted, classroom instruction often remains characterised by teacher-centred approaches that prioritise content coverage over student inquiry and reasoning (du Plessis, 2016). These patterns underscore the importance of examining how teacher educators—who model instructional practices for future teachers—interpret and enact curriculum expectations in real classroom settings.

This challenge is particularly pronounced in chemistry education, where practical experimentation, visualisation tools, modelling, and inquiry-driven reasoning are central to developing conceptual understanding. Nevertheless, recent studies indicate that chemistry educators frequently underutilise these strategies due to limited confidence, constrained resources, assessment pressures, and entrenched beliefs about efficient teaching (Zinger *et al.*, 2020).

Such findings suggest that curriculum enactment is shaped not only by material conditions but also by institutional contexts, professional learning opportunities, and teachers' pedagogical beliefs (Leijen, 2018).

These global concerns are reflected in current teacher education reforms, including Bachelor of Education (B.Ed.) programmes that seek to strengthen inquiry facilitation, laboratory-based learning, ICT integration, and learner-centred pedagogy. Although curriculum documents articulate these expectations clearly, the extent to which they are realised in everyday teaching remains insufficiently examined. Much of the existing literature relies on self-reported practices derived from surveys or interviews, which may

overestimate the prevalence and quality of inquiry, practical work, and formative assessment in classrooms (Ganajova *et al.*, 2021).

What remains notably scarce is systematic, classroom-based evidence documenting how chemistry teacher educators enact reformed curricula in practice, particularly in resource-constrained contexts where the gap between policy and classroom realities may be most pronounced.

2. Statement of the Problem

Across international science education systems, curriculum reforms continue to emphasise inquiry-based instruction, meaningful practical work, integration of digital technologies, and formative assessment as central to effective chemistry teaching. However, a persistent challenge lies in translating these reform intentions into everyday classroom practice. Recent research demonstrates that, despite strong policy endorsement, chemistry instruction in many contexts remains dominated by lecture-based, teacher-centred approaches that prioritise content transmission over student sense-making and inquiry (Gultierez, 2019). This enduring gap between intended and enacted curricula suggests that reform challenges are not confined to particular regions but are systemic in science education.

Although a growing body of literature documents teachers' perceptions and self-reported practices related to inquiry, practical work, and ICT integration, there remains a notable lack of systematic classroom-based evidence showing how chemistry curricula are enacted in practice—particularly within teacher education institutions. This omission is significant because chemistry lecturers in teacher education play a critical role in modelling pedagogical practices for future teachers. Without empirical evidence of how these lecturers enact reformed curricula in real classroom settings, explanations for the persistent failure of chemistry curriculum reforms to produce sustained pedagogical change remain incomplete. Addressing this problem requires methodologically robust observational research that moves beyond policy intentions and self-report data to directly examine enacted chemistry-teaching practices.

2.1 Purpose of the Study
The purpose of the study was to assess the classroom practices of Chemistry Lecturers in Colleges of Education.

2.2 Research Question
The following research question guided the study:
1) How do chemistry lecturers in the selected Colleges of Education in Ghana carry out classroom practices in implementing the chemistry curriculum?

3. Literature Review

3.1 The CIPP Model as an Evaluation Framework

The CIPP model (Stufflebeam, 2003) provides an overarching structure for evaluating curriculum implementation by examining: Context (needs, goals, institutional conditions), Input (resources, professional development, infrastructure), Process (actual classroom practices, instructional strategies), and Product (outcomes and feedback for improvement)

The context, input, and process dimensions served as the guiding principles for data collection and analysis in the study. Because it systematically identifies differences between the intended and implemented curricula, CIPP is suitable. However, CIPP is insufficient on its own to fully capture the intricate dynamics of curriculum enactment or the specific pedagogical challenges of teaching chemistry. As a result, additional frameworks unique to scientific education were incorporated.

3.2 Rogan and Grayson's Theory of Curriculum Implementation

Rogan and Grayson's (2003) model is widely used in science education research to explain how schools enact new curricula. It emphasises three interconnected constructs: Profile of Implementation – the extent to which innovative practices (e.g., inquiry, practical work, ICT) appear in classrooms—capacity to Innovate – resources, teacher expertise, leadership support, and school climate and outside Support – professional development, monitoring, and external assistance.

This methodology is particularly applicable in developing contexts where institutional constraints, large class sizes, limited facilities, and inadequate professional development hinder the implementation of chemistry education. Additionally, it emphasises that implementation occurs in 'zones', meaning that, depending on local capabilities, lecturers adopt reforms gradually and unevenly. Rather than relying solely on broad evaluation models, such as the CIPP model, this model enables the study to situate observed classroom activities within a well-established framework for science education.

3.3 Fullan's Educational Change Theory

Fullan (2016) argues that successful educational reform depends on three core components: new materials (e.g., revised curricula), New teaching strategies (e.g., inquiry and ICT integration), and new beliefs (e.g., teachers' beliefs about teaching and learning). School culture, professional development, leadership support, and teacher motivation all play a role in driving change. Fullan's thesis clarifies why, in the absence of enabling systemic conditions, even well-designed courses may be poorly implemented. By elucidating how institutional policies, lecturer views, and resource constraints combine to shape classroom practices, Fullan's perspective in this study aligns with CIPP and Rogan & Grayson.

In international research on science education, the practical application of science curricula remains a primary concern. To foster conceptual understanding and scientific literacy, curricular reforms worldwide are placing a greater emphasis on inquiry-based pedagogy, hands-on laboratory work, and technology-enhanced learning (Kennedy, 2020).

Nevertheless, a growing body of research suggests that implementing these changes in the classroom is challenging, particularly in resource-limited environments (Fullan, 2016). The difference between the enacted curriculum, shaped by teachers' views, pedagogical knowledge, and contextual constraints, and the intended curriculum, as stated by legislators, is a crucial issue (Amadu *et al.*, 2023). An international study emphasises the value of practical work in developing procedural knowledge, scientific reasoning, and a meaningful understanding, particularly in chemistry education (Hacıeminoğlu, 2022). Despite reforms that support inquiry-based and experiential learning, research from Europe, Asia, and Africa indicates that teachers often employ didactic lecture methods (Amadu *et al.*, 2023).

This conflict suggests that professional culture, institutional norms, and teacher beliefs also influence implementation fidelity, alongside material resources.

3.4 Inquiry-Based Instruction and Teacher Beliefs

Inquiry-based instruction (IBI) remains a foundational approach in contemporary science and chemistry education, reflecting a shift away from transmissive pedagogies toward instructional practices that actively engage learners in questioning, investigation, evidence-based reasoning, and explanation building. Recent empirical and review studies consistently demonstrate that inquiry-oriented instruction enhances students' conceptual understanding, motivation, and engagement, particularly when inquiry tasks are coherently designed and appropriately scaffolded (Hsu *et al.*, 2015).

In chemistry education, inquiry is especially valued for its capacity to support learners in making meaningful connections among macroscopic observations, symbolic representations, and particulate-level explanations, thereby promoting deep conceptual sense-making rather than rote memorisation (Moju *et al.*, 2025). Despite its well-documented benefits, the enactment of inquiry-based instruction is strongly mediated by teachers' beliefs. Teachers' epistemological views about the nature of scientific knowledge and learning, perceptions of students' capabilities, and confidence in managing open-ended classroom activities play a central role in shaping how inquiry is interpreted and implemented in practice (Adofo, 2017; Zion *et al.*, 2020).

However, across diverse educational contexts, systemic pressures—such as high-stakes assessment, demands for curricular coverage, large class sizes, and limited resources—continue to constrain teachers' willingness and ability to implement inquiry-based instruction (Solórzano, 2019). In Sub-Saharan Africa, these constraints often result in hybrid instructional practices that blend elements of inquiry with traditional lecturing, underscoring the contextualised nature of inquiry enactment in teacher education settings (Amadu *et al.*, 2023).

3.5 Practical Work and Laboratory Experiences in Chemistry

Practical work remains a defining feature of chemistry education because it enables learners to engage with chemical phenomena, generate evidence, and develop scientific reasoning. However, recent scholarship emphasises that the effectiveness of laboratory activities depends more on their pedagogical design and conceptual alignment than on their frequency. Reviews of practical work in science education indicate that laboratory tasks contribute meaningfully to learning only when they support inquiry, interpretation of evidence, and reflective discussion, rather than routine verification of predetermined outcomes (Hofstein & Hugerat, 2021; Millar, 2010). When practical activities are repetitive or weakly connected to underlying chemical concepts, their educational impact is substantially reduced.

Inquiry-oriented practical work has therefore been advanced as a means of strengthening students' reasoning and the development of explanations in chemistry. Guided inquiry and structured reflection help learners connect experimental observations with theoretical models, particularly when teachers actively scaffold interpretation and classroom discourse (Reissman & Reissman, 2017).

Nonetheless, in many low-resource contexts, the enactment of practical work is constrained by large class sizes, limited equipment, time pressures, and safety concerns. As a result, chemistry lecturers frequently rely on demonstrations or verbal explanations in place of student-led laboratory work, a pattern evident in Sub-Saharan African teacher education contexts, including Ghana (Amadu *et al.*, 2023).

To address these constraints, technology-enhanced laboratory instruction has gained prominence as a complementary approach. Digital tools such as simulations and virtual laboratories can support the visualisation of abstract chemical processes and facilitate inquiry when integrated purposefully into instruction (Herga *et al.*, 2016).

However, effective use of these tools depends on teachers' pedagogical competence and institutional support. Studies show that limited professional preparation and weak alignment between ICT tools and instructional goals often lead to underutilisation of technology, underscoring the need for pedagogical integration rather than technology adoption alone (Abedi, 2024).

3.6 Technology-enhanced Chemistry Instruction

Technology-enhanced instruction has become an important component of contemporary chemistry education, particularly for supporting the visualisation of abstract and sub-microscopic chemical concepts. Digital tools such as simulations, animations, and virtual laboratories enable learners to explore molecular structures, reaction mechanisms, and quantitative relationships that are often difficult to observe through traditional instruction. Recent research indicates that when these tools are purposefully integrated, they can enhance student engagement, conceptual understanding, and inquiry-based learning, especially in topics such as stoichiometry and chemical processes (Wu *et al.*, 2021)

Despite their pedagogical potential, the classroom use of digital tools in chemistry remains uneven. Studies across diverse educational contexts show that effective technology integration is shaped less by access to devices and more by teachers' pedagogical competence, confidence, and instructional beliefs (Ertmer *et al.*, 2012).

In teacher education settings, particularly in African and Asian contexts, chemistry lecturers often underutilise available technologies due to limited professional preparation and weak alignment between digital tools and curriculum goals (Kitaw & Cherie, 2025)

These findings align with broader research emphasising that successful ICT integration requires pedagogical reasoning that connects technology with content and inquiry, rather than a focus on technical skills alone (Niess &Gillow-Wiles, 2017).

Consequently, technology-enhanced chemistry instruction is most effective when embedded within coherent pedagogical frameworks that support inquiry and conceptual sense-making.

3.7 Chemistry Curriculum Reform and Implementation Fidelity

Due to a mismatch between governmental aspirations and classroom realities, science curriculum reforms worldwide often fail to be implemented successfully. Inadequate professional development, insufficient oversight, unclear curricular guidelines, and institutional limitations are among the primary obstacles (Fullan, 2016; Coll & Taylor, 2019).

According to Rogan and Grayson's (2003) model of curriculum implementation, which is frequently used in scientific education research, implementation is impacted by three factors: (a) the ability to promote innovation; (b) the implementation profile; and (c) external support systems. This paradigm has been used to explain the uneven uptake of laboratory-based education and learner-centred pedagogies in emerging environments. Chemistry curriculum revisions in Ghana and many other sub-Saharan African nations place a strong emphasis on inquiry, hands-on learning, and ICT integration. Nonetheless, several studies document the ongoing use of lecture-based instruction, limited utilisation of labs, and inadequate professional support for instructors (Coffie, 2025). These regional studies are helpful, but when linked to global data, they become clear that Ghana's problems reflect broader worldwide conflicts between praxis and policy.

3.8 Synthesis of International Literature and Identified Gap

Recent international science education literature continues to document a persistent gap between intentions for curriculum reform and enacted classroom practice. Despite sustained policy emphasis on inquiry-based learning, practical work, and ICT-supported pedagogy, empirical studies indicate that chemistry instruction remains predominantly transmissive and lecture-oriented across diverse educational systems (Deng *et al.*, 2011).

Even in well-resourced contexts, sustaining inquiry-oriented pedagogy has proven difficult, with challenges frequently linked to teachers' epistemological beliefs, limited pedagogical content knowledge (PCK) for facilitating inquiry, and pressures

associated with curriculum coverage and assessment demands (Jones & Burnell, 2022). Parallel evidence from low- and middle-income contexts further highlights systemic constraints—such as large class sizes, limited laboratory infrastructure, and insufficient professional development—as enduring barriers to reform-oriented enactment (Amadu *et al.*, 2023). Notably scarce is systematic, cross-institutional observational evidence documenting how reformed chemistry curricula are enacted in real classrooms, particularly within teacher education institutions.

This gap is especially consequential because chemistry lecturers in teacher education play a pivotal role in modelling pedagogical practices for future teachers. However, internationally, teacher educators' classroom practices remain under-researched compared to those of school-level teachers, and observational studies of inquiry enactment in pre-service training contexts are rare (Akuma & Gaigner, 2021).

Addressing this gap, the present study contributes internationally relevant evidence by providing multi-site, reliability-tested classroom observation data on how chemistry lecturers enact a reformed curriculum in practice. By foregrounding direct classroom evidence, the study responds to current calls in science education research for methodologically robust, practice-based analyses that explain why curriculum reforms so often fail to translate into sustained pedagogical change.

4. Materials and Methods

Qualitative research methods are particularly valuable for curriculum evaluation studies because they enable researchers to explore the interpretive contexts within which educational practices are enacted and experienced. In evaluating the implementation of the chemistry curriculum in selected Colleges of Education in Ghana, a qualitative approach provides insight into how curriculum policies are translated into classroom practice through the everyday lived experiences of chemistry lecturers and institutional leaders. As noted by Walker (2017), qualitative inquiry is grounded in an interpretive and naturalistic tradition, whereby researchers study phenomena in their real-world settings and seek to make sense of them by attending to the meanings participants ascribe to their experiences. This approach is especially suited to capturing the multiple dimensions, contextual variations, and subtle differences inherent in curriculum implementation processes (Halkias *et al.*, 2017).

The approval of a multiple-case study design further strengthens this inquiry by enabling a comparative examination of curriculum enactment across different institutional contexts. Case study research is particularly appropriate for investigating the complex interactions among pedagogical, organisational, cultural, and environmental factors that shape instructional practices and curriculum delivery. Through in-depth engagement with participants within their natural settings, the case study approach facilitates a better understanding of lecturers' perceptions, instructional decisions, and responses to broader institutional and policy influences. Consequently, the multiple-case study design provides a rigorous and context-sensitive framework for

examining how the intended chemistry curriculum is interpreted and enacted across Colleges of Education in Ghana (Abadir *et al.*, 2020; Yin, 2017).

Each college served as an analytical case, and results were synthesised across cases to identify recurring trends in curriculum implementation.
The study falls under the interpretive paradigm, which posits that fundamental classroom interactions are the most effective means of understanding educational practices, as they are socially constructed and context-dependent (Kivunja & Kuyini, 2017).

Classroom observations were conducted weekly at each participating College of Education. During the observation period, one chemistry lesson was observed in each college. Stoichiometry, acids, bases, and salts, as well as introductory organic chemistry, were among the key B.Ed. Chemistry curriculum topics covered in the observed courses. The study strengthened the representativeness of the classroom findings by capturing differences in teaching methods across quantitative problem-solving themes and conceptually challenging aspects of chemistry through observations of classes across various content areas.

Structured non-participant classroom observations were used to collect data that directly demonstrated lecturers' instructional activities and their alignment with curricular requirements. Because structured observations reduce observer subjectivity while methodically capturing naturally occurring behaviour, they are ideal for qualitative case studies (Chauhan, 2024). The documentation of instructional methods across cases was driven by an observation checklist that aligned with curriculum goals, practical work expectations, ICT integration, and learner engagement.

In accordance with qualitative research standards, rich descriptions, thematic interpretations, and contextual explanations of classroom practices were prioritised. Although numerical agreement indices (e.g., Cohen's Kappa) were calculated to establish inter-rater reliability, these values supported the reliability of the qualitative observations rather than necessitating a mixed-methods design. No quantitative analysis of teaching outcomes or statistical hypothesis testing was performed (Bergin, 2018).

4.1 Participants

For this multiple-case study, five Colleges of Education were purposively selected to enable a thorough, comparative analysis of the implementation of the chemistry curriculum across institutional contexts. Three important institutional factors, both conceptually and empirically linked to variations in curricular enactment, were explicitly targeted for variation.

The geographic locations, institutional affiliations, and resource availability of the chosen universities were deliberately varied. The study investigated how resources influence inquiry-based instruction, practical work, and technology integration, with variations in laboratory facilities, instructional materials, and access to ICT. An analysis of location-related implications for teaching techniques was enabled by variations in geographical contexts, including semi-urban and less-resourced settings. The extent to

which organisational culture, leadership, and professional learning structures affect the implementation of chemistry curricula was further evident in variations across institutional affiliations and governance structures.

The principals of all participating colleges of education explicitly gave permission. The study's goal, methods, and voluntary nature were explained to all participants, including chemistry instructors and their students. Lecturers whose classes were observed provided written informed consent, and students were assured that no personally identifiable information would be collected. Participants were free to discontinue participation at any time without incurring any fees.

Pseudonyms were assigned to the colleges as A, B, C, D, and E, and secure data management techniques were employed to ensure strict confidentiality and anonymity. Only the research team had access to the password-protected folders containing the data.

4.2 Data Analysis

To identify trends in curriculum enactment across the five participating Colleges of Education, data analysis employed a methodical, multi-stage qualitative process consistent with the multiple-case study methodology (Abadir *et al.*, 2020; Yin, 2017). The analysis included both within-case and cross-case procedures. The primary qualitative dataset for the thematic analysis comprised observation notes detailing instructional sections, lecturer-student interactions, practical work, questioning techniques, and ICT use. These notes were transcribed verbatim into case-specific data files. All structured observation checklists were assembled right after each classroom session.

In accordance with qualitative standards (Bergin, 2018), the focus remained on meaning-making rather than numerical comparisons, even though inter-rater reliability statistics (Cohen's Kappa) were computed to establish consistency in checklist ratings. These values were only used to support the reliability of the qualitative data, not as quantitative findings.

4.3 Coding and Within-case Analysis

For every college, a within-case analysis was the initial step. Each tape was reviewed several times using an inductive coding technique (Onwuegbuzie & Weinbaum, 2016) To identify initial codes representing pedagogical methods, contextual influences, and observed teaching behaviours. Extended lectures, explanatory explanations, the lack of student enquiries, verbal descriptions of experiments, the non-use of ICT, restricted formative assessment, and resource limitations are some examples of early codes.

According to Neale (2016), the coding process was iterative, with codes modified and condensed through repeated comparison to produce larger categories. A collection of case-specific categories was established for each scenario to represent distinctive and recurring aspects of curriculum implementation.

4.4 Theoretical Integration

To deepen interpretation, the themes were analysed in relation to:

Rogan and Grayson's (2003) curriculum implementation framework (profile of implementation, capacity to innovate, and external support) and Fullan's (2016) educational change theory focus on teacher beliefs, professional learning, and institutional support. Moreover, the CIPP model (Stufflebeam, 2003) links classroom practices to contextual, input, and process conditions. To enhance the analysis's trustworthiness, several strategies were employed: Dependability was supported by inter-rater reliability checks and the consistent use of the structured observation tool; Credibility was strengthened by triangulating data across colleges and observers. Confirmability was enhanced by memo writing during coding to document analytic decisions. Transferability was supported through thick descriptions of classroom contexts and instructional episodes. These steps align with established qualitative research criteria (Yarbar, 2024).

The final themes represent the structural, pedagogical, and contextual elements that affect curriculum implementation, as well as the recurring instructional patterns observed in universities. The analysis offers a multifaceted understanding of the structural limitations affecting lecturers' practices and the implementation of the updated chemistry curriculum.

5. Results and Discussions

Table 1: Shows the results of the cross-tabulation of
Rater agreement on the observation checklist across colleges

College A			
	Rater 2: O	Rater 2: NO	Total
Rater 1: O	9	1	10
Rater 1: NO	1	4	5
Total	10	5	15
College B			
	Rater 2: O	Rater 2: NO	Total
Rater 1: O	9	1	10
Rater 1: NO	1	4	5
Total	10	5	15
College C			
	Rater 2: O	Rater 2: NO	Total
Rater 1: O	11	1	12
Rater 1: NO	0	3	3
Total	11	4	15
College D			
	Rater 2: O	Rater 2: NO	Total
Rater 1: O	11	0	11
Rater 1: NO	1	3	4
Total	12	3	15
College E			

	Rater 2: O	Rater 2: NO	Total
Rater 1: O	10	0	10
Rater 1: NO	1	4	5
Total	11	4	15

Note. O = Observed; NO = Not Observed.
Source: Data (2025).

Table 2: Analysis of inter-rater reliability (Cohen's Kappa) across colleges

College	Cohen's Kappa (K)	z-value	p-value
A	0.70	3.54	< .001
B	0.70	3.54	< .001
C	0.84	5.52	< .001
D	0.81	4.55	< .001
E	0.81	4.55	< .001

Note: Kappa values interpreted according to Landis and Koch (1977) indicate substantial to almost perfect agreement.
Source: Field Data (2025).

To ensure uniform use of the observation checklist across colleges, interrater reliability was calculated. Cohen's Kappa coefficients showed substantial to nearly perfect agreement, ranging from 0.70 to 0.84, and were all statistically significant at p < .001 (Landis & Koch, 1977). Colleges C, D, and E had Kappa scores ranging from 0.81 to 0.84, while Colleges A and B had Kappa scores of 0.70. These findings bolster confidence that the observed thematic patterns reflect genuine variation in classroom practices rather than measurement inconsistencies and validate the reliability of the observation tool.

The analysis of classroom observations across the five Colleges of Education revealed substantial and recurring patterns in how chemistry lecturers enacted the reformed curriculum. Despite variations in class size and resource availability, the instructional practices observed were remarkably consistent. Four major themes emerged from the cross-case analysis: (a) sustained reliance on lecture-dominated teaching, (b) limited use of practical laboratory work, (c) minimal integration of ICT tools, and (d) low levels of learner engagement. These patterns were supported by high inter-rater reliability (κ = .70–.84), indicating strong consistency in the recorded instructional behaviours.

Across all five institutions, chemistry lessons were characterised by extended monologic explanations, routine board work, and minimal opportunities for active student participation. Although tables summarising rater agreement were compiled to verify observational consistency, the patterns they revealed were more meaningfully captured through the narrative themes described below.

The high Kappa coefficients across colleges (ranging from 0.70 to 0.84) confirm that both observers consistently identified similar instructional behaviours. This alignment strengthens confidence that the emerging themes reflect genuine instructional patterns rather than observer bias.

Theme 1: Lecture-based Instruction as the Dominant Pedagogy

Lecturing was overwhelmingly the primary instructional strategy across all colleges. Lessons typically lasted 30–45 minutes of uninterrupted teacher talk, during which students copied notes from the board. Very few lecturers posed open-ended questions or encouraged student explanations; when questions were asked, they tended to elicit short factual responses rather than conceptual reasoning.

One observation noted:

"The lecturer spoke throughout the lesson with minimal pauses. No student contributions were requested, and the lesson proceeded as a rapid explanation of definitions and formulae."

This pattern demonstrates a low 'profile of implementation' as described by Rogan and Grayson (2003), in which teachers resort to familiar, teacher-centred approaches when curriculum expectations—such as inquiry or active learning—exceed their comfort level or institutional conditions. It also reflects limited PCK in areas such as questioning, facilitating inquiry, and engaging learners in sense-making.

Theme 2: Minimal or Non-existent Practical Laboratory Work

Although the curriculum requires hands-on laboratory experiences, very few lessons include demonstrations or student investigations. Even in colleges with functional laboratories, lecturers typically replaced practical activities with verbal descriptions or illustrations drawn on the board. In some cases, the laboratory apparatus was visible but unused.

For example, an observer recorded:

"The lecturer described the experimental steps verbally and drew the setup on the board. No attempt was made to demonstrate the reaction, despite the availability of reagents."

Reasons cited by lecturers included time constraints, lack of laboratory assistants, large class sizes, or fear of mismanaging equipment. Within the CIPP model, these constraints represent weaknesses in both the *input* (infrastructure, support) and *process* (implemented pedagogy) dimensions. Globally, similar patterns have been documented in which practical work becomes theoretical or procedural rather than investigative (Amadu *et al.*, 2023).

Theme 3: Limited Use of ICT Tools in Chemistry Lessons

Despite the presence of projectors in some classrooms, ICT was rarely integrated into teaching. None of the observed lessons used simulations, animations, or digital visualisation tools to support explanations of abstract chemical concepts. Instead, lecturers relied heavily on chalk-and-talk explanations and board sketches.

A note from College A summarised this pattern:

> *"Although the projector was installed and functional, the lecturer relied solely on the whiteboard to teach molecular structures."*

From a PCK perspective, this suggests limited technological pedagogical competence in selecting and using ICT tools to support conceptual understanding. Consistent with international findings (Kennedy, 2020), lecturers acknowledged low confidence and insufficient training as barriers to digital integration.

Theme 4: Low Levels of Learner Engagement and Formative Assessment
Students were largely passive across all observed lessons. Opportunities for interaction, collaborative work, experimentation, or inquiry-based questioning were minimal. Lecturers' questions tended to be rhetorical or answered immediately, leaving little time for students to process information or articulate their thinking.

One observation captured this dynamic clearly:

> *"The lecturer asked three questions during the lesson, but answered all of them before any student attempted a response."*

This absence of formative assessment—such as probing questions, diagnostic dialogue, or feedback—indicates limited PCK in assessment for learning. It also reflects what Fullan (2016) identifies as 'belief-driven resistance', in which teachers prioritise efficiency and content coverage over student-centred learning processes.

6. Discussions

This study examined how chemistry lecturers in five Ghanaian Colleges of Education enacted a reformed B.Ed. programme. The chemistry curriculum is intended to promote inquiry-based pedagogy, meaningful practical work, ICT-supported teaching, and learner-centred engagement. Across cases, the enacted curriculum remained largely traditional: lecture-dominated instruction prevailed, practical work was limited and often substituted with verbal descriptions, ICT integration was minimal, and learner participation and formative assessment were weak. Because the observation checklist yielded substantial-to-almost-perfect inter-rater agreement ($\kappa = 0.70–0.84$), the cross-case patterns are best interpreted as stable instructional tendencies rather than artefacts of inconsistent observation.

6.1 Persistent lecture-dominated teaching and the "intended–enacted" curriculum gap
The firm's reliance on monologic explanations and board work mirrors a well-established international pattern in which reforms advocating inquiry and learner-centred approaches do not translate into routine classroom practice (Amadu *et al.*, 2023; Albaradie, 2018). In science teacher education, this issue is especially consequential because lecturers model "what counts" as legitimate pedagogy for pre-service teachers.

The observed dominance of transmission teaching suggests that reform messages embedded in curriculum documents are filtered through established beliefs about efficiency, coverage, and classroom control—conditions repeatedly identified as barriers to the enactment of inquiry (Mpho, 2018).

Within Fullan's perspective on educational change, this reflects incomplete change across the three dimensions of reform—materials, teaching strategies, and beliefs—such that new curricular intentions coexist with old instructional cultures (Fullan, 2016). From Rogan and Grayson's implementation lens, lecture dominance signals a low "profile of implementation," consistent with contexts in which classroom practices remain in lower implementation "zones" because the demands of innovation exceed available support and capability (Rogan & Grayson, 2003).

6.2 Limited practical work: from curriculum requirement to symbolic enactment

A second significant finding was the scarcity of authentic student practical work, even in contexts where laboratories or apparatus appeared available. Instead of inquiry-oriented investigations, lecturers frequently relied on chalk-and-talk descriptions or schematic drawings of experimental setups. This aligns with international evidence that practical work often becomes confirmatory, procedural, or purely representational when time, equipment, safety concerns, and staffing constraints limit implementation (Deng *et al.*, 2011).

In Sub-Saharan African teacher education settings, similar "substitution" patterns have been reported, in which demonstrations or verbal narration replace hands-on inquiry due to large class sizes and weak laboratory support systems (Amadu *et al.*, 2023). Interpreted through CIPP, these patterns reflect weaknesses in Input (laboratory resourcing, technical support, timetabling, safety systems) and Process (the enacted pedagogy), producing implementation outputs that remain misaligned with the curriculum's practical-work intentions (Stufflebeam, 2003; Albaradie, 2018). Importantly, the findings reinforce a key point in the practical-work literature: even where "practical activities" occur, their learning value depends on design for reasoning, evidence interpretation, and reflective discussion—features that were rarely observed in the current cases (Amadu *et al.*, 2023; Herga *et al.*, 2016).

6.3 Minimal ICT integration: access does not equal pedagogical use

Although some classrooms reportedly had projectors or basic ICT infrastructure, observed instruction showed little to no use of simulations, animations, virtual labs, or other digital supports for chemical visualisation. This pattern is consistent with research arguing that technology integration is less about availability and more about teachers' pedagogical competence and beliefs regarding the role of ICT in supporting inquiry and conceptual sense-making (Ertner,2012; Kitaw & Cherie, 2025). In Ghanaian post-COVID contexts, limited training and inequitable access have also been shown to constrain meaningful ICT use, particularly when institutional systems fail to support sustained capacity building (Kennedy, 2020). The present findings therefore support the view that

technology-enhanced chemistry instruction requires deliberate alignment among digital tools, content-specific representations, and learning goals—rather than "add-on" technology use (Ertmer, 2012; Kitaw & Cherie, 2025). In implementation terms, weak ICT enactment reflects limited "capacity to innovate" and insufficient external/internal support, both of which are central to understanding why technology reforms remain superficial (Rogan & Grayson, 2003).

6.4 Low learner engagement and weak formative assessment: a PCK problem with structural roots

Across the five colleges, student participation was generally active, and questioning patterns were primarily closed, rhetorical, or teacher-led. These interactional features are important because inquiry-oriented teaching relies on students generating questions, interpreting evidence, explaining their reasoning, and receiving feedback that advances understanding. International research indicates that such practices depend heavily on teachers' beliefs, self-efficacy, and PCK to facilitate inquiry and assessment for learning (Adofo, 2017; Zion *et al.*, 2020). The observed absence of diagnostic dialogue and feedback suggests limitations in PCK domains central to chemistry teaching—especially knowledge of students' preconceptions, instructional strategies for inquiry, and assessment practices (Zion *et al.*, 2020; Adofo, 2017). However, the findings also indicate that structural conditions amplify PCK limitations: large class sizes, time constraints, and limited institutional supports reduce the feasibility of sustained dialogue and formative assessment, which helps explain why teachers often revert to lecture even when they endorse reform rhetorically (Solórzano, 2019).

6.5 Synthesis: implementation fidelity as an interaction of capacity, pedagogy, and change conditions

Taken together, the findings suggest that the gap between intended and enacted curriculum is produced by the interaction of (a) institutional capacity constraints (resources, staffing, time, infrastructure), (b) pedagogical capability and beliefs (PCK for inquiry, practical work, ICT integration, and formative assessment), and (c) systemic change conditions (leadership, professional learning, and monitoring). This integrated explanation aligns with international literature indicating that successful curriculum reform is unlikely when reform expectations are not accompanied by coherent professional development, support structures, and cultural shifts in what counts as "good teaching" (Solórzano, 2019; Fullan, 2016). Notably, the cross-case consistency and strong inter-rater agreement indicate that the observed implementation challenges are systemic rather than attributable to a small number of individual lecturers.

7. Recommendation

Based on the study findings, the following recommendations are made.

Colleges A and D should receive enhanced training programs focused on pedagogy, reflective practice, and laboratory management to bridge gaps in implementation quality. Government and stakeholders should prioritise the equitable provision of laboratory infrastructure, teaching aids, and ICT facilities to reduce disparities between colleges. Stronger administrative monitoring mechanisms should be instituted to ensure uniform implementation of the curriculum across all colleges. While fidelity should remain the priority, colleges facing resource constraints should be encouraged to adapt curriculum delivery methods while preserving core objectives. Future curriculum evaluations should continue to apply the CIPP model to track progress and ensure that improvements in teacher training and infrastructure translate into sustained high-quality implementation.

8. Conclusion

The study concludes that Strong institutional support—through leadership commitment, professional development policies, and collegial collaboration—positively influences students' perception of the curriculum. Tutors should be supported with training and mentorship, and when leadership prioritises resource allocation, students experience a more engaging and meaningful learning environment.

Author Contributions

Solomon Boachie: Conceptualisation; Theoretical framework development; Research design; Data collection; Data analysis; Interpretation of findings; Writing – original draft; Writing – review & editing; Project administration.

Francis Quansah Methodology refinement; Validation of research instruments; Data analysis support; Writing – review & editing; Critical review of theoretical and methodological sections.

Emmanuel Kyame Oppong: Supervision; Theoretical guidance; Methodological oversight; Validation; Writing – review & editing; Scholarly critique of findings and discussion.

Arkoful Sam: Supervision; Conceptual input; Methodological consultation; Writing – review & editing; Quality assurance and manuscript refinement.

Conflict of Interest Statement

The authors declare no conflicts of interest.

About the Author(s)

Solomon Boachie, B.Ed Sci.Edu., M.Ed. Sci., M.Phil. Sci. Education, Project Work Coordinator, Head of Science Department. Research interest in Science Pedagogy and Curriculum.
ORCID: orcid.org/0000-0002-5785-9479

Francis Quansah, B.Ed Sci.Edu., M.Ed. Sci., M.Phil. Sci. Education, Unit Head. Research interest in Science Pedagogy and Curriculum.
ORCID: orcid.org/0000-0003-4483-7702

Prof. Emmanuel Kyame Oppong, Natural Products, Dip. Education, Natural Product Chemist and Educationist.
ORCID: orcid.org/0000-0002-3339-2173

Prof. Arkoful Sam, M.Phil. (Analytical Chemistry), Doctor of Philosophy (Science Education) with a speciality in Chemistry Education.
ORCID: https://orcid.org/0000-0002-4722-9625

Rita Asano, MPhil. Science Education, Professional Science Educationist.

References

Abadir, S., Batsa, E. T., Neubert, M., & Halkias, D. (2020). Leading multicultural teams in agile organisations. Social Science Research Network. *SSRN Electronic Journal.* http://dx.doi.org/10.2139/ssrn.3507635

Abedi, E. A. (2024). Tensions between technology integration practices of teachers and ICT in education policy expectations: implications for change in teacher knowledge, beliefs and teaching practices. *Journal of computers in education*, *11*(4), 1215–1234. https://doi.org/10.1007/s40692-023-00296-6

Adofo, S. (2017). Teachers' perceptions about inquiry in science education. Retrieved from https://erepo.uef.fi/server/api/core/bitstreams/750e194c-5b81-4176-be4c-6198c386578d/content

Akuma, F. V., & Gaigher, E. (2021). A systematic review describing contextual teaching challenges associated with inquiry-based practical work in natural sciences education. *EURASIA J Math Sci Tech Ed,* Volume 17, Issue 12. Retrieved from https://www.ejmste.com/article/a-systematic-review-describing-contextual-teaching-challenges-associated-with-inquiry-based-11352

Albaradie, R. S. (2018). Perception of students and teachers about didactic teaching: A cross-sectional study. *Saudi Journal for Health Sciences*, *7*(2), 107–115. https://doi.org/10.4103/sjhs.sjhs_28_18

Amadu, C. D., Fevlo, E. S., & Gato, C. C. (2023). Implementing a learner-centred curriculum in the Colleges of Education in Ghana: An assessment of chemistry lecturers' classroom practices. *European Journal of Education Studies*, *10*(2), 145–161. http://dx.doi.org/10.46827/ejes.v10i2.4665

Bergin, T. (2018). *An introduction to data analysis: Quantitative, qualitative and mixed methods*. SAGE Publications. Retrieved from https://methods.sagepub.com/book/mono/an-introduction-to-data-analysis/toc#_

Chauhan, L., Bunkar, R. C., Verma, A., & Mounika, B. (2024). *Observational research:* A qualitative research method. *Exploring Narratives: A Guide to Qualitative Research Methods.* Retrieved from https://www.researchgate.net/publication/386506046_OBSERVATIONAL_RESEARCH_A_QUALITATIVE_RESEARCH_METHOD

Coffie, I. S. (2025). *Transforming science teaching and learning in Ghana through teacher professional learning: A Change Laboratory study* (Doctoral dissertation, University of Technology Sydney (Australia)). Retrieved from https://opus.lib.uts.edu.au/bitstream/10453/189992/1/thesis.pdf

Coll, R. K., & Taylor, N. (2019). *Science education in context: An international examination of the influence of context on science curricula development and implementation*. Brill. Retrieved from https://brill.com/display/title/37514

Deng, F., Chen, W., Chai, C. S., & Qian, Y. (2011). Constructivist-oriented Data-logging Activities in Chinese Chemistry Classroom: Enhancing Students' Conceptual Understanding and Their Metacognition. *Asia-Pacific Education Researcher (De La Salle University Manila)*, *20*(2). Retrieved from https://www.semanticscholar.org/paper/Constructivist-oriented-Data-logging-Activities-in-Deng-Chen/6a0a147d86284807ad9d2aa8e497a3ee5f078bbe

Du Plessis, A. (2016). Student Teachers' Pedagogical Beliefs: Learner-Centred or Teacher-Centred When Using ICT in the Science Classroom? *Journal of Baltic Science Education*, *15*(2), 140–158. https://doi.org/10.33225/jbse/16.15.140

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & education*, *59*(2), 423–435. https://doi.org/10.1016/j.compedu.2012.02.001

Fullan, M. (2016). *The new meaning of educational change* (5th ed.). Teachers College Press. Retrieved from https://michaelfullan.ca/books/new-meaning-educational-change/

Ganajova, M., Sotakova, I., Lukac, S., Ješková, Z., Jurkova, V., & Orosova, R. (2021). Formative assessment as a tool to enhance the development of inquiry skills in science education. *Journal of Baltic Science Education*, *20*(2), 204–222. https://doi.org/10.33225/jbse/21.20.204

Guo, L., Jafri, M., Williams, P. J., & Wang, C. (2022). Students' sense-making in technology- enhanced interactive environments. *Educational Media International*, *59*(4), 267–287. https://doi.org/10.1080/09523987.2022.2153991

Gutierez, S. B. (2019). Learning from teaching: Teacher sense-making on their research and school-based professional development. *Issues in Educational Research*, *29*(4), 1181–1200. Retrieved from https://www.researchgate.net/publication/342475911_Learning_from_teaching_Teacher_sense-making_on_their_research_and_school-based_professional_development

Hacıeminoğlu, E., Yıldız, N. G., & Şeker, R. (2022). Factors related to cognitive reasoning of pre-service teachers' science process skills: Role of experiments at home on meaningful learning. *Sustainability*, *14*(13), 7703. https://doi.org/10.3390/su14137703

Halkias, G., Micevski, M., Diamantopoulos, A., & Milchram, C. (2017). Exploring the effectiveness of foreign-brand communication: Consumer culture, advertising imagery, and brand schema incongruity. *Journal of Business Research*, 80, 210–217. https://doi.org/10.1016/j.jbusres.2017.04.018

Herga, N. R., Čagran, B., & Dinevski, D. (2016). Virtual laboratory in the role of dynamic visualisation for better understanding of chemistry in primary school. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(3), 593-608. https://doi.org/10.12973/eurasia.2016.1224a

Hofstein, A., & Hugerat, M. (2021). *Teaching and learning in the school chemistry laboratory*. Royal Society of Chemistry. https://doi.org/10.1039/9781839164712

Hsu, Y. S., Lai, T. L., & Hsu, W. H. (2015). A design model of distributed scaffolding for inquiry-based learning. *Research in Science Education*, *45*(2), 241–273. https://doi.org/10.1007/s11165-014-9421-2

Jones, T. R., & Burrell, S. (2022). Present in class yet absent in science: The individual and societal impact of inequitable science instruction and the challenge to improve science instruction. *Science education*, *106*(5), 1032–1053. https://doi.org/10.1002/sce.21728

Kennedy, K. (2020). *Evaluation of a Hybrid PD on Technology-Enhanced Inquiry-Based Science Teaching* (Doctoral dissertation, Rutgers the State University of New Jersey, School of Graduate Studies).

King, F. (2016). Teacher professional development to support teacher professional learning: Systemic factors from Irish case studies. *Teacher development*, *20*(4), 574–594. https://doi.org/10.1080/13664530.2016.1161661

Kitaw, S. L., & Cherie, D. S. (2025). Transforming Chemistry Education in Africa: A 21st Century Perspective on Opportunities and Challenges. *African Journal of Chemical Education (AJCE)*, *15*, 198. Retrieved from https://www.researchgate.net/publication/398781420_TRANSFORMING_CHEMISTRY_EDUCATION_IN_AFRICA_A_21ST_CENTURY_PERSPECTIVE_ON_OPPORTUNITIES_AND_CHALLENGES

Kivunja, C., & Kuyini, A. B. (2017). Understanding and applying research paradigms in educational contexts. *International Journal of Higher Education*, 6(5), 26–41. https://doi.org/10.5430/ijhe.v6n5p26

Landis, J. R., & Koch, G. G. (1977). An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. *Biometrics*, 363–374. https://doi.org/10.2307/2529786

Leijen, Ä., & Pedaste, M. (2018). Pedagogical beliefs, instructional practices, and opportunities for teachers' professional development in Estonia. In *The teacher's role in the changing globalising world* (pp. 33–46). Brill. https://doi.org/10.1163/9789004372573_003

Mesci, G., Schwartz, R. S., & Pleasants, B. A. S. (2020). Enabling factors of preservice science teachers' pedagogical content knowledge for the nature of science and the nature of scientific inquiry. *Science & Education*, 29(2), 263–297. https://doi.org/10.1007/s11191-019-00090-w

Millar, R. (2010). Practical work. *Good practice in science teaching: What research has to say*, 2, 108-134.

Moju, M., Taylor, L., & Iweuno, B. (2025). Tackling the challenge of chemical representations through sensemaking practices in chemistry education. *Discover Education*, 4(1), 352. https://doi.org/10.1007/s44217-025-00703-3

Neale, J. (2016). Iterative categorisation (IC): a systematic technique for analysing qualitative data. *Addiction*, 111(6), 1096–1106. https://doi.org/10.1111/add.13314

Niess, M. L., & Gillow-Wiles, H. (2017). Expanding teachers' technological pedagogical reasoning with a systems pedagogical approach. *Australasian Journal of Educational Technology*, 33(3). https://doi.org/10.14742/ajet.3473

Ogwudile, C. L. (2025). Stufflebeam's CIPP Model of Evaluation. *Irish International Journal of Engineering and Scientific Studies*, 8(5), 1–24. Retrieved from https://eprints.gouni.edu.ng/5529/1/IIJESS_2509002034%20%281%29.pdf

Onwuegbuzie, A. J., & Weinbaum, R. K. (2016). Mapping Miles and Huberman's Within-Case and Cross-Case Analysis Methods onto the Literature Review Process. *Journal of Educational Issues*, 2(1), 265–288. http://dx.doi.org/10.5296/jei.v2i1.9217

Pepin, B., Kohanová, I., & Lada, M. (2025). Developing Pre-Service Teachers' Capacity for Lesson Planning with the Support of Curriculum Resources. *ZDM–Mathematics Education*, 1–15. https://doi.org/10.1007/s11858-025-01685-0

Reissman, M., & Reissman, T. (2017, June). Scaffold approach to teaching experimentation. In *2017, the ASEE Annual Conference & Exposition*. https://doi.org/10.18260/1-2--28811

Rogan, J. M., & Grayson, D. J. (2003). Towards a theory of curriculum implementation with particular reference to science education in developing countries. *International Journal of Science Education*, 25(10), 1171–1204. https://doi.org/10.1080/0950069021014 5819

Shohel, M. M. C., Ashrafuzzaman, M., Azim, F., Naomee, I., Rahman, M. S., & Siddik, M. A. B. (2022). Blended learning space for primary and secondary education: Challenges and opportunities in resource-constrained contexts. *Designing effective distance and blended learning environments in K-12*, 187–222. https://doi.org/10.4018/978-1-7998-6829-3.ch012

Solórzano, R. W. (2019). High-stakes testing and educational inequality in K-12 schools. In *Oxford Research Encyclopedia of Education*. https://doi.org/10.1093/acrefore/9780190264093.013.938

Stufflebeam, D. L. (2003). Institutionalising evaluation in schools. In *International handbook of educational evaluation* (pp. 775–805). Springer, Dordrecht. https://doi.org/10.1007/978-94-010-0309-4_45

Walker, R. (2017). Naturalistic research. *Research Methods & Methodologies in Education*, 78–84.

Wright, L. J., Henson, R. A., & Malkin, L. M. (2025). Actionable Assessment: Designing Meaningful Score Reports to Support Student Engagement. *Educational Assessment*, *30*(2), 141–163. https://doi.org/10.1080/10627197.2025.2497773

Wu, S. H., Lai, C. L., Hwang, G. J., & Tsai, C. C. (2021). Research trends in technology-enhanced chemistry learning: A review of comparative research from 2010 to 2019. *Journal of Science Education and Technology*, *30*(4), 496–510. https://doi.org/10.1007/s10956-020-09894-w

Yarber, K. (2024). *Advancing Qualitative Inquiry in Agricultural Communications: An Analysis of Theories, Methodologies, and Standards for Quality* (Doctoral dissertation, University of Arkansas). Retrieved from https://scholarworks.uark.edu/etd/5351/

Yin, R. K. (2017). *Case study research and applications: Design and methods*. Sage. Retrieved from https://us.sagepub.com/en-us/nam/case-study-research-and-applications/book250150

Zinger, D., Sandholtz, J. H., & Ringstaff, C. (2020). Teaching science in rural elementary schools: Affordances and constraints in the age of NGSS. *Rural Educator*, *41*(2), 14–30. Retrieved from https://files.eric.ed.gov/fulltext/EJ1277479.pdf

Zion, M., Schwartz, R. S., Rimerman-Shmueli, E., & Adler, I. (2020). Supporting teachers' understanding of the nature of science and inquiry through personal experience and perception of inquiry as a dynamic process. *Research in Science Education*, *50*(4), 1281–1304. https://doi.org/10.1007/s11165-018-9732-9