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Exploration of Science Teaching Self-Efficacy Sources from Multiple Narratives of Professional Development Experiences

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ABSTRACT

Professional developments are effective interventions for exposing teachers to self-efficacy sources that align with innovative (e.g., inquiry-based) science pedagogies. However, in many situations, teachers are tasked with implementing innovative science practices without consistent and enduring professional development experiences. The study explored science teaching self-efficacy sources in situations where provision of professional developments is inconsistent and circumstantial. In this multi-case study, self-efficacy sources were explored through narratives of science teachers and key educational administrators. Participants' real-life experiences with professional development (PD) were analysed to identify and understand the sources of self-efficacy they found most significant. It examined the nature, types, and relevance of these sources without imposing external control. The study context emphasized regular, mandatory PD experiences for teachers, but participants were not currently undergoing any PD experiences. The study used a mixed sampling method to select 18 science teachers, 12 head teachers, four circuit supervisors, 3 science coordinators, and four deputy directors and director of education in urban and rural Ghana. The findings indicated that nearly all PD experiences embedded and exposed instructors to various sources of science teaching self-efficacy, with the highest being traditional-oriented cognitive content mastery (63.4%) and cognitive pedagogical mastery (65.9%). The majority of PD experiences were brief, with most lasting no more than five days, and often involved multiple subjects rather than focusing specifically on science. Overall, the study highlights the complexity of self-efficacy sources and the need for tailored, ongoing professional development opportunities for science teachers. The study recommends that those components of professional development experiences be carefully selected and integrated to embed and expose instructors to relevant and sufficient self-efficacy sources that align with innovative pedagogies emphasized in curricula documents.

Keywords: Inquiry-Based Science Teaching, Junior High School, Multi-Case Study, Professional Development, Self-Efficacy Sources, Traditional Science Instruction

I. INTRODUCTION

Recent reforms in science teaching emphasize the creation of learning environments that actively engage students in hands-on and minds-on practices, including inquiry-based activities (Curriculum Research and Development Division [CRDD], 2007, 2012; National Council for Curriculum & Assessment [NaCCA], 2020; National Research Council [NRC], 1996, 2000, 2012). Teachers must have high self-efficacy (e.g., Bandura, 1977; Tschannen-Moran et al., 1998) to create successful learning environments that engage students in meaningful inquiries (e.g., Cetin-Dindar, 2022; Murphy et al., 2020; Perera et al., 2022). Professional developments (PDs) are effective interventions for exposing teachers to relevant self-efficacy sources that enhance the teachers' perceived capabilities in inquiry pedagogy. However, in many situations, teachers with years of traditional instruction experiences are tasked with implementing inquiry-based science curricula without consistent and strong professional development experiences. For instance, although it is mandatory for pre-tertiary institution teachers in Ghana to participate regularly in PD activities (National Teaching Council [NTC], 2020), the provision of PDs are inconsistent and circumstantial (Association for the Development of Education in Africa [ADEA], 2016; Japan International Cooperation Agency [JICA], 2014). Therefore, it is important to examine PD experiences that are provided in many situations, to ascertain if they embed sufficient and relevant self-efficacy sources.

Review of published journals from 2012-2024 show that substantial research into self-efficacy sources were focused on in-service teachers in PD contexts (Lee et al., 2022; Lotter et al., 2016; McKinnon & Lamberts, 2014;

Murphy et al., 2020; Peters-Burton et al., 2015). These studies relied on data (including questionnaire responses, observation notes, oral and written reflections, individual and focus group interview responses, achievement test scores, and artefacts) from the PD contexts to draw conclusions. However, there has been insufficient research within the same period to examine self-efficacy sources from teachers and participants not in the contexts of PDs, particularly in situations where provision of PDs is inconsistent and circumstantial. Examination and triangulation of narratives from multiple teachers and key educational stakeholders might be a useful approach to unravel the nature of self-efficacy sources typically inherent in PD experiences in these situations.

Again, most research into self-efficacy sources employed concepts from social cognitive theory (Bandura, 1977) and Palmer's (2006, 2011) theoretical framework. Apparently, no study has combined concepts from social cognitive theory and curriculum implementation theory (Rogan & Grayson, 2003) to explore science teaching self-efficacy sources. In response to the insufficient studies mentioned above, the current study examined narratives of multiple teachers and key educational administrators to answer the following questions:

1. What sources of science teaching self-efficacy were embedded in professional development experiences of instructors?
2. How often, if any, were instructors exposed to science teaching self-efficacy sources from professional development experiences?

II. CONCEPTUAL FRAMEWORK

The framework for this study consists of concepts from social cognitive theory (Bandura, 1977), curriculum implementation theory (Rogan & Grayson, 2003), inquiry-based science pedagogy (e.g., NRC, 1996, 2000, 2012), and science education literature.

2.1 Inquiry-Based Science Pedagogy

Inquiry-based science pedagogy is a constructivist approach in which teachers guide students to plan investigations; gather, analyse, and interpret data; and share findings with their classmates and others (Chang & Mao, 1999). Teachers coach students to identify and control variables, formulate hypotheses, and conduct experiments (Lati et al., 2012), and assist students to measure and classify objects (Şimşek & Kabapinar, 2010). Students search for information about the problem or phenomenon of their investigation; and connect what is known to evidence from their investigations (NRC, 1996). During inquiry-based investigations students work cooperatively under the guidance of teachers to accomplish shared learning goals, learn to listen to each other, give and receive help, clarify differences, and construct new understandings (Gillies, 2008). The collaborative context of inquiry enables students to think about issues in ways they had never considered before. Teachers use divergent questions to guide and challenge students to think beyond their current processes (Wolf & Fraser, 2008). Teachers tailor inquiry activities to fit unique circumstances of students.

2.2 Sources of Science Teaching Self-Efficacy

Teachers develop science teaching self-efficacy when they are sufficiently exposed to relevant mastery and vicarious experiences, verbal persuasions, and physiological states (Bandura, 1977); and cognitive content mastery and cognitive pedagogical mastery (Palmer, 2006, 2011). How teachers cognitively process direct, vicarious, and symbolic inquiry practices they encounter is critical in their acquisition, regulation, and retention of inquiry teaching behaviours. Teachers initially learn approximations of inquiry instruction from observing others. Then, they continuously modify the initial approximations based on feedbacks from their own practices of inquiry pedagogy (Bandura, 1977). Gradually, teachers construct appropriate conceptions of inquiry as they discern appropriate practices from their own instruction in different circumstances (Avery & Meyer, 2012; Lotter et al., 2016; Naidoo & Naidoo, 2021; Coppola, 2019; Seung et al., 2019).

Teachers who gain deeper understanding of science from performance accomplishments in inquiry-based hands-on activities gain improved self-efficacy. Performance accomplishments in novel instruction strongly improve teachers' self-efficacy because performance accomplishments provide real proofs of one's abilities to successfully enact similar instruction in future (Bandura, 1977).

Vicarious experiences enhance self-efficacy when teachers observe successful modelling of inquiry instruction from others (Lee et al., 2022; Lotter et al., 2016; Naidoo & Naidoo, 2021; Coppola, 2019; Seung et al., 2019). When teachers observe others' enactment of inquiry instruction without setbacks they persuade themselves that they too can perform successfully if they intensify and persist in their efforts (Bandura, 1977, p. 145). Vicarious experiences are likely to generate enhanced self-efficacy when teachers observe variety of models perform the same or similar inquiry-based instruction successfully. Teachers become reasonably convinced that if people with different characteristics can perform it, they can also perform it (Bandura, 1977).

Improvements in self-efficacy can also occur from verbal persuasions that teachers receive from mentors, peers, instructors, students, researchers, experts, and others (Lee et al., 2022; Naidoo & Naidoo, 2021; Coppola, 2019). The comments, feedback, encouragements, and suggestions that teachers receive lead them into believing that they can successfully enact innovative science instruction (Bandura, 1977; Naidoo & Naidoo, 2021). Verbal persuasions are more likely to promote self-efficacy if teachers trust the authenticity of feedbacks and comments they receive (Lee et al., 2022).

Physiological states of teachers also generate changes in self-efficacy. When teachers experience high anxieties, fears, and stress upon contemplation of inquiry instruction, they anticipate poor performance which diminish their efficacy expectations (Bandura, 1977; Naidoo & Naidoo, 2021; Seung et al., 2019). However, when teachers engage in independent self-directed inquiry instruction successfully, they develop coping skills which diminish their fears, anxieties, and stress, resulting in positive shifts in their self-efficacy (Bandura, 1977).

This study sought to examine, identify, and determine whether the types, concurrence, and nature of self-efficacy sources inherent in teachers' and educational administrators' PD experiences align or not with self-efficacy sources stated in the theory.

2.3 Self-Efficacy Professional Development

Professional developments are effective interventions for exposing science teachers to relevant and sufficient sources of self-efficacy. Components of PD experiences are carefully selected, structured, and embedded to provide effective mastery and vicarious experiences, verbal persuasions, and physiological states (Bandura, 1977); as well as cognitive content mastery and cognitive pedagogical mastery (Palmer, 2006, 2011) that enhance self-efficacy.

For example, during field-based workshops teachers are taken through presentations and discussions of various instructional strategies to expose them to cognitive content mastery and cognitive pedagogical mastery (Murphy et al., 2020; Naidoo & Naidoo, 2021). Afterwards, teachers act as elementary school learners to engage in authentic, meaningful, and collaborative inquiries under the guidance of instructors (Avery & Meyer, 2012; Naidoo & Naidoo, 2021; Seung et al., 2019). Subsequently, teachers are given multiple opportunities to plan and enact inquiry-based science lessons in elementary school classrooms or in microteaching environments (Avery & Meyer, 2012; Naidoo & Naidoo, 2021; Coppola, 2019; Seung et al., 2019). The field-based experiences also include assignment of teachers to mentors and coaches who provide essential feedbacks, comments, encouragements, and reflection sessions. From the experiences, teachers achieve performance accomplishments, observe modelled instruction, and overcome their fears, anxieties, and stress.

2.4 Curriculum Implementation Theory

Curriculum implementation theory (Rogan & Grayson, 2003) recognises diversity of teachers in various schools. It places importance on considering diversity of teachers in various schools in when organising PD experiences. The theory consists of three core constructs: profile of implementation, capacity to support innovation, and support from outside agencies (Rogan & Grayson, 2003).

Profile of implementation indicates the need to establish and disseminate acceptable levels of innovative curriculum implementation. It allows schools to start and progress with curriculum implementation based on strengths, limitations, context, and capacity of the school (Rogan & Grayson, 2003).

Capacity to support innovation involves understanding and communication of factors that facilitate or impede the implementation of innovative curriculum. This includes physical resources, teacher and learner factors, and the school ecology and management. Since different schools have different support capacities, teachers tasked with implementing innovative curriculum must be supported in various ways (Rogan & Grayson, 2003).

Outside agencies are organizations outside the school that are interested and interact with the school to implement innovative curriculum (Rogan & Grayson, 2003). They include governmental, non-governmental, and multinational organizations; and agencies affiliated to foreign governments. They provide sponsorships, funding, expertise, professional development, physical resources, and assist with policy formulation. Some external agencies have the authority to apply pressure for compliance with the goals of curriculum implementation, while others inspire and persuade for compliance.

III. METHODOLOGY

3.1 Research design

The study used multi-case design to explore self-efficacy sources from multiple narratives of science teachers and key educational administrators not in the context of professional developments. It examined and compared multiple and varied narratives of previous PD experiences of science teachers and educational administrators in their real schools and offices. This design was suitable because the researchers had no influence in deciding the content and frequency of the PD experiences (Cohen et al., 2007; Creswell, 2013). It enabled the researchers to explore the types, concurrence, nature, and relevance of self-efficacy sources embedded in the participants' PD experiences. It also allowed the researchers to explore self-efficacy sources from viewpoints of the participants, without imposing any external control or influence. Insights about self-efficacy sources constructed from this study relied on in-depth and holistic descriptions of PD experiences from the multiple cases.

3.2 Context of the study

Documented guidelines for PDs in the current study context show that pre-tertiary institution teachers are to regularly participate in mandatory, ranked, and recommended activities to enhance their skills, knowledge, and experiences; and renew their job licenses and teaching contracts (NTC, 2020). This include regular participation in School-Based INSETs (SBI), Cluster-Based INSETs (CBI), and District-Based INSETs (DBI) (ADEA, 2016; JICA, 2014).

However, the population of participants in this study was not under any PD experiences when the research was conducted. The population comprised diverse science teachers and head teachers in public and private junior high schools (JHSs) in two rural districts and, an urban and a rural-urban municipality in one coastal region of Ghana. The population also include circuit supervisors of schools, district science coordinators, deputy directors and directors of education in the districts and municipalities. The science teachers were engaged in day-to-day teaching, assessment, and curriculum activities in schools; while the educational administrators were engaged in day-to-day administration, management, and supervisory activities.

3.3 Sample

The study combined convenience, purposeful, and stratified random sampling procedures to select 18 science teachers and 12 head teachers from 16 public and private JHSs in rural and urban localities of various factors. Four circuit supervisors, three science coordinators, three deputy directors and a director of education were also selected from the urban and rural localities. The three deputy directors of education replaced three directors who were not available for interviewing. One science coordinator and four head teachers were unavailable for interviewing and not replaced. Ten instructors were from government schools and eight from private schools. Seventeen were males and one was female. All instructors from government JHSs had professional training and were holding DBE and BED certificates. By contrast, all instructors from private JHSs had no professional training and were holding pre-university certificates. The teachers' ages ranged 21-40 years and had 1-15 years working experiences in education sector.

Eight head teachers were males and four were females. Their ages ranged 24-58 years. Most private JHS head teachers had no professional teacher training and were holding WASSCE and GCE Ordinary Level certificates. By contrast, most public school head teachers had professional teacher training and were holding BED and BSC certificates. The head teachers had 4-36 years of working experiences in education sector. Six head teachers were from rural schools and another six from urban schools. Eight head teachers were from public schools and four from private JHSs.

Two circuit supervisors were males and two were females. Two were from urban and another two from rural localities. All circuit supervisors had professional teacher training and were holding BED certificates. Their ages ranged 46-50 years and had 25-26 years working experiences in education sector. Two district science coordinators were males and one was female. Their ages ranged 40-46 years and had 16-19 years working experiences in education sector. All the science coordinators had professional teacher training and were holding BED and MSC certificates. Two were from urban localities and one from rural locality. All the deputy directors and director of education were males. Their ages ranged 49-56 years and had 23-38 years working experiences in education sector. They had professional teacher training and were holding BED, BSC, MED, and MPhil certificates.

3.4 Instrument

Open-ended questions were constructed for semi-structured interviews. Some questions were used to elicit participants' background information. The main questions were used to elicit participants' experiences about the content and frequency of PD experiences for science instructors. The open-ended questions enabled participants to provide detailed information of their experiences. It also allowed the interviewer to probe participants' responses for clarification and elaboration; and changed the order of questioning based on answers from participants (Cohen et al., 2007; Jacob & Furgerson, 2012).

The questions were pilot tested on six science teachers, three head teachers, one circuit supervisor, one science coordinator, and one deputy director of education. Participants involved in the pilot test were not included in the main study. The pilot test enabled the researchers to modify some questions, removed redundant questions, and checked working conditions of the recording equipment. It also permitted the researchers to devise contingency measures to address unanticipated challenges that occurred during the main study.

3.5 Data Collection Procedure

Face-to-face, one-on-one semi-structured interviews were used for the data collection. All participants gave full consents to participate in the study. Ethical issues addressed included participants' informed consents, anonymity, privacy, confidentiality, and rights to refuse participation and/or withdraw from the study. Arrangements were made with the participant for convenient dates, times, and places for the interviews. Sufficient rapport was established with the participants. This enabled them to open up, talked freely, and gave credible information. All the interviews were conducted and recorded by the corresponding author. Most of the interviews were completed within one hour.

3.6 Data Analysis

In the first stage, the audio recorded interviews were transcribed, audited, edited, and imported into Nvivo (version 12) for analysis. In the second stage, each transcript was read many times to identify essential codes relevant to the research questions. The coding was done iteratively to ensure consistent application of the codes. Most of the codes emerged inductively from the data. In the third stage, similar codes were grouped to generate categories. Additionally, there was re-coding and re-categorising of some existing codes; and new coding of some data. In the fourth stage, the generated categories were compared to the conceptual framework to identify self-efficacy sources associated with each category. Again, the contexts in which each code was used in participants' responses were identified to establish relationships between the codes, categories, and self-efficacy sources. Additionally, the conceptual comparisons allowed the researchers to classify frequencies of teachers' exposures to self-efficacy sources as inadequate, moderately adequate, or quite adequate.

In line with Palmer's (2006) approach, the level of each self-efficacy source was indicated by the frequency and percentage of instructors who mentioned it. Similarly, frequencies and percentages were used to express the levels of categories generated from the thematic analysis. The total percentages were more than 100%, because participants gave more than one response for the categories generated. The nature of each self-efficacy source was classified as traditional-oriented or constructivist-oriented (inquiry-based).

IV. RESULTS

4.1 Sources of Science Teaching Self-Efficacy Embedded In Professional Development Experiences Of Instructors

Nearly all components of PD experiences embedded and exposed instructors to multiple and concurrent sources of science teaching self-efficacy (Table 1). Components of PD experiences that embedded and exposed instructors to self-efficacy sources include, identification of topics in the science syllabus that teachers found difficult to teach; demonstration of traditional teaching procedures; explanation of traditional teaching procedures; discussion and preparation of traditional lesson plans and schemes of work; discussion and preparation (improvisation) of traditional teaching and learning materials; explanation of paper-and-pencil assessment practices; engagements in confirmatory hands-on science activities and usage of equipment and technology; discussions of usage of new textbooks and syllabus; and others.

Table 1
Frequency of Components of PD Experiences and Embedded Self-Efficacy Sources (n = 41)

Component of PD experience	Frequency (%)	Sources of science teaching self-efficacy
Identification of difficult and challenging teaching topics and subjects	16(39.0%)	Cognitive content mastery, cognitive pedagogical mastery, physiological state
Explanation of traditional teaching procedures	8(19.5%)	Cognitive content master, cognitive pedagogical mastery, verbal persuasion
Demonstration of traditional teaching procedures	11(26.8%)	Cognitive content mastery, cognitive pedagogical mastery, vicarious experiences, verbal persuasion
Discussions and preparation of traditional lesson plans and schemes of work	6(14.6%)	Cognitive content mastery, cognitive pedagogical mastery, vicarious experiences, mastery experiences, verbal persuasion
Explanations of paper-and-pencil assessment practices	3(7.3%)	Cognitive content mastery, cognitive pedagogical mastery, verbal persuasions
Engagements in confirmatory hands-on science activities, and usage of science equipment and technology	6(14.6%)	Mastery experiences, vicarious experiences, cognitive pedagogical mastery, cognitive content mastery, physiological states, verbal persuasion
Discussions and preparation (improvisation) of traditional teaching and learning materials	2(4.9%)	Cognitive pedagogical mastery, vicarious experiences, verbal persuasion, mastery experiences
Discussions of usage of new textbooks and syllabus	2(4.9%)	Cognitive content mastery, cognitive pedagogical mastery, verbal persuasion
Other activities	3(7.3%)	Unspecified self-efficacy sources

Table 2 shows frequencies and nature of science teaching self-efficacy sources inherent in participants' PD experiences.

Table 2
Frequency and Nature of Science Teaching Self-Efficacy Sources in PD Experiences (n=41)

Source of science teaching self-efficacy	**Frequency (%)**	**Nature of self-efficacy source**	
		Traditional-oriented	**Constructivist-oriented**
Cognitive content mastery	26(63.4)	√	
Cognitive pedagogical mastery	27(65.9)	√	
Vicarious experience	20(48.8)	√	
Physiological influences (states)	17(41.5)	√	
Verbal persuasion	11(26.8)	√	
Mastery experience	5(12.2)	√	
Unspecified self-efficacy source	3(7.3)		

4.1.1 Traditional-Oriented Cognitive Content Mastery and Cognitive Pedagogical Mastery

Nearly all components of school-based, cluster-based, and district-based PD experiences embedded and exposed instructors to high concurrent traditional-oriented cognitive content mastery 26(63.4%) and cognitive pedagogical mastery 27(65.9%), (Table 2), in addition to mastery and vicarious experiences, physiological states, and verbal persuasions (Table 1). There was no or little evidence of PD experiences that embedded and exposed instructors to constructivist-oriented cognitive content mastery and cognitive pedagogical mastery (Table 2).

Most traditional-oriented cognitive content mastery and cognitive pedagogical mastery were inherent in experiences designed to address JHS teachers' perceptions of certain difficult topics in the science syllabus 16(39.0%), (Table 1).

This term a circular was issued from the district education office to schools, asking teachers to identify and compile topics that they find very difficult to teach, especially in science ... (CS 2)

Traditional-oriented cognitive content mastery and cognitive pedagogical mastery were also inherent in experiences designed to address primary school teachers' inadequate content and pedagogical knowledge, which made them skipped some topics and taught science less frequently.

Some teachers at the primary level don't teach ... science. They only teach science ... topics they understand and leave the others ... Sometimes we organise school-based in-service training for the teachers in ... science. (HT 10)

Again, the PD experiences embedded high traditional-oriented cognitive content mastery and cognitive pedagogical mastery partly because the resource persons 15(36.6%) were themselves imbued with and portrayed traditional understandings of subject content and teaching.

If it is Physics INSET, we look for the teacher who did Physics and has background in the subject to act as resource person. (HT 10)

There was no mention or little evidence of resource persons having requisite knowledge, skills, and expertise in inquiry-based science pedagogy.

Substantial traditional-oriented cognitive content mastery and cognitive pedagogical mastery were inherent in explanations of subject content and traditional teaching procedures 16(15.53%), (Table 1). Resource persons used lectures, discussions, and other traditional methods to explain and promote instructors' understandings of subject content and teaching procedures. The instructors asked questions for clarification and wrote essential notes.

The education officers usually call the teachers to meet at a place in the school. There are some topics that teachers find difficult to teach. So, the education officers come and give further explanation on how to teach those topics. (HT 2)

There was no mention or little evidence of resource persons explaining strategies for inquiry-based science instruction.

At times, resource persons explained subject content and traditional teaching methods from textbook readings, without engagement of instructors in nor demonstration of hands-on activities.

... the science coordinator or resource person ... goes to the workshop ... to read from books without putting things [hands-on activities] together for teachers to see. (CS 3)

At other times, resource persons drew diagrams and wrote key points of their explanations on blackboards for instructors to note and copy.

It's like what we do in the classroom. They [resource persons] also use the blackboard as their equipment to do sketches. (ST 10)

Substantial traditional-oriented cognitive content mastery and cognitive pedagogical mastery were inherent in demonstrations of traditional teaching procedures 16(15.5%), (Table 1). Resource persons used general teaching procedures to demonstrate transmission of knowledge. The instructors acted as learners and received content and pedagogical knowledge.

... the resource persons teach [teaching demonstration] topics that ... teachers say they are finding difficult to teach in their classrooms. The resource persons take the teachers through methods of teaching the topics. (CS 4)

Afterwards, instructors engaged in discussions, shared ideas, and asked questions to advance their understandings.

After the lesson delivery we ask questions on the topic [subject matter knowledge and teaching procedure]. (HT 7)

In other situations, resource persons demonstrated traditional teaching procedures in elementary classrooms for instructors to observe. Afterwards, resource persons and instructors discussed and critiqued the lessons for instructors to understand the content knowledge and teaching procedures.

... in the second demonstration lesson, a teacher [resource person] taught primary 3 and 4 pupils in classroom for the instructors [PD participants] to observe. After that the lesson was critiqued. (DD 1)

At other times, resource persons demonstrated traditional hands-on lessons, where they verified science phenomena for instructors to observe. Then, they engaged instructors in discussions to improve their understandings of the subject content, process skills, and instructional strategies.

The whole demonstration activity was teacher-centred. We gathered in a circular form with the resource person in the centre. He performed the activity, explained the procedure and science knowledge involved. We observed the activity, answered questions he asked, and participated in discussions afterwards. (ST 4)

There was no mention or little evidence of resource persons demonstrating inquiry-based science pedagogy for instructors to observe and discuss.

… I must say that we did not specifically go into the inquiry method of teaching. We gave them [teachers] general methods or general strategies of teaching science at the basic level. (SC 3)

Considerable traditional-oriented cognitive content mastery and cognitive pedagogical mastery were embedded in discussions and preparations of traditional lesson plans and schemes of work 11(10.68%), (Table 1). Resource persons led discussions and question-and-answer sessions to promote instructors' understandings, after which groups of instructors shared ideas to prepare sample lesson plans under the guidance of resource persons.

I remember he [resource person] brought and showed us the sections of a sample lesson plan. Then he gave us sheets of papers to prepare new lesson plans on assigned topics. He went round from group to group to observe what we were doing and assisted those having difficulties. (ST 11)

There was no mention or little evidence of resource persons discussing, preparing, or giving instructors opportunities to plan inquiry-based science lessons.

Significant traditional-oriented cognitive content mastery and cognitive pedagogical mastery were embedded in discussions and construction of paper-and-pencil assessments 7(6.80%), (Table 1). Resource persons led discussions to improve instructors' conceptions of paper-and-pencil tests, validity and reliability of tests, and strategies for coaching students to pass external examinations.

… the new assessment form which was introduced specify the number of questions that should be set for learners at a grade level … In-service training was organised to explain things to us. (ST 3)

… The in-service training was based on how students should answer questions … how the teacher should prepare students to pass external examinations in science. (ST 17)

There was no mention or little evidence of instructors being taught how to conduct performance assessments of inquiry-based learning outcomes.

Other PD experiences that embedded didactic-oriented cognitive content mastery and cognitive pedagogical mastery were improvisation of teaching and learning materials, and discussions about usage of the new syllabus and textbooks (Table 1).

4.1.2 Traditional-Oriented Vicarious Experiences

Almost all components of school-based, cluster-based, and district-based PD experiences embedded and exposed instructors to fairly high traditional-oriented vicarious experiences 20(48.8%) (Table 2), concurrently with traditional-oriented cognitive content mastery, cognitive pedagogical mastery, verbal persuasions, physiological states, and mastery experiences (Table 1).

Substantial traditional-oriented vicarious experiences were inherent in demonstrations of traditional teaching procedures 11(26.8%), (Table 1). Resource persons used lectures, discussions, question-and-answer sessions, chalk-and-talk method, and other didactic procedures to demonstrate subject matter instruction for teachers to observe. This influenced the teachers' convictions about traditional instruction.

… during in-service trainings the resource persons teach topics that the teachers say they are finding difficult to teach in their classrooms. The resource persons take the teachers through methods of teaching the topics. (CS 4)

Again, significant traditional-oriented vicarious experiences were embedded in engagements of instructors in confirmatory hands-on activities, and usage of equipment and technology 6(14.6%), (Table 1). Resource persons modelled confirmatory hands-on science lessons for instructors to observe. This influenced the instructors' confidence about traditional hands-on instruction.

There was a time we invited a resource person to take the teachers through the laboratory equipment. The teachers went to the science lab and they were taught how to perform experiment. (HT 12)

There was no mention or little evidence of resource persons modelling inquiry-based science lessons for instructors to observe.

Additionally, considerable traditional-oriented vicarious experiences were embedded in discussions and preparation of traditional lesson plans and schemes of work 6(14.6%), (Table 1). Resource persons modelled statements of traditional lesson objectives; and selection of resources, teaching strategies, and activities for instructors to observe. The observations influenced instructors' confidence.

The resource person took us through various sections of preparing lesson plans, including statement of the lesson topic, objectives, and core points; as well as selection of teaching and learning materials, activities, and evaluation procedures. (ST 11)

There was no mention or little evidence of resource persons modelling inquiry-based lesson planning for instructors to observe.

Other PD experiences that embedded some traditional-oriented vicarious experiences are discussions and preparation of traditional teaching and learning materials 2(4.9%), (Table 1).

> *... if there is somebody [teacher] in the school who is very good at TLM preparation, he leads the other teachers to prepare materials for use.* (DD 1)

4.1.3 Physiological States

Nearly all components of PD experiences embedded and exposed instructors to substantial physiological states 17(41.5%), (Table 2), concurrently with traditional-oriented cognitive content mastery, cognitive pedagogical mastery, vicarious experiences, mastery experiences, and verbal persuasions (Table 1).

Most physiological states were embedded in JHS teachers' perceptions of difficult topics in the science syllabus 33(32.04%), (Table 1). The perceptions made instructors nervous, anxious, and stressful when they contemplated on teaching the topics.

> *We identify issues or areas or topics that teachers have difficulties in teaching. We then mobilise the science teachers at a place and take them through resolving those difficulties.* (SC 3)

Physiological states were also inherent in primary school teachers perceived inadequate content and pedagogical knowledge, which made them skipped some topics and taught science less frequently.

> *Last term when we had workshop for primary school teachers, it came to light that many teachers jump some topics in the syllabus because they find the topics or science subject difficult to handle*. (CS 1)

Significant physiological states were also embedded in the interest and enjoyment instructors had from PD experiences involving the usage of ICT and technology to visualize science concepts and phenomena; and engagement in hands-on activities 6(14.6%), (Table 1).

> *I attended one in-service training ... about ICT based learning in science. I enjoyed that one.* (ST 16)

There was no mention or little evidence of PD experience in which resource persons facilitated instructors to use tools, ICT, and technology to collect and analyse data from inquiry-based science investigations.

4.1.4 Traditional-Oriented Verbal Persuasions

Nearly all PD experiences embedded and exposed instructors to substantial traditional-oriented verbal persuasions 11(26.8%), (Table 2), concurrently with traditional-oriented cognitive content mastery, cognitive pedagogical mastery, vicarious and mastery experiences, and physiological states, (Table 1).

Demonstrations 11(26.8%) and explanations 8(19.5%) of traditional teaching procedures collectively embedded fairly high levels of traditional-oriented verbal persuasions (Table 1). As resource persons and instructors discussed, critiqued, shared ideas, asked questions, and gave answers about traditional methods explained and demonstrated, instructors received direct and indirect feedbacks and suggestions which influenced their convictions of traditional instruction.

> *We pick some subjects, look for a teacher [resource person] who can teach the subject very well, ask him/her to prepare, and come and deliver [lecture/transmit] for all of us to listen [receive]. Then after that we ask questions on the topic.* (HT 7)

Again, significant traditional-oriented verbal persuasions were collectively embedded in discussions and preparations of traditional lesson plans and schemes of work 6(14.6%), and engagements of instructors in confirmatory hands-on activities, and use of equipment and technology 6(14.6%), (Table 1). As resource persons led group and whole class discussions, sharing of ideas, and question-and-answer sessions about traditional lesson plans and hands-on science experiences, instructors received feedbacks, suggestions, comments, and encouragements which influenced their confidence about traditional instruction.

> *... a district education officer came here and explained how we should go about teaching, in reference to the scheme of work we have prepared from topics in the syllabus ... he taught us how to prepare the scheme of work.* (HT 2)

Some levels of traditional-oriented verbal persuasions were respectively embedded in explanations of paper-and-pencil assessment practices 3(7.3%), discussions and preparation of improvised teaching and learning materials 2(4.9%), and discussions about the usage of new textbooks and syllabus 2(4.9%), (Table 1). As resource persons led instructors to discuss the types of tests and assessments, construction of test items, content of test items, and validity and reliability of tests, instructors received feedbacks, comments, and suggestions which influenced their convictions.

There was no mention or little evidence of discussions, sharing of ideas, and critique of performance assessments of inquiry-based learning outcomes.

4.1.5 Traditional-Oriented Mastery Experiences

The PD experiences embedded and exposed instructors to low levels of traditional-oriented mastery experiences 5(12.2%), (Table 2), concurrently with traditional-oriented cognitive content mastery, cognitive pedagogical mastery, verbal persuasions, physiological states, and vicarious experiences, (Table 1).

Some traditional-oriented mastery experiences were inherent in discussions and preparations of traditional lesson plans and schemes of work 6(14.6%), (Table 1). As resource persons guided instructors to combine content and pedagogical knowledge, and selected resources and strategies to plan traditional lessons, the instructors' performance accomplishments influenced their confidence.

I remember he [resource person] brought and showed us sections of a sample lesson. Then he gave us sheets of papers to prepare new lesson plans on assigned topics. He went round from group to group to observe what we were doing and assisted those having difficulties. (ST 11)

Additionally, some traditional-oriented mastery experiences were inherent in instructors' engagements in confirmatory hands-on activities, and usage of equipment and technology 6(14.6%), (Table 1). As the instructors achieved successes in handling and using equipment, materials, and technology; and designing hands-on science lessons, they had performance accomplishments, which influenced their convictions.

…That was the first time I actually had the chance to handle these equipment … it [the PD] was structured in a way that allowed science teachers to design experiments on particular topics … (ST 18)

Again, some traditional-oriented mastery experiences were embedded in discussions and preparation of improvised materials for traditional teaching 2(4.9%), (Table 1). As resource persons led instructors to discuss and prepare improvised materials, the instructors' performance successes influenced their confidence.

… the resource person came up with certain topics and assisted us [instructors] to prepare teaching and learning materials (TLMs) that we can improvise by ourselves. (ST 1)

There was no mention or little evidence of instructors' exposures to mastery experiences and performance successes in inquiry-based science instruction.

4.1.6 Unspecified self-efficacy source

Some PD experiences embedded and exposed instructors to an unspecified self-efficacy source 3(7.3%), (Table 2). The unspecified self-efficacy source was embedded in experiences related to marking school attendance register, and health education on Ebola and Chlora (Table 1).

If certain things such as … marking of daily attendance registers … are not going on properly, we organise in-service trainings for the teachers. (HT 5)

The last time the District Education Office organised in-service training was on Cholera and Ebola … (HT 12)

4.2 Frequency of Instructors' Exposures to Science Teaching Self-Efficacy Sources from Professional Development Experiences

Table 3 shows frequencies of teachers' engagements in PD experiences.

Table 3
Frequency of teacher's Engagement in Self-Efficacy Professional Development (n = 41)

Number of times teacher engaged in professional development (PD)	Frequency f (%)	Sample quotations
No PD	15(36.6%)	We haven't had any in-service training for the science teacher in particular. I haven't organised any in-service training for the science teacher …
One PD	4(9.8%)	Since I came to this school three years ago, I have attended science and mathematics workshop only once. As for in-service trainings for science teachers, we have done only one … this is my second year in this school.
Two PD	6(14.6%)	I have attended two workshops in the district capital … I don't think that we have had any in-service training in this school. … I remember we had one in-service training. Then another one was organised for us when the new syllabus was introduced … the earlier one … was four years before the new syllabus came into being.
Undisclosed frequency of PD	16(39.0%)	I can't actually say how regular … As to how often in-service trainings are conducted … it depends on teachers identifying problems that they have. … we don't have mechanism to monitor in-service trainings in schools … so whether the structures are working or not, we cannot determine. It is woefully inadequate … we have school-based and cluster-based in-service trainings but it is not happening as it should.

Many participants articulated that the PD guidelines for pre-tertiary institutions mandate teachers to be frequently exposed to self-efficacy sources through regular participation in school-based, cluster-based, district-based, and other in-service trainings.

> *… Every school is supposed to organise two school-based … and one cluster-based INSETs … particularly in Mathematics and Science*. (DD 1)

But, in reality, most science teachers had insufficient exposures to self-efficacy sources from PD experiences. While many teachers had never been exposed to self-efficacy sources from PDs 15(36.6%) (Table 3),

> *I have not received any in-service training as a science teacher.* (ST 2)

many others had few exposures to self-efficacy sources from either one 4(9.8%), two 6(14.6%), or undisclosed frequency 16(39.0%) of participation in PDs. No interviewee articulated that science teachers had sufficient engagements in PDs.

> *… we don't have the chance to organise in-service trainings frequently for science teachers* (SC 3)

Many novice instructors had never been exposed to self-efficacy sources from PD experiences.

> *I haven't been given any in-service training since I came out of the teacher training college.* (ST 15)

Again, private school science instructors had lesser exposures than their counterparts in public schools.

> *… the concentration is on the public schools … if we are inviting say hundred teachers, we invite sixty-five teachers from public schools and forty-five teachers from the private schools …* (SC 3)

Most PD experiences intended to expose teachers to self-efficacy sources were of short duration. Most of the experiences lasted no more than five working days.

> *… it was a two-day workshop … we covered one potted plant with rubber bag and placed it at a dark place. The other potted plant was placed uncovered in the sun. The next day we went to the workshop venue and saw that there was a colour change*. (ST 4)

While most PD experiences involved teachers of all subjects, many experiences involved teachers of two or three subjects.

> *… they always bring other subjects and put them together. So, Science is not getting its own INSET.* (CS 3)

Only a few PD experiences were organised specifically to expose science teachers to self-efficacy sources.

> *Last term we organised teachers and gave them training on how to teach and handle some difficult topics in integrated science.* (SC 3)

V. DISCUSSIONS

Generally, the findings show that nearly all components of PD experiences embedded and exposed instructors to multiple and concurrent science teaching self-efficacy sources. This finding empirically confirms a statement of self-efficacy concept, that, the manner one self-efficacy source is applied to influence coping abilities will more or less draw on another source or sources of self-efficacy (Bandura, 1977). This finding and others (e.g., Lee et al., 2022; Naidoo & Naidoo, 2023; Seung et al., 2019) suggest that most preservice and in-service education experiences embed multiple and concurrent self-efficacy sources. Therefore, it is important to carefully select and integrate components of PD experiences to embed and expose instructors to self-efficacy sources that align with innovative pedagogies emphasized in curricula documents. If selection and integration of components of PD experiences are not properly accomplished, instructors might be exposed to inappropriate self-efficacy sources that misalign with innovative pedagogies.

This finding makes significant methodological contribution to the science education literature. Most studies that examined and unravelled self-efficacy sources relied on data from the contexts of preservice and in-service education experiences (e.g., Avery & Meyer, 2012; Lee et al., 2022; Lotter et al., 2016; Naidoo & Naidoo, 2023; Palmer, 2006, 2011; Coppola, 2019; Seung et al., 2019). However, this finding suggests that examination and triangulation of multiple narratives from teachers and key educational administrators is a useful approach to unravel self-efficacy sources typically inherent in PD experiences, in situations where provision of PDs is inconsistent and circumstantial.

Specifically, the study found that nearly all components of school-based, cluster-based, and district-based PD experiences neither embedded nor exposed instructors to constructivist-oriented cognitive content mastery, cognitive pedagogical mastery, physiological states, vicarious and mastery experiences, and verbal persuasions. Instead, the experiences embedded and exposed instructors to traditional-oriented cognitive content mastery, cognitive pedagogical mastery, physiological states, vicarious and mastery experiences, and verbal persuasions. This finding partly aligns with the concept of self-efficacy (Bandura, 1977; Palmer, 2006, 2011) and other findings (d'Alessio, 2018; Lee et al., 2022; Menon, 2020; Menon & Sadler, 2018; Naidoo & Naidoo, 2023 Seung et al., 2019; Webb & LoFaro, 2020) and shows that cognitive content mastery, cognitive pedagogical mastery, vicarious and mastery experiences, verbal persuasions, and physiological states are important science teaching self-efficacy sources. Contrary to other findings which show that self-efficacy sources are inherent in constructivist preservice and in-service education experiences, this finding suggests that self-efficacy sources are also inherent in traditional in-service education experiences. Therefore, self-efficacy sources can be constructivist or traditional in nature. This is similar to d'Alessio's (2018) sentiment that self-efficacy sources can enhance, decrease, or have no effect on perceived teaching capabilities. Constructivist-oriented self-efficacy sources enhance perceptions of inquiry teaching capabilities, while traditional-oriented self-efficacy sources enhance perceptions of didactic teaching capabilities. This finding has not been sufficiently reported in the literature, and is another significant contribution of this study.

Although teachers accustomed to traditional science instruction (e.g., Ampiah, 2008; Mohammed et al., 2020; Ngman-Wara, 2015) are tasked with implementing inquiry-based practices in many situations, this finding suggests that PD experiences intended to enhance the teachers' inquiry capabilities also embedded inappropriate self-efficacy sources. This is different from the issue in many other situations where teachers tasked with implementing inquiry-based practices had exposures to relevant self-efficacy sources from preservice and in-service education experiences (Lee et al., 2022; Lotter et al., 2016; McKinnon & Lamberts, 2014; Murphy et al., 2020; Peters-Burton et al., 2015). Where teachers tasked with implementing inquiry pedagogy are comfortable with traditional instruction, and PD experiences intended to improve their self-efficacy also embed inappropriate self-efficacy sources, there will be no or rare implementation of inquiry instruction in classrooms (e.g., Mohammed et al., 2020), resulting in failure of innovative curriculum initiatives.

This study shows that traditional PD experiences mostly embed and expose instructors to cognitive content mastery and cognitive pedagogical mastery compared to mastery and vicarious experiences, verbal persuasions, and physiological states. This is partly consistent with other findings (d'Alessio, 2018; Menon & Sadler, 2018; Palmer, 2006, 2011; Webb & LoFaro, 2020). However, contrary to this finding, the others showed that cognitive content mastery and cognitive pedagogical mastery were inherent in inquiry-based field experiences, in which teachers actively learned content and pedagogical knowledge in relevant, meaningful, real-life investigations and classroom settings (d'Alessio, 2018; Menon & Sadler, 2018; Palmer, 2006, 2011;Webb & LoFaro, 2020). This implies that cognitive content mastery and cognitive pedagogical mastery alone are insufficient to enhance perceived inquiry teaching capabilities, especially for instructors accustomed to traditional teaching. Instructors are more likely to acquire inquiry teaching capabilities when they are exposed to relevant cognitive content mastery and cognitive pedagogical mastery concurrently and proportionately with mastery and vicarious experiences, physiological states, and verbal persuasions. When teachers accustomed to traditional instruction are given opportunities to engage in and enact inquiry-based instruction during PDs, their performance accomplishments might provide powerful authentic evidence of their perceived capabilities (Avery & Meyer, 2012; Bandura, 1977; Naidoo & Naidoo, 2021; Coppola, 2019).

Again, the study found that most resource persons selected to lead PD experiences had no or little expertise in inquiry-based science instruction. Instead, they were themselves imbued with and portrayed traditional content and pedagogical knowledge. Instructors form perceptions of inquiry pedagogy when they observe successful enactment of inquiry instruction by others (Bandura, 1977; Lee et al., 2022; Murphy et al., 2020; Naidoo & Naidoo, 2021; Coppola, 2019; Seung et al., 2019). Education faculties, researchers, coaches, and mentors with adequate expertise in inquiry pedagogy are more likely to enact successful unambiguous instruction with clear learning outcomes (e.g., Lotter et al., 2016; McKinnon & Lamberts, 2014; Webb & LoFaro, 2020). Therefore, it is inappropriate to select resource persons imbued with traditional content and pedagogical knowledge to lead PD experiences intended to enhance inquiry teaching self-efficacy.

Additionally, findings show that instructors had insufficient exposures to science teaching self-efficacy sources from PD experiences. While many instructors had apparently never been exposed to self-efficacy sources from PDs, many others had few exposures from either one, two, or undisclosed frequency of participation in PDs. This finding has not been sufficiently reported in the literature over the past decade. This finding contradicts others which showed that perceptions of inquiry teaching capabilities occurred after instructors had been exposed to self-efficacy sources for months (Avery & Meyer, 2012; Menon, 2020; Menon & Sadler, 2018; Murphy et al., 2020; Naidoo & Naidoo, 2021; Coppola, 2019; Peters-Burton et al., 2015). Repeated exposures to vicarious experiences of successful inquiry instruction are necessary to generate substantial enhancements in the level and strength of teachers' self-efficacy, but brief exposures generate limited increases. Similarly, prolonged exposures to inquiry instruction are more effective in enhancing teachers' self-efficacy than intermittent exposures which end prior to teachers achieving performance successes (Bandura, 1977). Therefore, it is less likely for teachers accustomed to traditional science instruction to develop high and durable perceptions of inquiry teaching from insufficient exposures to self-efficacy sources over few days of PD experiences.

Again, most PD experiences involved instructors from various subjects, and schools in rural and urban localities of diverse characteristics. This finding is contrary to the theory of curriculum implementation (Rogan & Grayson, 2003) which states that failure or inability to consider the diversity of instructors across various school settings has been partly accountable for the poor outcomes of PD experiences intended to enhance teachers' self-efficacy toward innovative pedagogies. Different school types in different locations might not have the same/similar physical resources, teacher and learner factors, school ecology and management, and support from external agencies (Rogan & Grayson, 2003). Therefore, it is important to design PD experiences that expose instructors to self-efficacy sources in phases, based on the school's support capacity, external agencies support, and level of innovative curriculum implementation in the school (Rogan & Grayson, 2003).

VI. CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusions

This study examined and compared multiple narratives from teachers and key educational administrators to unravel the nature of self-efficacy sources inherent in components of typical professional development experiences in situations where provision of PDs is inconsistent and circumstantial. It explored science teaching self-efficacy sources from multiple narratives of professional development experiences. The study found that self-efficacy sources are also inherent in traditional-oriented in-service education experiences, apart from self-efficacy sources previously found in constructivist-oriented preservice and in-service education experiences. Although, teachers accustomed to traditional science instruction are tasked with implementing inquiry-based pedagogy in many situations, it was found that nearly all PD experiences intended to enhance the teachers' inquiry capabilities also embedded and exposed them to inappropriate and insufficient self-efficacy sources. Additionally, it was found that resource persons selected to lead PD experiences were themselves imbued with and portrayed traditional content and pedagogical content knowledge.

6.2 Recommendations

Based on the findings it is recommend that sufficient PD experiences that embed relevant, multiple, concurrent, and proportionate self-efficacy sources be designed to enhance teachers' perceptions of inquiry teaching capabilities. It is also recommended that resource persons imbued with inquiry teaching expertise and experiences be selected to facilitate PD experiences.

More studies must be conducted in the contexts of professional developments to investigate effects of inquiry-based self-efficacy sources on perceptions and behaviours of teachers accustomed to traditional science instruction.

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