Transforming science teaching and learning in Ghana through teacher professional learning: A Change Laboratory study

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under the supervision of

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Certificate of Original Authorship

I, Isaac Sonful Coffie declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of International Studies and Education, Faculty of Arts and Social Sciences at the University of Technology Sydney. This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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Dedication

This work is dedicated to my father, Isaac Sonful Coffie and my mother Akua Takyiwaa who all are deceased. Their sacrifice, dedication and hard work made me to reach this far.

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List of Abbreviations Used in this Thesis

Abbreviation	Full meaning
MOE	Ministry of Education
CHAT	Cultural-historical activity theory
JHS	Junior high school
SHS	Senior high school
BECE	Basic education certificate examination
WASSCE	West Africa Senior School Certificate Examination
EGRA	Early Grade Reading Assessment
ICT	Information and communication technology
STEM	Science, Technology, Engineering and Mathematics
UTS	University of Technology Sydney
HOD	Heads of department
TADS	Transformative agency by double stimulation
PEN	Practical Education Network
TIMSS	Trends in International Mathematics and Science Study

Abstract

Teachers are key actors in curriculum change, and their learning at such times is crucial. However, this critical aspect is often neglected in curriculum reforms, especially in Africa. This thesis explores science teacher professional learning at a time of significant curriculum reform in Ghana. A key aspect of the reform intends to change teaching from dominant teacher-centred pedagogies to more student-centred approaches. This is something that has proven difficult to achieve in many African countries. The aim of the study was to explore possibilities of aligning the intended curriculum with the implemented curriculum, using a Change Laboratory approach to foster teachers' professional learning. The study design was a qualitative formative intervention grounded within the theoretical framework of cultural-historical activity theory (CHAT). Six Change Laboratory sessions were conducted with six junior high school science teachers in the Sefwi Wiawso Municipality of Ghana. The Change Laboratory sessions were complemented by two interviews with each teacher (before and after the Change Laboratory), six focus group with students, and 18 lesson observations over three months.

The analysis drew on three key aspects of CHAT: systemic contradictions, double stimulation (specifically, Sannino's recent framework of transformative agency by double stimulation, or TADS) and Anne Edwards' concept of common knowledge. Secondary contradictions between components of the science teaching activity system were identified including between the tools and object where perceived lack of resources led teachers to feel it was impossible to foster active students' engagement in science lessons.

Regarding TADS, the key conflict of motives experienced by the teachers was a clash between teaching in a more engaging manner to realise the intended curriculum, and the motive to maintain the status quo of transmissive teaching to ensure curriculum coverage. The main auxiliary motive that enabled the teachers to escape this conflict of motive was to teach in a way that aligned with *what matters* to students.

Three themes were identified to understand *what matters* to students. These were engagement and interestedness, support and attention, applicability and connectedness. The participating teachers' understanding of these things that matters to students became common knowledge, serving as a resource for transforming their teaching practice.

Together, these processes produced four significant changes in the teachers practices that brought their practices into closer alignment with more student-centred nature of the intended curriculum. These focused on the use of questioning, assessment, teaching beyond the classroom, and designing a range of activities.

The study contributes to knowledge in three key areas. The first key area is an empirical contribution as this study is among the first in Africa to show how science teachers can develop their own solutions to key challenges in curriculum reforms when provided with opportunities to collaborate and explore ideas that work in their own classrooms. Previous studies have highlighted challenges and barriers to effective teaching and learning of science in Africa. This study is novel as it shows how the challenge can be overcome when *what matters* to students is folded in as key aspect of developing more student-centred pedagogies.

The second is a theoretical contribution to the literature on agency in CHAT where two different frameworks have been brought into dialogue. These frameworks are TADS and relational agency, where the study established that *common knowled*ge can be crucial in addressing the conflict of motives in the TADS framework. These frameworks have not been integrated in this way previously.

The third contribution is methodological in nature. Change Laboratories usually involve a group of people working together in the same institution. This study adapted the Change Laboratory to suit the Ghanaian science teaching context, where teachers often teach alone as a science teacher in their school. The study brought teachers from different schools to collaboratively design solutions and apply them to meet their own classroom conditions. The key recommendations from this study are as follows. Teachers' understanding of *what matters* to students can be powerful in enabling them to tailor their instructional strategies and develop more student-centred pedagogies. Furthermore, teachers need to be provided with effective professional development that offer them the opportunities to collaboratively develop their own solutions to bring transformation in their practice. Finally, it is suggested that research on science education in Africa should adopt more solution-oriented to address some of the challenges in science education, and that CHAT provides a relevant theoretical and methodological framework for doing so.

Chapter 1: Introduction

This introductory chapter is arranged in eight sections. Section 1.1 provides the background to the study in relation to teacher professional learning in curriculum reforms. Section 1.2 sets the context of the study, welcoming readers into the educational system of Ghana. Section 1.3 presents the justification for the study, while section 1.4 introduces the theoretical framework. Section 1.5 presents the research questions. Section 1.6 summarises the methodology used in the study. Section 1.7 presents a brief discussion of its findings, its contribution to knowledge, and its implications for further study. Section 1.8 outlines the structure of this thesis.

1.1 Background: Teacher professional learning in curriculum reforms

This thesis explores the possibilities of aligning intended curriculum with implemented curriculum in Ghana, using an interventional approach called Change Laboratory to foster science teachers' professional learning. The key outcome of this research is pedagogical change among a group of science teachers in Ghana as they implement a new curriculum.

This section provides the background to the study, highlighting the need to support teacher professional learning during curriculum reforms.

Two terms are used in the literature which are similar but distinct. These are teacher professional learning and teacher professional development. Teacher professional development typically refers to formal programs in which teachers participate to enhance their knowledge and skills. In contrast, teacher professional learning encompasses a broader range of activities, both formal and informal, that teachers engage in to improve their practice (Korthagen, 2017; Kwakman, 2003; National Academies of Sciences, Engineering, and Medicine, 2015). I chose to frame the study using "teacher professional learning." However, many studies refer to "teacher professional development," and these were also relevant to my research. Therefore, I have not focused on the vocabulary distinction between these two similar terms, as it does not materially affect my study's objectives.

A key trigger for many educational changes is curriculum reform mandated by national educational authorities. Curriculum reforms are crucial for introducing change in educational systems (Yan, 2012), potentially leading to change in teachers' practices (Scholtz et al., 2004). However, the gap between the intended curriculum and the enacted curriculum can remain a persistent issue (Rechsteiner et al., 2023; Yan, 2012). This challenge is particularly pronounced in African countries, where, despite significant efforts expended on curriculum development to foster change, science classroom practices have proved difficult to transform (Nsengimana et al., 2020). Professional development has therefore been suggested as one way of supporting teachers to bring about change in their practices, especially during periods of curriculum reform (Pyhältö et al., 2012; Scholtz et al., 2004).

Teachers are key actors in curriculum change, and their professional learning is crucial (Van den Akker, 2010). Opportunities for teacher professional learning to bring about more fundamental changes in teaching practice during curriculum reforms cannot be underestimated. A successful curriculum implementation cannot be carried out without attending to teacher professional learning (Ogunnniyi & Rollnick, 2017). However, this critical aspect is often neglected in curriculum reforms, especially in Africa. Evidence from the literature indicates that curriculum policies have often been implemented with little or no consideration for teacher professional learning, and the lack of teacher professional development is a key factor affecting the quality of teaching in Africa (Gyimah & Ayinselya, 2022; Mabula, 2012; Mbelani, 2018). In the case of Ghana, Abakah (2019) has highlighted this neglect: "A critical look at Ghana's implemented reforms and educational policies to improve quality education over the past decades reveals the neglect of teachers' CPD [continuous professional development]" (p. 1).

The research literature shows that opportunities for teachers in sub-Saharan Africa to engage in effective professional development are rare, and the few opportunities they do get are often ineffectual (I will discuss this issue in more detail in Chapter 2). This situation is largely due to the predominant use of the cascading approach in Africa, especially during curriculum reforms, where large numbers of teachers are drawn into centralised training sessions and provided with information deemed relevant to their practice (Attah & Mensah, 2015; Gyimah & Ayinselya, 2022; Hassler et al., 2018; Vhurumu, 2021). When local context is not considered and support or opportunities for collaboration are not offered, there is often a disconnect between the intended curriculum and the implemented curriculum as teachers struggle to adapt the new information to their specific teaching environments (Gyimah & Ayinselya, 2022; Perry & Bevin, 2019; Van den Akker, 2010). Scholtz et al. (2004) argued: "Teachers need more than simply being told what to do. They need support in adapting innovations to their own priorities so that they address the realities of the contexts within which they work" (p. 52). Therefore, to achieve high-quality teaching in Ghana, there is the need to invest in teacher professional development programs that provide opportunities for sustained support and collaboration among teachers.

To address the mismatch between the intended and implemented curriculum, there has been a call for researchers to support teachers in their professional learning, especially during curriculum reforms (Lelliott et al., 2013; Postholm, 2020; Rechsteiner et al., 2023; Scholtz et al., 2013). At such times, teachers need more collaborative opportunities to actively develop their pedagogical practices. Studies in Ghana have shown that teachers want to be empowered to effect change in their practices through opportunities to take control, evaluate, and reflect on their practices and develop new pedagogies (Abakah, 2023; Attah & Mensah, 2015; Gyimah & Ayinselya, 2022). As professionals, they can identify and analyse the changes needed. It has been argued that teachers are change agents capable of transforming their pedagogic practice (Lilley, 2022). The challenge lies in how to bring about these changes successfully (Pyhältö et al., 2012). It has argued that this challenge can be overcome when educational reform and research put teachers' agency at forefront (Lilley, 2024).

The literature suggests that professional development should not only provide new knowledge but also create conditions for teachers to critically reflect on their practices, engage in meaningful collaboration, and develop locally relevant solutions (Hopwood et al, 2023; Lilley, 2020; Postholm, 2020). By fostering such environments, teacher professional learning can lead to the implementation of significant curriculum reforms and improved teaching practices. It is against this background that this study seeks to support a group of science teachers in the professional development in implementing a new curriculum to bring about transformative change in their pedagogical practices.

1.2 The context of the study: Introduction to the Ghanaian education system

This section sets out the context of the study by providing an overview of the Ghanaian education system and the reasons for the recent reforms.

1.2.1 A brief history of education in Ghana

In pre-colonial times, education in Ghana, formerly called Gold Coast, was informal in nature, with knowledge and skills passed from older people to the youth verbally or by way of apprenticeship (Adu-Agyem & Osei-Poku, 2012). Formal education started with the arrival of the European merchants and Christian Missionaries (Adu-Agyem & Osei-Poku, 2012; Opoku et al., 2015). The focus of education was on reading, writing and arithmetic aimed at producing educated indigenous people to function in the colonial government (Adu-Agyem & Osei-Poku, 2012). A great transformation in education was brought into the country by Great British colonialists including making English the medium of instruction. After independence from Britain in 1957, many governmental changes improved the accessibility and quality of education, making it one of the best in the sub-Saharan African in the 1960s (Ministry of Education, [MOE], 2017). Over the past seven decades there have been six major educational reform efforts, all aimed at making education relevant to the Ghanian citizens: The Accelerated Development Plan of 1951; the Education Act of 1961; the New Structure and Content of Education in 1974; the 1987 Educational Reform; the Educational Reform of 2007; and the current educational reform (Adu-Gyamfi et al., 2016; MOE, 2017)

1.2.2 Contemporary structure of education in Ghana

The formal educational system of Ghana has three levels: basic, secondary and tertiary. The basic level is made up of kindergarten (2 years), primary (6 years) and junior high school (3 years), all of which are free and compulsory for all children (MOE, 2018a). Kindergarten education is a pre-school education for children aged 4. Primary education is divided into two stages: lower primary, which covers the first 3 years for children aged 6 to 8; and upper primary, which also covers 3 years for children aged 9 to 11 (Adu-Agyem & Osei-Poku, 2012). Junior high school (JHS) education is 3 years for children aged 12 to 15.

It is worth noting that the purpose of basic education is to endow all children with "foundational skills and confidence" for good decision making and to prepare them for learning at secondary level (MOE, 2018a). Students complete basic school after undertaking the national Basic Education Certificate Examination (BECE). The secondary level, for students aged 15 to 18, consists of senior high school (SHS) or technical and vocational education training, which is currently free and takes 3 years to complete. Students then sit the West Africa Senior School Examination (WASSCE), after which an individual can choose to enter a tertiary institution such as a university, a college of education, and another specialised college for further studies and training.

This study is located at the JHS level, with data generated from a group of teachers and students in the Sefwi Wiawso Municipality of Ghana. Refer to section 4.6 for detail discussion of the context of study.

1.2.3 Challenges affecting the quality of education in Ghana

This subsection presents some of the fundamental challenges that affect the quality of education in Ghana. It focuses more on students' performances in national examinations and how the results are skewed due to structural challenges in the education system.

Ghana, as a developing country, faces many challenges in providing quality education for its citizens. As mentioned earlier, the educational system of Ghana was recognised as one of the best in sub-Saharan African in the 1960s, but the quality of education has decreased in recent times, with learning outcomes of great concern (MOE, 2017). For instance, the 2016 National Education Assessment results indicated that only 37% of primary school class 4 pupils showed proficiency in literacy and 22% showed proficiency in numeracy (MOE, 2018a). Early Grade

Reading Assessment (EGRA) results also show that in both 2013 and 2015, only 2% of pupils in primary school class 2 could read at grade level, with 50% unable to read a single word (MOE, 2017).

There are also wide variations in national examinations scores, with some regions performing very poorly compared to others, and results skewed against girls in all four core subjects (English, Mathematics, Science and Social Studies) (MOE, 2018a). Some SHSs are able to achieve nearly 100% pass rates in the core subjects, while others get 0% (MOE, 2018b). Those producing good results in WASSCE are few, and 99% of their students are from private JHSs (MOE, 2018b). The WASSCE results show that these few SHSs also supply over 90% of those admitted to tertiary education, while the rest produce almost 90% of the failure rates in the examination (World Bank, 2017, as cited in MOE, 2018b). The available data also show that students from urban areas outperform their counterparts in the rural areas at the basic and secondary levels (MOE, 2018b). These factors, among others, have resulted in Ghana embarking on major educational reforms, especially at the basic and secondary levels.

1.2.4 Science education in Ghana

The subsection presents a brief overview of the structure, goals and challenges of science education in Ghana. It also highlights students' performance in science at both national and international level. More details are provided in Chapter 2, the literature review.

Science education in basic schools in Ghana has two main goals. The first is to inculcate scientific literacy and culture so that citizens can make informed choices in their personal lives and approach challenges in the workplace systematically and logically. The second is to produce competent professionals in the various scientific disciplines who can carry out high-level research and development (MOE, 2012).

The study of science in Ghana extends from the first year in primary school through to SHS, and it is a compulsory subject for all pre-tertiary students. Below SHS level, science is taught as single subject covering biology, physics, and chemistry, and it is referred to as integrated science (MOE, 2012). It is taught as separate subjects at SHSs that offer elective science programs for students.

Ghanian students' performance in science at both international and national levels has been very poor. Ghana has participated three times in Trends in International Mathematics and Science Study (TIMSS) for its JHS 2 (Grade 8) students – in 2003, 2007 and 2011. Table 1.1 shows the performance of the students in science in these three years.

Table 1:1 Ghana' Performance in TIMSS Participation

Year	International average	Ghana's score	No. of Countries	Ghana's Position
2003	466	255	45	44
2007	500	303	48	47
2011	500	306	42	42

Source: TIMSS, 2003, 2007, 2011

From Table 1.1, it can be seen that in 2003, Ghanaian students were placed 44th out of the 45 participating countries; in 2007 they were also placed last but one out of 48 countries; and in 2011 they were placed last of 42 countries. Although there was upward trend in their performance scores over these eight years, all were far below the international averages.

The story is the same at the national level. Student performances in science in both the Basic Education Certificate Examination (BECE) and West African Secondary School Certificate Examination (WASSCE) have also been poor. For many years, less than half of the candidates who sat for the WASSCE were able to make the pass grade of A1-C6. For example, in 2014, 71.3% of the 68,965 candidates failed integrated science, and in 2015, 76.7% the 62,374 candidates failed (Fletcher, 2018). Students' performance in science at the WASSCE has also been consistently poor compared to the other core subjects: "The weak performance in mathematics and science is of great concern as it could negatively affect human capital development in science and technology" (MOE, 2018b, p.45). It is clear that science education in Ghana needs improvement if it is to bring about positive change in students' performance.

Many studies have aimed to identify the factors affecting the teaching and learning of science in Ghanaian schools (Adu-Gyamfi, 2014; Boakye & Ampiah, 2017; Coffie et al., 2019; Fletcher, 2018; Humphrey-Darkeh et al., 2022; Marcourt et al., 2022). This issue is discussed in more detail in Chapter 2. Major factors found include the lack of science instructional resources; the broad nature of the science curriculum leading to inability to complete the syllabus; the lack of in-service training for science teachers; the challenge of handling some science contents such as electronics; students' inability to understand science because of their poor knowledge of the English language, which is used as a medium of instruction; the excessive use of didactic approaches in teaching science; and "teaching to the test".

1.2.5 The current curriculum reform in Ghana

Ghana is currently undertaking a major curriculum reform in its pre-tertiary education. The new curriculum is standard-based. It provides a set of core competencies and standards that learners are to know, understand and demonstrate as they progress through content standards and from one phase to the next. Implementation began at the primary school level in 2019 and at the JHS level in 2022.

The main reason stated for the introduction of the new curriculum in Ghana is to make pre-tertiary education more responsive to the human and resource development needs of the country (MOE, 2018a). The older, objectives-based curriculum emphasised cognitive development and examinations, but the new standards-based curriculum focuses on the affective and psychomotor domains of learning for total development. The new reforms are intended to shift the structure and content of Ghana's education system from merely passing exams to building character, nurturing values, and raising confident citizens who can think globally and critically (MOE, 2018a).

The previous curriculum was also overloaded with content and did not allow for more in-depth coverage. Ghana has therefore introduced a standard-based curriculum, where the same courses done at JHS will be continued at SHS 1 within the same content area. Hence, the new curriculum will allow learners to engage with richer content than the previous curriculum (MOE, 2018a).

Stakeholders in the education sector realise the need for strong science education in this technological age, especially at the foundational levels of education. The MOE (2018a) reform therefore has

> [at] its heart educational strategies that ensure that all learners leave school as scientifically literate citizens. Good foundations must be laid in mathematics and the other STEM subjects – especially in the early years of schooling. It is therefore crucial that the country is transformed into a mathematics friendly one in which Science, Technology, Engineering and Mathematics (STEM) education is at the fore. (p. 1)

The reforms are about changing not only the contents of the curriculum but also the approach to teaching from dominantly teacher-centred to student-centred (MOE, 2018a). They emphasise creative and inclusive pedagogies that engage students in meaningful learning. Teachers, especially science teachers, will therefore need to adopt different teaching strategies to achieve this vision of the curriculum. The teaching of science should be inquiry based and learner-centred, with teachers serving as facilitators (MOE, 2020). Science teachers are to guide and facilitate learning by generating discourse among learners and challenging them to accept and share responsibility for their own learning based on their unique individual differences. They are to select science content and adapt and plan lessons to meet the interests, knowledge, understanding, abilities, and experiences of learners. Also, they are to use multiple methods and systematically gather data about learners' understanding and ability that will further guide science teaching and learning, with arrangements to provide feedback to both learners and parents (MOE, 2019).

The curriculum thus places a lot of demand and learning on the science teachers. It will be very important to know how the science teachers can respond to those demands of making teaching student-centred. To make this reform work especially in science education, we need different kind of research; one that focuses on the immediate context of the teacher, the student and *what matters* to them as they learn science so that teachers can align their practices to that. This may create space for teachers to adapt teaching to needs of their students thus bringing a change in their practice and which could lead to an improvement in the teaching and learning of science in Ghana.

1.2.6 Changes to the science curriculum within the current reform

While the National Pre-Tertiary Education curriculum framework (MOE, 2018a) sets out the guidelines for developing various subjects under the new curriculum reform, the science curriculum (MOE, 2020) provides guidance on the learning outcomes, experiences and assessment in science. This sub-section explains the changes to the science curriculum in regard to its teaching and learning philosophy, its rational, and its aims.

Teaching and learning philosophy: The curriculum advocates for inquiry- and student-centred approaches to the teaching and learning of science. Effective teaching must be "pivoted on a learner-centred approach to teaching that engages learners physically and cognitively in the knowledge-acquisition process, in a rich and rigorous inquiry driven environment" (MOE, 2020, p. 9). It calls for science to be taught using practical and "mind-on[1]" to engage students in meaningful ways, emphasising students' engagement in classroom activities and projects (inside and outside of the classroom). Teachers are to act as facilitators who enable students to construct their own knowledge based on their prior experiences and existing knowledge. They are to encourage students to develop competencies such as critical thinking, problem-solving skills, creativity, innovation, communication, collaboration, and digital literacy.

Rationale and aims: The rationale for teaching science is to provide JHS students with a foundation to discover and understand the world around them and to prepare them for science and it related studies at higher levels of education. It is to make students "scientifically and technologically literate for sustainable development" (MOE, 2020 p.9).

The 10 aims of the curriculum are for learners to:

1. Develop the spirit of curiosity, creativity, innovation and critical thinking for investigating and understanding their environment.

[1]Mind-on means that the approach to teaching must engage learners physically and cognitively in the knowledge-acquisition process, in a rich and rigorous inquiry driven environment.

2. Develop skills, habits of the mind and attitudes necessary for scientific inquiry.
3. Communicate scientific ideas effectively.
4. Use scientific concepts in explaining their own lives and the world around them.
5. Live a healthy and quality life.
6. Develop humane and responsible attitude towards the use of all resources in Ghana and elsewhere.
7. Show concern and understanding of the interdependence of all living things and the Earth on which they live.
8. Design activities for exploring and applying scientific ideas and concepts.
9. Develop skills for using technology to enhance learning.
10. Use materials in their environment in a sustainable manner. (MOE, 2020 p. 9)

As set out in the curriculum, these aims are expected to be achieved within five thematic or broad areas of content referred to as strands, with specific sub-topics under each, as shown in the Table 1.2.

Table 1:2 Outline of the Topics in the new JHS Curriculum

Strands	**Sub-strands**
Cycles	1. Earth Science 2. Life Cycle of Organisms 3. Crop Production 4. Animal Production
Systems	1.The Human Body Systems 2.The Solar System 3. Ecosystem 4. Farming Systems
Forces and energy	1. Energy 2. Electricity and Electronics 3. Conversion and Conservation of energy 4. Force and motion 5. Agricultural Tool
Humans and the environment	1. Waste management 2. Human Health

	3. Science and Industry 4. Climate Change and Green Economy 5. Understanding the Environment

1.3 Justification for the study

The tendency for teachers to work without any support when updating their practice in response to new curriculum demands can hinder effective pedagogical change (Bannister, 2015). Rechsteiner et al. (2023) argue that effective educational change during curriculum reforms requires collaborative activity, where teachers work with other stakeholders to achieve the intended objectives. Van den Akker (2010) also recommended that when it comes to learning for curriculum enactment, "teachers [will] need to get out of their customary isolation" (p. 186). Providing opportunities for collaborative teacher learning during curriculum implementation is therefore important for achieving the intended objectives.

Through collaboration, teachers can share knowledge, exchange perspectives, and tap into each other's expertise. Voogt et al. (2015) emphasised that when teachers engage in collaborative professional development, they are more likely to "assume individual and collective responsibility, leading to intentional and transformative action and learning from the process" (p. 262). Collaborative approaches to teacher professional development have been shown to be effective in supporting teachers to improve their teaching practice (Hopwood et al., 2023, Kijkuakul, 2019; Thorgeirsdottir, 2019). Teachers will need effective professional development and support for them to change their practices (Thorgeirsdottir, 2019). However, the literature shows that such opportunities have been absent in professional development organised for teachers in Ghana (Abakah, 2023; Gyimah & Ayinselya, 2022). It is therefore conceivable that despite the introduction of the new curriculum, Ghanaian teaching practices are unlikely to change without adequate support for teacher professional development.

In response to the lack of opportunities for effective professional development and to the documented struggles that teachers face in enacting expected changes during curriculum reforms (Luttenberg et al., 2013; Pyhältö et al., 2012; Yakavets et al., 2022), this study employed an interventionist approach known as the Change Laboratory. Change Laboratory provides opportunities for teachers to work collaboratively to develop their own solutions, and it has proven effective in supporting many educational change efforts (Augustsson, 2021; Batane, 2017; Botha, 2017; Englund & Price, 2018; Hopwood et al, 2023; Lilley, 2020). By engaging teachers in this process, this study sought to address the challenges and barriers encountered during curriculum reforms and facilitate meaningful pedagogical change in science education in Ghana.

As will be shown in Chapter 2, a large body of literature on science education in Africa has focussed on studying students' perceptions, interests and attitudes toward science because these important factors are believed to influence students' study of science (Baidoo-Anu & Mensah, 2018; Buabeng et al., 2012; Chetcuti & Kioki, 2012; Egbenya & Quayson, 2022). It been argued that there is the need to address students' perspectives to develop and improve classroom teaching practices (Thorgeirsdottir, 2019). However, an important gap found in this literature is that students' attitudes, perceptions, and interests towards science have not been fed into pedagogical practices. This is very important, given that the new curriculum emphasises student-centred pedagogies in delivering the curriculum (MOE, 2018a; 2020). This study addresses this gap by surfacing students' perspectives for teachers' professional learning, with the aim of facilitating a more student-centred approach to teaching science.

Research on science education in Ghana has tended to identify its challenges, rather than collaboratively developing workable solutions (see Chapter 2). Most of these studies are descriptive, only enquiring into the challenges faced in the teaching and learning of science in schools without looking at the how to improve the teaching and learning of science in the schools. This study addresses the gap in the literature by exploring ways of improving science teaching and learning at JHSs in Ghana under the new curriculum through teacher professional development.

1.4 Outline of theoretical framework

This section outlines the theoretical framework used in this study, the details of which are presented in Chapter 3. This framework shaped many aspects of the thesis, including the research questions and Sections 2.3 and 2.4 of the literature review.

The theoretical framework used for this study is cultural-historical activity theory (CHAT), an interventional and analytical framework that not only seeks to observe and understand existing conditions but also aims to actively transform them (Engeström, 2015; Engeström & Sannino, 2010; Sannino, 2011). The focus of CHAT is things in motion, as they are changing, to understand what is coming to be, not what is (Chaiklin, 2012). The interventional focus of CHAT enables researchers to create conditions for expansive learning, where participants can collaboratively analyse their activity systems, identify contradictions, and design innovative solutions (Sannino et al., 2016; Virkkunen & Newnham, 2013). This participatory approach not only empowers teachers but also ensures that the solutions they develop are contextually relevant and practically feasible, thereby increasing the likelihood of successful implementation and sustainable change.

There have been four generations of CHAT (Engeström & Sannino, 2021), and I locate my study within the second generation, the focus being on key ideas such as expansive learning, systemic contradictions, and double stimulation. I further draw on conceptual aspects from the fourth generation, taking up some features of contemporary CHAT, including Sannino (2015) work on transformative agency by double stimulation (TADS) and Edwards (2012) work common knowledge.

1.5 Research questions

The main research question that guides this study is:

> *How can barriers to pedagogic change be overcome in the context of science curriculum reform in Ghana?*

The following four sub-questions explore this question in more detail:

1. *What contradictions are present in the implementation of the new science curriculum?*
2. *What do teachers learn, expansively, when collaborating on resolving these contradictions in implementing the new science curriculum?*
3. *How does agency emerge as teachers collaborate on implementing the new science curriculum?*
4. *How can teachers' understanding of what matters to JHS students be used as a resource to expand interpretations and possible actions as they meet the demands of teaching the new science curriculum?*

1.6 Summary of methodology

Chapter 4 explains in detail the methodology of this research. In summary, the study applied qualitative formative intervention, with Change Laboratory as the research design. It was conducted in Sefwi Wiawso Municipality of Ghana, where six JHS science teachers were recruited as participants through purposive sampling. These teachers were from six different schools, of which one was a private school, and the others were public schools. Eighteen students were selected from these schools, three from each school, to be part of this study.

The data generation process, which spanned over a period of three months, involved six Change Laboratory sessions with the participating teachers. Each Change Laboratory session lasted for an average of 90 minutes and was audio-recorded and transcribed verbatim for analysis. Two interviews with each teacher were also conducted. The interviewing of teachers was in two phases: before and after the Change Laboratory sessions.

Each teacher was observed in the classroom on three occasions, with each lesson observation lasting 70 minutes. The observation was in three phases: before, at the midpoint and after the Change Laboratory sessions. The first interview and observation were used as mirror data to stimulate the discussions during the early sessions of Change Laboratory. Six focus group were conducted in six different schools, with three students in each group. Each focus group took between 45 and 60 minutes. All the interviews and focus groups were transcribed and used in the analysis.

1.7 Thesis structure

This thesis is organised into eight chapters. Following this introduction, Chapter 2 reviews the research literature identifying the challenges to science education in Africa. The literature related to the teaching and learning of science; students' perceptions, interests and attitudes towards science; and teacher professional learning are also review. The literature on CHAT in science education and Change Laboratory in the African context are discussed, and the gaps in the literature are articulated. Based on the literature, I argue that a more dynamic view of science teaching that recognises its complexity rather simply classifying science teaching as either student-centred or teacher-centred and that professional development framed within

CHAT can provide a good support for a teacher's learning and enable transformative changes in their teaching practice.

Chapter 3 describes the theoretical framework used for the study. I justify why I considered CHAT a suitable framework. I argue that the challenges in teaching and learning of science are deeply rooted in historical and systemic structures, and therefore a theoretical framework capable of addressing these challenges from these perspectives was needed. I justify why an interventional approach is crucial, highlighting the importance of CHAT as an intervention of Change Laboratory that is capable of providing opportunities for participants to analyse their activity systems, identify the contradictions, and then develop their own ways of addressing the contradictions in the teachers' activity system. I discuss the key concepts and ideas in CHAT that I applied in this study and how these informed the data analysis and interpretation. I then locate my study within the second generation of CHAT. To enhance the analysis of the data, I draw on conceptual aspects from the fourth generation of CHAT, such as transformative agency by double stimulation and other associated concepts.

In Chapter 4, the methodology chapter, I justify the use of the Change Laboratory intervention. After providing a reflexivity and philosophical basis of my study, I describe and justify the methods of data generation and how they meet ethical compliance. I devote a considerable amount of attention to explaining the Change Laboratory process. Data generation from the focus groups, the interviews with teachers, and the lesson observations are also highlighted. I then present the strategy for the analysis of the data.

Chapter 5 presents an overview of the data collected, particularly from the Change Lab sessions. To familiarise readers with the workshop proceedings and to highlight the key issues discussed in each Change Lab session, these data are presented in chronological order and in a relatively raw and unanalysed form. The aim is to provide insight into the content and flow of the Change Laboratory sessions, allowing the readers to grasp the progression of discussions and the emergence of key analytical ideas.

The results of the study are presented in Chapters 6 and 7. The results on the participating teachers' expansive learning were reported in an article, Coffie et al (2025) in which I highlighted the key changes in the teachers' practices that aligned with the intended curriculum. The second part of Chapter 6 is presented as companion text that discusses the contradictions that the teachers faced to bring changes in their teaching practices. In Chapter 7, I show how the teachers developed common knowledge of *what matters* to students and used that as a key resource for the transformation in their teaching practices. I then show the teachers' transformative agency from two theoretical perspectives (the Germ Cell Approach and Forward Anchoring) based on the conceptual framework of transformative agency by double stimulation.

Chapter 8 concludes the study where I respond to the research questions and discuss them in the light of the literature and the results of the study. I also highlight the study's contribution to knowledge and its implications for further research, along with its limitations.

Chapter 2: The Literature Review

This chapter has five sections. Section 2.1 introduces the chapter. It discusses the literature search strategies, including the cut-off date and the inclusion and exclusion criteria. Section 2.2 looks at science education in Africa. Attention is paid to teaching and learning of science in schools; students' perceptions of, interests in and attitudes towards science; and teacher professional learning. Section 2.3 discusses research on CHAT and science education, while Section 2.4 takes a critical look at Change Laboratories, an interventional aspect of CHAT, in the African education context. Section 2.5 summarises the literature review and outlines the research gaps identified in the chapter.

2.1 Introduction

This study explored Ghanaian science teachers' professional learning and the use of CHAT to enable curriculum intentions to be achieved. It is located within the scholarship of science teachers' professional learning in the African context. The most relevant literatures were categorised into the next three sections of the chapter. Section 2.2 focuses on science education in Africa, including studies of the teaching and learning of science in schools, science teacher professional learning, and students' perceptions of, interests in and attitudes towards science. Although the focus of my research is on teacher professional learning, students' attitudes are important because a key hypothesis of my study is that understanding *what matters* to students might be a valuable resource for fostering teachers' agency. It must be noted that my study was not about student voice, hence I did not review the large body of literature on that topic. In

Section 2.3, I review empirical studies that applied CHAT in science education. Section 2.4 relates to the nascent body of work using Change Laboratories in African education contexts.

Scope and strategies of the literature search: This section explains the scope and search strategies deployed in this literature review. I included studies published up to the end of 2023 related to primary and secondary schools, but not to preschool or higher/vocational education settings. Key terms used in the literature search were

- "students' interest in science",
- "students' attitudes toward science",
- "students' perceptions about science",
- "teaching and learning of science",
- "challenges in science teaching"
- "science teacher professional learning or development"
- "CHAT and science education"
- "Change Laboratory".

These terms were usually followed with the names of specific African countries, for example, Ghana, Nigeria, South Africa, and Tanzania. I used the following databases: Google Scholar, University of Technology Sydney (UTS) Library, JSTOR, ProQuest, SAGE, SCOPUS, Education Research Complete, and Taylor & Francis.

A key strategy was to use a backward and forward citation reference search, whereby key references related to a particular article were followed up (Haddaway et al., 2022). A Google Scholar alert was also up for articles on some key ideas. I perused the abstract of each article to determine if it was worth further reading. The full text of the articles I deemed important for this review were downloaded and filed in different folders with names such as "Change Labs in Africa", "Curriculum Materials", "Interests, perceptions and attitudes", "Pedagogical practices" and so on. To avoid losing these documents, I stored them on external hard drives, and UTS OneDrive. I retained all the folders in Mendeley Software for easy access and referencing.

2.2 Studies in science education in Africa

This section considers research on science education in Africa, with a particular emphasis on Ghana. It identifies key challenges in African science education and outlines how researchers have addressed them. Section 2.2.1 focuses on teaching and learning of science. Section 2.2.2 explores students' perceptions of, interests in and attitudes towards the study of science, and Section 2.2.3 examines research on teacher professional learning in the light of documented pedagogical challenges.

The main point of this section is to show how challenges in Ghanaian science education have led to science teaching becoming mostly transmissive and teacher-centred, thus creating disinterest among students. Despite the seemingly unsurmountable challenges facing science education in Africa, my study is based on the premise that addressing students' perspectives, needs and interests can facilitate a pedagogical transformation from teacher-centred to student-centred approaches which can be difficult for many science teachers in Africa. This premise stems from my personal experience as a student and teacher of science in Ghana and from discussions with colleagues since I began this study. As I delved deep into the scholarly literature, I realised this premise is well supported in the literature.

Incorporating students' views into teaching practices can enhance students' interests and participation in science lessons, as well as serve as a foundation for teacher reflection that allows educators to evaluate and refine their methods (Hoban & Hastings, 2006; Lodge, 2005). It can promote collaborative classroom environments where students and teachers work together, fostering a sense of partnership, improving teaching practice, and making instruction more effective and relevant (Cook-Sather, 2017; Cook-Sather et al., 2020). Addressing students' perspectives also helps teachers connect with students' everyday experiences, making lessons more engaging and meaningful (Street, 2005). It can encourage teachers to be more sensitive to diversity, allowing them to tailor lessons to meet the needs of all students and make lessons more inclusive and effective (Grosemans et al., 2015). Ultimately, this can lead to the development and improvement of classroom practices, fostering a more dynamic and responsive educational environment (Thorgeirsdottir, 2019). Given the Ghanaian science curriculum's emphasis on student-centred teaching, I believe understanding students' perceptions of, interests in, and attitudes towards science can be instrumental in achieving this objective.

The literature reveals that curriculum coverage has traditionally been a primary focus in teaching, often at the expense of active student engagement. By integrating these insights, I aimed to explore and promote pedagogical approaches that balance active student involvement with the effective delivery of curriculum content. A salient finding from this section of the literature reviews is that students' perspectives often reflect their unmet needs of science, highlighting the importance of incorporating *what matters* to students into teacher learning. Furthermore, it was identified that science teachers seek professional development opportunities that not only offer support but also foster collaboration. In response to this need, this study was designed to also provide meaningful support to science teachers and to promote collaborative practices among them.

2.2.1 Teaching and learning of science

In this subsection, I examine the literature on the teaching and learning of science in Africa with a view to identifying the dominant pedagogy of schoolteachers, as compared to curriculum expectations. I explore teacher-centred and student-centred teaching approaches. I end the section with a discussion of the identified challenges in the teaching and learning of science. It must be noted that empirical research on the teaching and learning of science in Africa, while spread across several countries, remains relatively thin when compared to other parts of the world, especially the Global North.

The literature shows that current teaching approaches have been dichotomised into teacher-centred and student-centred categories, with the latter prevailing. However, Kalu-Uche et al. (2015) contend that studies in science education have dichotomised teaching methods or strategies without considering the composite nature of teaching. Schroeder et al. (2007) also argued that teaching approaches are not discrete and cannot be categorised. In alignment with these perspectives, I have adopted a more dynamic approach that views teaching as an interplay of both student- and teacher-centred methodologies, thus acknowledging both the complexity of classrooms and the flexibility teachers need when responding to them. This perspective recognises that effective teaching strategies should be fluid and adaptable to accommodate different learning contexts and goals.

Numerous surveys and observations have been conducted across different African nations, including Ghana, to determine dominant pedagogical practices within science classrooms. The results consistently point in the same direction: science teaching tends be transmissive, predominantly teacher-centred, and often characterised by extensive teacher talk, rote memorisation of content, and a focus on syllabus coverage to prepare students for final examinations.

Kalu-uche et al. (2015) studied pedagogical practices in the teaching of science in in Nigeria. The aim of their research was to determine the extent to which teaching was constructivist or transmissive and to explore the relationship between the secondary school teachers' self-reported pedagogical practices and their actual classroom practices. Data were collected through questionnaires and observations. Kalu-uche et al. identified significant differences between the classroom practices they observed and the participating teachers' self-reported practices. The teachers' pedagogical practices were observed to be more transmissive oriented, with their students just listening and answering questions.

The aforementioned findings corroborated those of a South African study conducted by Singh and Singh (2012), who found that the teaching of science was dominated by reliance on textbooks, chalk and talk, and the giving of scientific facts. This approach presents science as product, not as a process or means of understanding students' immediate environments and addressing societal issues. It also aligns with Tytler et al.'s (2017) contention that much of the science taught in schools has not been seen as relevant to students' lives.

In similar study to map out teaching strategies used in science classrooms in Ghana, Agbene et al. (2023) identified significant misalignment between teachers' practices and the requirements of the curriculum. Teacher-centred approaches dominated the teaching of science, instead of the student-centred approaches prescribed by the syllabus arguing that it contributes the poor academic performance of students in science (Agbene et al., 2023). Agbene et al. found that the teachers took centre stage in class and did not create opportunities for students' interactions, participation and questioning. Moreover, the students' engagements in hands-on activities were limited. These findings are similar to those of Mabula (2012), who examined the status of science teaching and learning in Tanzania. The author identified that the teaching approaches mostly used involved copying notes and giving explanations, with no opportunities for students to ask questions or express their ideas. The students were mostly passive recipients of information.

Researchers have raised concerns about pervasiveness of the dominant teacher-centred and transmissive approaches to teaching science, to the extent that students tend to perceive it as an inherent characteristic (Lyons, 2006). Such approaches foster the belief that science primarily constitutes a body of knowledge to be memorised, which does not encourage students to understand science concepts (Marcourt et al., 2022).

In their separate investigations of physics teaching in secondary schools in Ghana, Buabeng et al. (2014) and Coffie et al. (2020) identified that physics classroom interactions were mostly teacher-centred, involving the use of lectures, demonstrations and brainstorming. There was no support for inquiry-based learning, nor for the promotion of students' conceptual understanding. In a related study, Achor et al. (2019) found that students exposed to teacher-centred practices gained less of a positive attitude towards the study of physics than their colleagues who were taught using student-centred practices. Furthermore, the teacher-centred practices inhibited the students' participation and failed to foster in them a sense of responsibility for their own learning.

With teacher-centred and transmissive pedagogies predominating in African schools, it is not surprising that students in Ghana, for example, use the phrase "chew pour, pass and forget" to describe their experiences of science learning (Beem, 2020); this captures the way students are keen to remember information given by their teachers to pass their examinations, and then to forget it. The Mabula (2012) study mentioned earlier aimed to promote science subject choices among Tanzanian students. However, it found that most students were dissatisfied with the teaching approaches used (such as the lecture method), which led to poor performances and of loss interest in science, especially at higher level. In the same vein, students in Nigeria have perceived their science teachers to have poor pedagogical skills, which negatively influence their attitude towards science (Benson et al., 2020).

Scholars have called for a shift in the pedagogical approach to teaching science in Africa (Beem, 2020; Matachi, 2012). Beem (2020), for instance, has advocated for interventions and transformative change in teaching practices in Ghana. Such interventions should start at the lower levels of education, before students choose what to study at the higher levels. The factors contributing to the prevalence of transmissive and teacher-centred teaching practices in Africa are complex and interconnected with the broader challenges facing science education in the continent, which I will explore later.

Learner- or student-centred pedagogies: Curriculum policies for many African countries advocate for student-centred teaching of science (Nsengimana et al., 2020). This is because student-centred teaching is believed to be the best approach for developing students' knowledge and skills and to raise their achievement levels (Bremner, 2021; Otara et al., 2019; Overby, 2011). Research into science teachers' classroom practices has found that student-centred teaching tends to be poorly implemented due to large class sizes, lack of resources, and use of a foreign language as medium of instruction. I will discuss these challenges later.

Using observation, interviews, and video analysis of science teaching, Mkimbili (2018) explored how student-centred teaching of science in secondary schools in Tanzania is realised. The teachers found it difficult to engage students in critical thinking and problem-solving skills, open-mindedness, and asking questions for clarification. A key finding was that the use of resources within students' environments and the linking of questions to students' experiences can help facilitate student-centred teaching of science. The students were observed to be actively engaged when they were exposed to resources from their community and when instruction was done in their local language. Active student engagement in learning is an important aspect of student-centred teaching (Bremner, 2021; Paris & Combs, 2006).

In an effort to understand South African teachers' experience of student-centred teaching, Du Plessis (2020) conducted a qualitative study of their perceptions, experiences and challenges. The participants understood student-centred teaching to mean the active involvement of students in the learning process for their own knowledge construction. They also emphasised the need for personal and individual attention to be given to students. One feature of a student-centred approach the teachers articulated was collaboration among the students themselves and also among the teachers. Bremner's (2021) systematic review on student-centred teaching similarly found that the most frequently mentioned aspect of student-centred education is to allow students to interact with each other (see also Lee et al., 2021).

In her study of teachers' attitude towards the implementation of student-centred pedagogies in science classrooms in Kenya, Ndirangu (2017) worked with a sample of 147 science teachers who were in an in-service training aimed at developing their skills in using student-centred pedagogies. Using questionnaires, interviews, and observations, Ndirangu found that most of the participants had a positive attitude towards the implementation of the ideas learnt in the training. However, the implementation was not successful because the teachers lacked supportive environments. There was thus a dissonance between the teachers' positive attitudes and their implementation of student-centred ideas in their classrooms. In contrast, Otara et al.'s (2019) study in Rwanda showed teachers having positive attitudes to student-centred teaching pedagogies when compared to teacher-centred approaches. However, they showed negative attitudes to the use, significance, and challenges of applying student-centred teaching in the classroom. This implies that these teachers preferred to use student-centred pedagogies but did not practice them in their classrooms.

Challenges in teaching and learning of science: The main challenges arising from the large of body of research documenting the poor teaching of science in African classrooms include lack of resources, language of instruction, and overcrowded classrooms. There is a clear consensus among researchers that these challenges have contributed to the poor teaching of science experienced in the classrooms.

The literature extensively highlights the challenge of inadequate resources in teaching and learning science in Africa. This lack of resources includes the absence of teaching and learning materials, laboratory equipment, science textbooks, and adequate classroom facilities (Brobbey et al., 2020; Humphrey-Darkeh et al., 2022). Several studies found the lack of resources forced teachers to resort to teacher-centred methods, such as lectures, and questioning and answering (Adu-Gyamfi, 2014; Annafo, 2018; Marcourt et al., 2022; Ogunniyi & Rollnick, 2017). To understand the experiences of new qualified science teachers in Ghana, Boakye and Ampiah (2017) studied the challenges they faced. The teachers expressed frustration over the unavailability of teaching and learning materials, which hindered their ability to effectively teach certain scientific concepts. This lack of resources compelled them to resort to traditional lecture-based methods, thus limiting their students' engagement and interaction in the learning process. Science teachers' inability to implement student-centred teaching has also been reported in South Africa (Singh & Singh, 2012) and Tanzania (Mkimbili, 2018).

Another major challenge articulated in the literature on science education in Africa is the use of a foreign language such English as medium of instruction. Studies have shown that teachers face difficulties in ensuring that students understand science lessons effectively when using foreign language, and often resort to using local languages to facilitate better understanding (Acquah et al., 2013; Singh & Singh; 2012). Students' understanding of science concepts has been shown to improve when teachers use both the local and foreign languages (Asabere-Ameyaw & Ayelsoma, 2012; Boakye & Ampiah, 2017; Quansah et al., 2019). Most teachers in Africa therefore combine both the local language and a foreign language when teaching science. This approach also has its own implication for the teaching and learning of science since students only write in the foreign language like English. Students may therefore not be able to present the ideas well in the foreign language

Other challenges found in the literature relate to

- overcrowded classrooms (Humphrey-Darker et al., 2021; Ogunnniyi & Rollnick, 2017; Singh & Singh, 2012),
- lack of qualified science teachers (Brobbey, 2020; Mabula, 2012; Ogunnniyi & Rollnick, 2017),
- the broad nature of the science curriculum leading to an inability to complete the syllabus (Adu-Gyamfi, 2014).
- lack of in-service training for science teachers (Mabula, 2012),
- overreliance on didactic approaches in teaching science (Adu-Gyamfi, 2014, Coffie et al.,2020) and
- the tendency to "teach to the test" (Agbene et al., 2023; Boakye & Ampiah, 2017).

In his study of teachers of integrated science in Ghanian junior high schools, Adu-Gyamfi (2014) attributed the challenges they faced to the loaded nature of science curriculum; the lack of science teaching and learning materials; students' perceived difficulty of science; and teaching to the test. These challenges compelled the use of teacher-centred approaches, which negatively affected the students' performance, their interest in doing science and their participation in science lessons.

Engida (2010) observed that while science education research influences curriculum policies in Africa, its impact on their implementation remains unsatisfactory. This underscores the need for alternative approaches to research in science education that address the challenges rather than just highlighting them. My study is focussed on finding a more proactive and solution-oriented approach to researching science education in Africa.

Despite the amount of research on the challenges in science education in Africa, there has been limited discussion on how to address them. Even so, the key issues identified, such as inadequate resources, teacher-centred practices, and the lack of effective professional development have proved foundational for my study. The next crucial step is to focus on solutions and strategies for overcoming these obstacles as Ghana’s curriculum reforms shift teaching towards more student-centred approaches. This study supports this transformative agenda.

One significant finding from the literature on teaching and learning science demonstrate that transforming teaching practices has been challenging in certain contexts. The findings of the various researchers mentioned in the previous sections informed my decision to adopt an interventionist approach to support the Ghanaian curriculum's transformative agenda. The Change Laboratory was selected to help teachers learn and bring about changes in their practice in light of the new curriculum. It aimed at providing a structured environment for teachers to collaboratively identify challenges, develop solutions, and implement changes in their classrooms.

From the literature, it is evident that teachers generally tend to focus on curriculum coverage without engaging with their students’ interests. It is therefore crucial to ensure that the changes implemented by Ghanian teachers in lessons are closely aligned with both the curriculum content and their students’ active involvement. This alignment is particularly important because the pressure to cover curriculum content can often overshadow any focus on students’ engagement. Ensuring that changes are tightly connected to curriculum objectives and actively involving students is essential for meeting the intended curriculum.

The literature showed that teachers want to teach differently but feel constraint in their ability to do because of certain challenges. Being of aware of this and particularly the challenging situation in the study context, I embarked on this research not with the intention of correcting teachers' practices but to provide a platform for them to teach in ways that meet the intentions of the new curriculum.

2.2.2 Student's attitudes towards, perceptions of, and interests in science

This section analyses and synthesises studies on school students' attitudes towards, perceptions of, and interests in science, with the aim of identifying what is important to them as far the teaching and learning of science is concerned. I look first at studies on students' attitudes and then I focus on research on students' perceptions and interests.

In the research on science in education in Africa, a significant focus has been on students' perceptions, interests, and attitudes. This is motivated by the belief that, along with motivation, these qualities are crucial aspects of scientific literacy and therefore vital to students' academic success and to their personal and career choices (Chetcuti & Kioko, 2012; Egbenya & Quayson, 2022). Such studies are relevant to my research because I take the view that understanding *what matters* to students is important for fostering student-centred approaches to teaching science.

Students' Attitudes Towards Science*:* Several studies across various African countries have reported that school students generally exhibit positive attitudes toward science (Chetcuti & Kioko, 2012; Egbenya & Quayson, 2022; Jebson & Hena, 2015; Reddy, 2019). For instance, Chetcuti and Kioki (2012) studied the attitudes towards the study of science of 120 Kenyan girls from four different secondary schools. Data were collected through interviews and questionnaires. The results revealed that most of the participants had favourable attitudes, and the key factors influencing them were the enjoyment of science lessons and the relevance of the subject to everyday life and to a future career. These results align with those of Anamuah-

Mensah and Asabere-Ameyaw (2004), who found that a student's inclination to learn science can depend on whether they enjoy the subject, place value on it, and think it is important for success in school and for future career aspirations.

In Ghana, Egbenya and Quayson's (2022) survey of 162 junior high school students from seven basic schools in the Cape Coast Metropolis showed that these students had positive attitudes towards the study of science. A similar result was found by Jebson and Hena (2015), who used stratified sample techniques to study 250 science students in Nigeria.

The results of these African studies of students' attitudes agree with research undertaken in other developing countries (Awan & Sarwar, 2011; Zangmo et al., 2016). Even so, only a few have investigated teachers' attitudes. Abidoye et al. (2020), for example, found teachers generally had positive attitudes towards the teaching of science.

In contrast with these more positive findings, other African studies have reported unfavourable or negative attitudes towards the study of science. For example, in Nigeria, Harry's (2011) study of 300 students revealed they had negative attitudes. In a study in Ghana, Oppong et al. (2022) measured students' attitudes in four main areas: their motivation (encouragement) to learn science, their interest (enjoyment) in science lessons, their level of involvement (participation) in science lessons, and the types of interpersonal relationship that exist between them and their science teachers. The results in all the four areas were negative. Similarly, in Tanzania, Kihwele (2014) found that students had negative attitudes towards the subject and hence did not show interest in it.

Gender has also been found to affect students' attitudes towards the study of science internationally (Osborne et al., 2003; van Aalderen-Smeets et al., 2011) and in Kenya (Chetcuti & Kioki, 2012) and South Africa (Reddy, 2019). There is some evidence suggesting that there is no significant difference between boys and girls concerning their attitudes towards science in Ghana (Egbenya & Quayson, 2022), Nigeria (Harry, 2011; Olasehinde & Olatoye, 2014; Sakariyau et al., 2016) and South Africa (Reddy, 2019). Egbenya and Quayson (2022) attributed the lack of gender differences to awareness creation by government, school authorities and NGOs, the aim of which is to encourage girls' participation in science programs, thus contributing to their positive attitudes.

Other studies, for instance, by Jebson and Hena (2015) in Nigeria, have reported that, in certain cases, boys exhibit a more positive attitudes towards science than girls. Jebson and Hena attributed this difference to social norms, cultural barriers, the lack of role models, parental influence, and personal influence.

***Students' perceptions of and interests in science*:** Various studies have focused on students' perceptions and interest in science (Baidoo-Anu & Mensah, 2019; Kihwele, 2014; Mohammed et al., 2020; Singh & Singh, 2012). The consistent findings across most of these studies is that African students perceive science to be difficult, primarily because of the inherent challenges associated with the teaching and learning of it. The results of students' interests in science however tends to be ambiguous.

With exception of a few studies (e.g., Buabeng et al., 2014; Kihwele, 2014), the evidence shows that most students tend to be dissatisfied with transmissive approaches to teaching science in Africa. In Ghana, for example, Baidoo-Anu and Mensah (2019), used a descriptive survey of 290 students and 14 teachers to identify that most of the students found science difficult, boring and irrelevant. Also in Ghana, Amponsah and Mohammed (2019) found that students perceived their science curriculum to be loaded and inflexible. Earlier research by Adodo and Gbore (2012) found that students' interests, rather than attitudes, were stronger predictions of their performance. Another Ghanaian study by Agbene et al. (2020) concluded: "The majority of the students were not satisfied with their engagement in the teaching and learning process by their teachers" (p. 202). These publications underscore a prevailing sentiment among students regarding the lack of satisfaction with transmissive classroom teaching and learning experiences.

In Tanzania, Mkimbili (2018) researched the implementation of student-centred teaching in secondary schools. From the students' perspectives, challenges such as limited resources, use of foreign language as medium of instruction for teaching science, teacher-centred and transmissive approaches to teaching, and large content coverage militated against their learning of science. The students suggested student-centred science teaching and learning that involved discussion and questioning, resources from their surroundings, incorporation of real-life examples, and inclusive approaches would motivate them to participate more actively in class.

In summary, numerous studies have measured students' attitudes towards, interests in, and perceptions of science education in Africa. However, the research has predominantly focused on quantifying these perspectives rather than on exploring them in depth from the standpoint of what truly matters to students in the context of science education. This approach has provided valuable data but it has fallen short of harnessing students' perspectives to drive meaningful change that could inform and improve teaching practices. Students' perspectives remain abstract and underutilised in the context of practical classroom improvements. To enhance teacher learning and practice, this study has built on the literature by highlighting students' perspectives for teacher professional development.

This section of the literature review shows that students have diverse attitudes towards, perceptions of, and interests in science. It is a concern that a subject which students have positive attitude towards and find potentially interesting is often the one they do not enjoy. This observation highlights the need to incorporate students' perspectives into teaching practice. It is primarily the reason I draw on *what matters* to students as an important part of my conceptual framework (see Chapter 3), surfacing these perspectives for teacher professional learning with the aim that by addressing these issues it will encourage a shift in teaching practices towards alignment with students' interests, ultimately fostering greater student engagement with science.

A salient finding from this section of the literature review is that students' perspectives represent their unmet needs in the teaching and learning of science, thus underscoring the importance of surfacing *what matters* to students as part of teacher learning. The literature further highlights the fact the students not only recognise challenges in the way science is taught, but they can also make useful suggestions for its improvement. This insight strengthens my belief that incorporating students' perspectives – *what matters* to them – can significantly enhance teaching practices. It informs my decision to highlight *what matters* to students as a critical component of teacher learning.

2.2.3 Science teacher professional learning

I begin this section by highlighting the challenges in teacher professional learning in Africa, especially for science teachers. I then discuss the dominant professional development approach and how researchers have studied it. I also look at new approaches to professional development before concluding the section with their implications for my study. The key point in this section is that a growing number of researchers have shown that opportunities for science teachers in Africa to engage in professional development are scarce, and the few opportunities they do have are often ineffective for bringing about changes in their practices.

The lack of teacher professional development has been identified as a key challenge facing Africa's education systems, often impacting negatively on the quality of teaching, especially during reform implementation (Gyimah & Ayinselya, 2022; Mabula, 2012). Successful curriculum implementation is seen as contingent upon addressing teacher professional learning, with the belief that providing high-quality professional development is crucial for supporting changes in science classrooms (Mabula, 2012; Ogunnniyi & Rollnick, 2017). Curriculum reforms present challenges to science teachers, who may not be well prepared for the demands associated with them because of the lack of serious efforts to develop effective professional development programs to achieve intended goals reforms (Bantwini, 2009, 2010, 2019). This perspective aligns with that of Leu (2004), who argued that teacher professional development was a neglected area in developing countries.

In Tanzania, changes and modifications were made in the science curriculum without any professional development organised for teachers (Mabula, 2012). A survey conducted by Sodangi et al. (2022) in Nigeria revealed that the participating science and mathematics teachers rarely participated in professional development activities because of the lack of incentives, insufficient support, high costs, and poor publicity. Similarly in Ghana, Abreh (2018) identified the absence of a structured scheme for the continuous professional development of science and mathematics teachers as a major challenge. Bantwini (2019), in a South African study, found that science teachers' professional learning was neither formalised nor frequent.

The cascading approach to professional development in Africa. The literature shows that professional development for teachers in Africa, including science teachers, often adopts the cascading or multiplier workshop approach, which involves large, centralised training sessions to disseminate information relevant to teachers' practices (Gyima & Ayinselya, 2022; Hassler et al., 2018; Vhurumuku, 2023). The cascading model is known for its efficiency in reaching many teachers quickly and at a low cost, particularly during curriculum reforms (Lue, 2004; Ono & Ferreira, 2010).

However, the approach has been criticised for being less effective in implementing reforms that emphasise active learning, student-focused teaching, critical thinking, and problem-solving (Lue, 2004) – characteristics that are often highlighted in science education reforms in Africa. In a study of Ghanaian teachers' views about their professional development, Gyimah and Ayinselya (2022) criticised the cascading approach, arguing that the facilitators in these programs are often not teachers themselves, and their inability to relate the training to the realities of the classroom can impede teachers' capacity to apply new ideas there. The teachers thus become passive recipients of information, which hindered their abilities to translate knowledge into classroom practice. This point is supported by Abakah (2023), who studied Ghanaian teachers' engagement in continuous professional development.

Bantwini's (2009) South African study focused on the professional development of teachers following natural science curriculum reforms. The study highlighted the challenges faced by teachers as a result of the approach used. The cascading model, which is often chosen because of the constraint of not being able to take teachers out of their classrooms for an extended period, was found to be insufficient for addressing the complex issues affecting science teaching. It oriented the teachers toward the new curriculum but fell short of building teachers' science content knowledge and addressing their specific needs. The new curriculum expected teachers to adopt different teaching methods, but the professional development did not offer adequate support for this. Lack of follow-up and ongoing support also emerged as critical issues that hindered the successful implementation of the new curriculum.

After concluding that the cascading professional development models were incapable of addressing structural and historical challenges faced by science teachers, Bantwini (2009) advocated for models that would address historical and systemic challenges; meet new curriculum demands; provide ongoing support and opportunities for follow-up; and encourage teacher collegial collaborations. Such features were seen as crucial for helping teachers navigate the complexities arising from the legacy of the education system and the demands of new curriculum reforms.

Researching teacher professional development: A key observation in the literature is that much of the research on science teacher professional learning in Africa has predominantly focused on investigating teachers' perceptions of the programs they participated in. Such studies often highlight the challenges without attempting to address them (Abreh, 2018; Coffie, 2019; Kariuki et al., 2023; Oguta & Getange, 2019; Orado, 2023). For example, Gyimah and Ayinselya's (2022) used open- and closed-ended questionnaires to collect data in Ghana. They identified several challenges, including lack of motivation, and inadequate and inappropriate professional learning. The teachers also expressed dissatisfaction with the level of support they received, citing limited opportunities to attend workshops and conferences due to financial constraints. One of Gyimah and Ayinselya's (2022) key findings was the participating teachers' desire for empowerment through support and opportunities for collaboration. They wanted a platform where they could share experiences and learn from each other, indicating a preference for collaborative professional development approaches. Despite participating in professional development activities, teachers reported that these efforts were often ineffective as they fell short of their expectations, suggesting a gap between their needs and the effectiveness of existing programs.

In Ghana, Abreh (2018) studied heads of departments' (HOD) perceptions of teachers' participation in professional development programs and its influence on science and mathematics teaching. Using an exploratory survey method with a sample size of 170, he found that these HODs agreed that attending professional development workshops positively impacted science teaching, particularly in the areas of practical science, students' engagement in practical work, and teaching new concepts. It is important to note that these findings were based on the perceptions of HODs and not the teachers themselves. Abreh acknowledged this limitation and highlighted the need for caution in interpreting the results, given the potential differences in perspectives and the contradictions with the literature. His recommendations align with the broader discourse on the importance of providing more opportunities for the effective professional development for teachers.

Bantwini's (2019) study of South African science teachers' perceptions of their professional development also provided significant insights into the challenges they face. Through surveys, Bantwini found that teacher learning was not formalised and the teachers lacked opportunities to collaborate with their colleagues, both being factors they considered essential for enhancing their teaching practices. The professional development offered predominantly took the form of top-down, short-duration workshops of one or two days that often failed to address classroom-level issues. This left many teachers dissatisfied and feeling ill-prepared for their teaching roles. The study highlighted the need for ongoing support for science teachers, especially since some of them had not received formal training in the subject. It underscored the value of effective, supportive, and collaborative approaches to addressing the challenges in science education in Africa generally

***The call for new approaches in professional development*:** With the current models of professional development in Africa criticised as ineffective for addressing the challenges in science education, there have been calls for new forms of professional development. For example, Bantwini (2019) argued that "a search for new professional learning approaches, best structures, support and approaches that will likely enhance, and advance teacher learning and student achievement is essential" (pp. 221-222). Gyimah and Ayinselya (2022) have called for professional development that provides more opportunities for teachers to collaborate to learn from each other, share ideas, and work together to meet reform demands, arguing that the process of collaborating would make teachers more agentic: "The best way could be empowering them by giving teachers themselves more opportunities to determine and control their own learning activities” (pp. 28-29). Mabula (2012) suggested that researchers and facilitators can address the gaps in professional development, thus supporting teachers in their professional learning while government addresses other factors such as inadequate resources.

With the cascading approach to science teacher professional development having proved ineffective, various alternative approaches have been explored, with mixed results. These include lesson study intervention (Ono & Ferreira, 2010); action research (Msomi et al 2014); practice-based approaches (Jeram & Davids, 2020); school-based teacher professional development (Hassler et al., 2018); participation in science fairs (Mbowane et al., 2017), and short learning programs (De Beer, 2020).

A study in Ghana conducted by Beem (2020) that focused on the Practical Education Network (PEN)'s approach to training teachers in Science, Technology, Engineering, and Mathematics (STEM), is a positive example of the potential impact of targeted professional development. This two-and-a-half-month intervention, which involved weekly support sessions with a focus on hands-on activities, led to encouraging results in terms of students’ learning outcomes, attitudes toward science, and interest in STEM. These findings suggest that well-designed and targeted professional development programs for teachers can contribute to addressing challenges in science education in African contexts, such as Ghana.

Conversely, a study conducted by De Beer (2020) involving a short learning program aimed at transforming teaching practices, showed that 70% of the teachers did not exhibit any change in their teaching approaches. De Beer attributed this lack of impact to the brief duration of the intervention, which did not provide enough support for the teachers, and recommended a more systematic approach to the intervention. This highlights the complexity of implementing effective professional development, and the need for a theoretical framework that can provide valuable insights into understanding how the interplay of cultural, historical, and social factors can contribute to the development of more effective and contextually relevant teacher professional development programs.

As previously mentioned, the literature on science teacher professional development has predominantly focused on studying teachers' perceptions of professional development programs, and not on the practical implications and effectiveness of them. To gain a comprehensive understanding of how these programs impact teaching practices and student outcomes in Africa, it is essential to explore not just teachers' perceptions but also the tangible outcomes and transformations resulting from them. This is the purpose of my study.

A noticeable finding in this section is that the lack of effective professional development for science teachers contributes to the gap between the intended curriculum and its implementation. The predominant approaches to teacher professional development in Africa have been ineffective due to their prescriptive nature, which often results in ideas that teachers find challenging to implement. Furthermore, it has been observed that teachers desire professional development opportunities that offer support and foster collaboration. My study was therefore designed to demonstrate the value of meaningful support and collaboration among science teachers, and how they can use a bottom-up approach to develop their own ideas and implement them in their classrooms.

Another significant finding from the literature, which has considerable implications for my study, is that effective professional development should not only support teachers in adopting new practices but also create conducive environments that facilitate the implementation of these changes. Therefore, my study focused on the support and conditions needed for teacher professional learning.

The literature review further shows that in the African context, science education in general and science teacher professional learning in particular are not much theorised. Very few studies have applied theories like situational learning theory (Bantwini, 2019) or constructivism and social learning theory (Abreh, 2018) to study science teacher professional development. This means that there is a lack of robust theoretical frameworks guiding research and practice in these areas. Consequently, the field may not benefit from the application of established theories to provide deeper insights and more effective strategies for improving science education and teacher professional development in the African context. In this study, I apply CHAT as the theoretical framework. CHAT has been used considerably in research into science teacher professional learning in Europe but scarcely at all in Africa.

2.3 CHAT and science education

In this section, I review the literature on CHAT and how it has been applied in science education. The focus here is on the empirical literature, while the conceptual and theoretical ideas will be addressed in Chapter 3. After articulating the importance of CHAT for research in science education, I discuss the diverse areas in which CHAT has been applied in that field and reflect on the implications of CHAT for my own study.

Much of the work on the use of CHAT in science education has been analytical rather than interventionist, they focus more on teacher learning, especially in preservice teaching. Such studies have mostly identified contradictions in participants' activity systems but not provided evidence of their resolution. Moreover, research involving science teachers from multiple schools is very rare.

The literature indicates that CHAT offers a relevant set of concepts for understanding teacher professional learning, particularly in the context of transformative change, enabling a nuanced understanding of how transformations occur. However, studies that applied CHAT in science education used a limited range of CHAT concepts. There are clear opportunities to expand this, notably in relational agency and in transformative agency by double stimulation (TADS) (Hopwood, 2024).

The relation between CHAT and science education has been described as a mature area of research (Trugillo et al., 2023). The importance of CHAT as a theoretical framework for understanding and transforming practice in education generally and science education in particular is well documented in the literature. CHAT is considered a powerful tool for reshaping and empowering research in science education and fostering collaboration to drive meaningful change (Roth et al., 2009). Its primary aim is to enable understanding and transformation of practice, while addressing the gap between theory and praxis (Plakitsi, 2013).

According to Lee (2011), CHAT can address some of the major challenges in educational change research: “We are on safe ground if we adopt activity theory as a practitioner-oriented model for praxis that complements our present knowledge-base and methods in educational change research” (p. 419). Essentially, CHAT can be a methodological framework for analysing educational activity with the aim of identifying motives that people bring to bear on the activity and the contradictions within the activity. In this way, research participants can better understand the process in the activity and identify actions needed to bring about improvements in their practices (Wilson, 2014)

CHAT has been applied across wide range of context in science education, as illustrated in Table 2.1. Most of these studies focus on understanding contextualised and mediated human activity, with an emphasis on transformation (Alvaro & Ametller, 2021).

Table 2.1 Application of CHAT in Science Education

Area of application	Studies
Preservice teacher education	Ahmed, 2014; Anderson & Stillman, 2013; Chikunda, 2014; Rutt & Mumba, 2023; Sezen-barrie & Marbach-ad, 2021; Wilson, 2014.
Teacher professional development and practice	Beer, 2020; Feldman & Weiss, 2010; Forbes et al., 2020; Goodnough, 2016; Goodnough, 2019; Koumara & Plakitsi, 2020; Longhurst et al., 2017
Understanding, designing and implementation of science education policies	Lee, 2011; Chikunda, 2014
Teaching and learning of science	Cripps Clark, 2014; Alvaro & Ametller, 2021; Barma, 2011; Beer et al., 2021; Cripps Clark & Groves, 2012; Patchen & Smithenry, 2014; Salloum & BouJaoude, 2021
Other aspects including: Science education collaboration; argumentation in science education; researching science education	Clark et al., 2021; Lazarou, 2011; Lazarou et al., 2016; Saka et al., 2009; Trugillo et al., 2023

In the following sections, I focus on science education research studies using CHAT that are most relevant to my study, namely, those that concerned with teacher professional development; understanding, designing, and implementing science education policies; and the teaching and learning of science. However, I acknowledge the important contributions of eminent CHAT scholars like Marilyn Fleer to early childhood education and Wolff-Michael Roth to the theory of science education. While these researchers have made significant contribution to CHAT research within and beyond science education, my work focuses on the teaching of students older than Fleer's, it draws more on concepts related to Change Laboratories than does Roth's work.

Teacher professional development and learning: Goodnough (2019) applied CHAT to a study of the professional learning experiences of three teachers. The aim was to gain insights into the complexities of teacher learning, taking into account the social, cultural, and historical dimensions of their classroom practices. This research was part of a 5-year-long professional development initiative using action research to support teachers in STEM subjects through inquiry-based approaches. Goodnough collected data through classroom observations, interviews, and the examination of teacher-created artifacts.

The results of the Goodnough's (2019) study revealed notable improvements in teacher pedagogical knowledge and teaching practices as a result of the professional development initiative grounded in CHAT. The teachers exhibited a positive change in their ability to adopt various tools and strategies for authentic student assessments. A key area of transformation was the teachers' utilisation of questioning techniques. The participants developed skills to employ questioning effectively, thus fostering students' problem-solving and critical thinking abilities in support of the inquiry process. Goodnough concluded: "The teachers adopted new pedagogical tools …, which necessitated the adoption of new ways to support students' learning. The teachers were also able to gain more insight into students' thinking through expanding their assessment repertoire" (p. 377). The results of the study show how access to an effective professional development was germane to the change in teachers classrooms practice.

Similarly, in an earlier study Goodnough (2016) used CHAT to examine the participating K-6 science teachers' professional development, which was aimed at making their teaching practices more engaging and hands-on through collaborative action research. The professional development was also designed to support teachers in becoming more confident in teaching STEM subjects by adopting student-centred inquiry-based approaches in teaching. Goodnough also used CHAT to examine how contradictions or tensions might have become sources of change for the teachers by addressing the following research questions: (a) How will teachers' activity systems change as they participate in professional learning through action research? (b) What contradictions will arise in their activity systems? (c) How will the contradictions that arise in their activity systems become sources of learning?

Goodnough (2016) collected data through a pre-implementation inquiry brief, teacher reflections, post- implementation semi-structured interviews, a teacher-created multimedia presentation, and researcher notes. Data analysis showed that the contradictions in the teachers' activity systems became sources of their professional growth. Goodnough concluded that as a result of participating in a teacher-centred form of professional development focused on the needs of the teachers and of their students, the participants became more confident teachers of science, enhanced their pedagogies, and successfully addressed some of the contradictions in their activity systems.

De Beer and Kriek (2021) undertook a professional development initiative for science teachers aimed at contextualising their curriculum by incorporating indigenous knowledge. The teachers were provided with an opportunity to infuse indigenous knowledge alongside natural science in their classrooms through an interventional professional development session conducted in two iterative cycles. Throughout each cycle, CHAT was employed to gain insights into the teachers' learning processes. Data for the study were gathered through observations, questionnaire portfolios, and interviews. The results of the study indicated that the teachers did not effectively incorporate indigenous knowledge into their science content after the program, even though they were well informed about it. Applying CHAT as a framework, De Beer and Kriek articulated reasons for this lack of integration, identifying key factors such as pressure to produce positive academic results and a deficiency in resources. They concluded their study by emphasising the utility of CHAT as a valuable framework for assisting researchers in interpreting complex data in the context of educational change.

Longhurst et al. (2017) studied the factors influencing teachers' appropriation of professional learning focused on the use of technology in science classrooms. Their research involved four teachers from a group of science teachers who were engaged in professional development using cyber-enabled technologies. Longhurst et al. collected data through observations and interviews. The data analysis, which was done using CHAT, showed that the factors that influenced appropriation of professional development and instructional strategies included opportunities for personalised paths to appropriate conceptual or practical tools; planning for intentional adaptation, which allowed the teachers to develop ownership attributes of pedagogical tools of instruction; and the support for the creation of trusting cultures of learning where teachers could develop long-term support systems.

The challenges faced by novice teachers as they learn to transition from teacher preparation programs to the reality of the classroom were explored through the lens of CHAT in a study conducted by Saka et al. (2009). The authors recognised that the demanding nature of the early stages of teaching often leads to a mismatch between the theoretical knowledge acquired during teacher preparation and the practical realities encountered in the classroom. They used the CHAT perspective with a particular emphasis on the role played by communities of practice in this process. Data were collected through questionnaires, interviews and observations of two novice science teachers. The results showed that the extent the teachers learned to be involved in the community of practices, their instructional practices were influenced by the structures put in place at the school and by support from other staff.

One distinct study of science teacher professional development that used CHAT, not only as an analytical framework but also as a guide in designing, implementing and analysing the data, was conducted by Kourama and Plakitsi (2020). The aim of the program was to help a group of science teachers integrate science knowledge into their teaching. Forty-nine teachers were involved in four 3-hour meetings held fortnightly, in which both the teachers and researchers co-participated. Upon initial data analysis, Koumara and Plakitsi concluded that the professional development program was successful. It not only enhanced the teachers' knowledge about the nature of science but also cultivated a positive attitude toward its incorporation into the classroom. The participants acknowledged the positive interactions during the program and expressed a desire for more of similar professional development sessions. The use of CHAT in the design and analysis of the program showcased its versatility as a framework that not only provides insights into the learning process but also serves as a valuable tool in shaping and evaluating professional development initiatives in science education.

Understanding, designing and implementing science education policies: The application of CHAT as an analytical tool for understanding, designing and implementing science education policies is evident in studies such as those of Lee (2011) and Chikunda (2014), which focused on different aspects of science curricula. Lee used CHAT as an analytical tool to understand educational change, with a focus on science curriculum. Using a case of a secondary school in Singapore that had devised an inquiry-based science curriculum, Lee showed how CHAT facilitated change in five key areas, thereby contributing valuable insights to the broader understanding of the educational change process. Data were collected through videotaped lessons of six teachers; audio tapes made during curriculum development meetings; interviews with teachers and students; field notes; and documentary analysis. By employing CHAT, Lee was able to dissect the complex interactions and dynamics involved in implementing a new curriculum, shedding light on the transformative elements at play.

Chikunda (2014), on the other hand, adopted the CHAT framework to investigate the tensions in gender-responsive curriculum practices within science teacher education in Zimbabwe. The data collection process included interviews, focus group discussions, and documentary analysis. Chikunda highlighted the efficacy of CHAT in unpacking practices into components, allowing for the identification of tensions hindering progress toward gender-responsive curriculum practices. He was able to identify some of the underlying tensions that hindered progress toward gender-responsive curriculum practice, such as the teachers' low levels of gender awareness, the patriarchal socialisation of teacher educators, and the rigid curriculum requirements in the institution.

Teaching and learning of science: CHAT has proven to be a versatile and valuable framework in various studies related to the teaching and learning of science. Patchen and Smithenry (2014) applied CHAT to a study of how teachers support the practical integration of student-directed inquiry in their science classrooms. They sought to answer two research questions: (1) How do class members (the teacher and students) engage in these distinct participant structures and who holds authority? (2) How does the teacher work through the dilemmas associated with diversifying instruction across structures while assuring that students build the capacity to act with disciplinary authority? Data were collected through observation, field notes and interviews, and then analysed using CHAT to get a sense of the participant's enacted curriculum. Patchen and Smithenry considered one teacher's day-to-day teaching within a chemistry curriculum by examining the teacher's and students' practices in the classroom. The teacher was able to transition between participant structures using both traditional and novel ways to transform classroom activity. Also, using CHAT, Patchen and Smithenry explained how traditional modes of teaching were used to support changes in authority as the teacher diversified participants' structures in the development of student-directed inquires.

Morales (2017) also researched physics education in the Philippines, utilising CHAT to study students' learning experiences and misconceptions as they were taught physics for 10 weeks using designed culture- and language-influenced curriculum materials. Data were collected through classroom observations, interviews and focus group discussions. With the results indicating a better conceptual understanding of physics, Morales concluded that the blending of culture and language in the physics classroom contributed to addressing the students' misconceptions in physics. The CHAT framework had enabled an explanation of how the mediating artifacts addressed the students' misconceptions.

In an earlier study, Barma (2011) adapted CHAT to investigate a biology teacher's planning and implementation of lessons during a pedagogical reform in Quebec, Canada. The study sought to answer the research question: In the context of the implementation of a new science and technology curriculum, how does a science teacher make an effort to change her practice as she plans and implements an awareness campaign on the risks of tanning salons? The methodological framing of the research was anchored in the theme "Awareness of the Risks of Tanning Salons", the salons serving as mediating tools in the curriculum implementation. CHAT played a crucial role in interpreting the data, which were collected over a 4-month period through observations and interviews. The results showed that the teacher resolved several tensions encountered in reforming her classroom practice, enabling her to move from mostly didactic teaching to a more interactive approach. By examining the interactions within different aspects of the teacher's activity system, Barma demonstrated how the teacher applied new tools to implement the reformed pedagogy. CHAT played a crucial role in interpreting the data, allowing the researcher to make explicit connections to the changes in practice that the teacher underwent because of the pedagogical reform.

In a similar way, Salloum and BouJaoude (2021) used CHAT to analyse the extent to which students' ideas were taken up and built upon for conceptual understanding in multilingual science classrooms in Lebanon. The researchers collected data from observation and videotaped science lessons, together with semi-structured interviews to address two key research questions: (1) How are teachers' and students' language and pedagogical practices situated in the classroom activity systems in different multilingual science classrooms? (2)

What contradictions emerge within the activity systems of the different multilingual science classrooms and what do these involve?

Utilising activity systems as an analytical framework, Salloum and BouJaoude (2021) identified that contradictions within the science teachers' classrooms were mostly related to the use of English language as medium of instruction, textbook usage, and the school's limited resources. Their study illustrates how CHAT can serve as a powerful tool for unpacking complex interactions and dynamics within multilingual science classrooms, thereby contributing to the enhancement of science education practices.

In a related context, Cripps Clark and Groves (2012) used CHAT to investigate the interplay between the choices primary teachers make when using practical activities in teaching science and the purposes they attribute to their emotions, beliefs, and identities as primary science teachers. They collected video recordings of science lessons and interviewed both students and teachers. Drawing on case studies of four exemplary teachers of science in the primary school, the study showed that the identities of the teachers were developed through the interactions with their emotions; their relationships with the children and the school community; their backgrounds in and beliefs about science; and their experiences of using practical activities in the classroom.

In summary, the literature reviewed in this section shows that studies applying CHAT in science education have predominantly concentrated on a limited range of conceptual ideas, mainly focusing on systemic contradictions and activity systems. Key concepts such as double stimulation, germ cells, and transformative agency were scarcely used in data analyses, thereby failing to fully leverage CHAT's potential for understanding and addressing systemic challenges. My study sought to expand the application of CHAT and address the gaps in the current literature by integrating established concepts from existing research and introducing new concepts such as TADS and Common Knowledge, which have yet to be explored in the context of science education.

Moreover, as previously indicated, most studies on science teacher professional development that utilised CHAT employed it primarily for analytical rather than interventionist purposes. While these studies offer insights into the contradictions within participants' activity systems and illustrate how CHAT provides a nuanced understanding of their learning processes, they often fail to capture the full transformative potential of CHAT interventions.

One notable finding from the literature reviewed in this section is that professional development grounded in CHAT provides effective tools for enacting change and offers profound insights into the transformative process. In my study, which aimed to support teachers in implementing changes in their practice, CHAT was instrumental in offering tools like systemic contradictions and expansive learning. Additionally, there are other CHAT-related tools, such as Common Knowledge and TADS, that are yet to be applied in science education. To effectively leverage these insights and tools in my study. I chose to incorporate CHAT as the framework when designing my research and for analysing the participating teacher's professional learning.

2.4 Change laboratories in the African educational context

CHAT favours interventional methodologies. For my study I used Change Laboratory, an established formative intervention that is grounded in CHAT. In Chapter 3, I explain in detail the theory underpinning Change Laboratory, and in Chapter 4, I present its methodological aspects. In this section of the literature review, I synthesise the findings from Change Laboratories in different African educational settings, providing insights into its applications, challenges, and successes. This will help to pinpoint the aspect of novelty in my research.

I begin with a brief introduction to Change Laboratory. This is followed by the review of the various research studies that applied Change Laboratory in Africa educational context.

Change Laboratory is a theoretically informed type of action research rooted in CHAT (Sannino et al., 2016a), which aims to provide appropriate and contextually relevant responses to systemic challenges (Botha, 2017; Sannino et al., 2016a). It is an interventional approach designed to transform practices, especially education practices with deep-seated challenges (Batane, 2017; Winberg et al., 2023). For Hopwood (2024), Change Laboratory provides a grounded approach to changing teachers' practices by allowing them to recognise the challenges they face when acting alone as change agents. Teachers can thus collaboratively address the challenges in their activity systems (Garraway, 2020). Virkkunen and Newnham (2013) elaborated on the importance of Change Laboratory by outlining how its outcomes encompass enhanced knowledge and understanding of developmental challenges and possibilities within the relevant activities. Additionally, Change Laboratory interventions allow for collective and individual transformative agency; the formation of new concepts, tools, and organisational forms; and overall change and development in both the specific activity and the individuals involved (Virkkunen & Newnham, 2013).

There is evidence that Change Laboratory interventions can lead to meaningful transformations in aspects of schooling in the African continent by addressing systemic issues and bringing about positive changes in educational practices. The studies I review in this section highlight the adaptability of Change Laboratory to diverse educational settings, emphasising its role in helping professionals learn about and resolve challenges in their pedagogic practices including: school dropout, information and communication technology (ICT) integration, student leadership, teacher development, and gender-responsive curriculum transformation.

Batane (2017) conducted a Change Laboratory intervention to address school dropout in a primary school in Botswana. It involved a series of eight video-recorded Change Laboratory sessions. Participants systematically identified the root causes of school dropout and collaboratively developed viable solutions. Batane concluded that the Change Laboratory not only empowered the teachers to recognise and address challenges but also facilitated the development of their capabilities as effective change agents. This, in turn, resulted in tangible improvements in their students' learning outcomes and behaviours.

Also in Botswana, Virkkunen and Newnham (2013) reported the results of a Change Laboratory initiative implemented during a critical time when the government was introducing ICT in school education. They initiated the Change Laboratory by collecting ethnographic data, primarily through interviews with various stakeholders within the school where the intervention took place. This methodological foundation allowed for a comprehensive understanding of the contextual nuances and challenges associated with the integration of ICT in education. The Change Laboratory process engaged a cohort of 10 teachers in seven sessions, each lasting a minimum of 2 hours. All sessions were video-recorded, providing a rich dataset for subsequent analysis.

Virkkunen and Newnham (2013) concluded that the Change Laboratory process resulted in some key changes. Apart from creating new concepts of teaching, it supported teachers in developing their activities, specifically the incorporation of ICT in teaching. Importantly, it also provided the participants with knowledge and understanding of the challenges in their activities, stimulating a sense of responsibility for finding solutions. Collaborative teaching emerged as a significant outcome, with the teachers wanting to combine it with a student-centred approach that was grounded, at least partly, in their students' projects.

In a separate report on the same Change Laboratory project, Virkkunen et al. (2012) demonstrated how the process had empowered the school to interrupt the problematic practice of teachers classifying science students as single, double, or triple, which was identified as a significant issue during the Change Laboratory. The initial data gathered during the Change Laboratory revealed a contradictory state where the teachers' categorisations of students and their teaching methods failed to address the existing heterogeneity. Participants actively sought solutions to overcome these contradictions by proposing and experimenting with various ideas.

In their article titled "Change Laboratory Workshops as Tools for Improving Learner Leadership in Schools: A Researcher-Interventionist Approach," Kandjengo and Shikalepo (2021) described a Change Laboratory conducted in a secondary school in Namibia with the aim of developing students' leadership potential in a context "where children are taught to listen and are discouraged from questioning their elders" (p. 359). Over two Change Laboratory sessions, Kandjengo and Shikalepo provided students with an opportunity to identify and plan solutions for the contradictions and challenges they faced. Labelling the process as "partially successful", they reported that the Change Laboratory had enabled the student leaders to map their leadership directions.

In a related study by Grant and Kajee (2023) conducted in a rural school in Namibia, which drew on data from "learner-led" student-authored reports for school change within the framework of school-based learner leadership development, the Change Laboratory assisted students in developing leadership skills. However, deriving conclusions from secondary reports posed limitations, as the intervention's specifics were not clearly outlined, despite the authors' assertion that they had employed a Change Laboratory methodology.

Mbelani (2018) implemented a Change Laboratory to reshape teachers' development of their students' visual literacy in South Africa. The intervention engaged nine teachers in four Change

Laboratory sessions, each lasting two hours. The Change Laboratory was specifically designed to raise awareness among teachers of how their teaching approaches could either facilitate or impede the achievement of visually literate students. It aimed to identify contradictions within the teacher activity system and leverage these contradictions as a springboard for change. Through the Change Laboratory, teachers were encouraged to scrutinise their own practices, reject certain aspects, envision new possibilities for action, and take consequential steps to transform their teaching methods. This transformative process resulted in heightened student participation. Mbelani highlighted that the Change Laboratory offered a valuable opportunity for teachers to learn from each other, thus fostering a collaborative environment. Additionally, it expanded teachers' pedagogical content knowledge, leading to the adoption of new approaches to teaching.

In contrast to the predominant focus on Change Laboratories improving teaching across Africa, Bhurekeni (2021) demonstrated how this approach could effectively enhance primary school students' learning in Zimbabwe. The Change Laboratory engaged the participating students in philosophical discussions to empower them as critical thinkers. Bhurekeni observed the successful realisation of this objective, as the students involved in the intervention demonstrated the ability to formulate their own philosophical questions. This capacity was evident both after a stimulus had been presented to them and during deliberations in the Community of Inquiry sessions. The positive impact of the Change Laboratory on these students' learning was evident in the way they adeptly followed the logical flow of arguments and used questions and inquiry to drive their own learning and to cultivate an interest in exploring the world. Bhurekeni's study provides valuable insights into the potential of Change Laboratories to not only enhance teaching but also to significantly improve students' learning experiences.

A few of the Change Laboratories in Africa have addressed issues in tertiary education. Chikunda et al.'s (2017) research in Zimbabwe provides insights into the boundary learning process that was undertaken to support gender-responsive curriculum transformation in STEM within preservice teacher education. Different Change Laboratory sessions were conducted for various teacher education stakeholders. Chikunda et al. concluded that the Change Laboratory provided a valuable opportunity for the stakeholders to address contradictions within the system and collaboratively design improved ways of approaching their work. Their study highlights the efficacy of the Change Laboratory methodology in fostering positive transformations in preservice teacher education.

In a tertiary education context, Garraway (2021) showed how a Change Laboratory assisted academics in a newly formed university to learn about and resolve challenges in their work. In a related study, Garraway and Christopher (2020) found that through the Change Laboratory their research participants could provide solutions to the challenges in mentoring emergency medical care students in their work placements. Such studies broaden our understanding of the applicability of Change Laboratory, showcasing its potential impact on academic development within evolving institutional environments.

While the Change Laboratory methodology exhibits transformative capabilities, it is essential to acknowledge that not all Change Laboratories yield the intended outcomes (Hopwood 2024; Winberg et al., 2023). Various factors have contributed to setbacks, including incomplete processes during Change Laboratory sessions due to time constraints; participant disengagement and withdrawal; and communication breakdown (Winberg et al., 2023). In addition, reverting and resistance, which stem from institutional levels; participant reluctance; and other stakeholders can contribute to the potential failures of Change Laboratories (Hopwood, 2024). It is imperative to note that these challenges do not necessarily reflect inherent weaknesses in the approach; rather, they highlight the complexities in the implementation process (Hopwood, 2024).

The primary focus of the literature reviewed in this section has been on identifying contradictions within participants' activity systems and exploring how the Change Laboratory methodology can assist in addressing these issues. However, the literature does not provide sufficient discussion on how the Change Laboratory enables participants to develop agency in resolving these problems. Additionally, the literature scarcely mentions or reports on key concepts such as the germ cell and the mechanisms of first and second stimuli. Fundamental principle of the Change Laboratory is the concept of double stimulation, which involves the strategic use of first and second stimuli and surfaces. Some of the studies on the Change Laboratory in Africa lack clarity regarding the types of stimuli and surfaces employed, particularly the second stimulus.

This review has demonstrated that the Change Laboratory approach has been effective in addressing challenges and fostering positive changes in educational practices in Africa. A significant finding from the literature review is that when teachers are provided with appropriate interventions and support, they can become effective agents of change. This provides compelling evidence for my utilising the Change Laboratory methodology as a crucial tool to support science teachers in implementing the new curriculum in Ghana.

An outstanding finding in the literature review for my study is that when teachers are provided with the necessary support and intervention, they can become effective change agents. This served as key anchor for my study to assist teachers in enacting changes in their practice. Additionally, the literature highlights the need for contextual adaptations to ensure that CHAT effectively addresses the specific challenges faced by participants. This understanding guided my approach to tailoring CHAT interventions to the local context and maximising their impact.

Considering that teacher professional learning is the most common issue addressed by Change Laboratory studies internationally (Hopwood, 2024), it is surprising the research on Change Laboratories in Africa has paid little or no attention to teacher professional learning, particularly in the context of curriculum implementation Also given the enormous challenges facing science education on the continent, it would be expected that Change Laboratory will be conducted see how it helps providing opportunities to address some of these challenges. However, research on science using Change Laboratory is lacking the African context.

This observation suggests an opportunity for the Change Laboratory approach to address a potential gap in science teacher professional learning. Further exploration should significantly enhance the effectiveness of curriculum implementation in the African context, particularly in science education, which is the focus of my study.

2.5 Summary of the literature review and the gaps identified

This review has shown that, even though most science curricula in Africa advocate for student-centred approaches to the teaching of science, it is dominated by the transmissive teacher-centred approach, which students often find unsatisfactory. This has been attributed to factors such as lack of teaching and resources, overcrowded classrooms, the use of a foreign language as medium of instruction, and overloaded curriculums. While the existing research has effectively outlined these challenges across Africa, there is a noticeable gap in discussions concerning concrete strategies and interventions to address these issues and enhance the quality of science education. I have aimed to fill this gap by taking a proactive approach, shifting the focus from solely identifying problems to actively seeking and implementing solutions.

A large amount of research literature on science education in African has focussed on students' perceptions of, interests in, and attitudes towards science because these dispositions influence the study of the subject in schools. While a clear pattern of results shows that students tend to have positive attitudes towards the study of science, they perceive science to be difficult because of the way it is taught. An important gap in this aspect of the literature is that studies of pedagogical practices have made no attempt to surface or address students' perspectives. My study has addressed this gap in a unique way by going beyond students' perceptions of the challenges in the teaching and learning of science to encouraging them to articulate solutions for teachers' learning, thereby facilitating a more student-centred pedagogy.

This review identified that the few opportunities for science teachers in Africa to engage in professional development are often ineffective because most adopt the cascading approach, with large numbers of teachers gathering at one place for information but not receiving support for their classroom practices. A major gap identified in the literature on teacher professional development is that researchers tend to focus on teachers' perceptions of the challenges they face, but not actually on the teachers' professional learning. While understanding teachers' perspectives is valuable for identifying areas of improvement, it is important to move beyond merely documenting challenges and to explore actionable solutions that can enhance teacher professional development and ultimately improve science education.

Many of the science education studies reviewed in this chapter applied CHAT for analytical purposes rather than for interventions, while the few that applied it for interventions were restricted to one particular school. Moreover, there is a small body of research that applied CHAT to the study of science teachers' professional learning and this study contributes to that field. My study applied the Change Laboratory methodology, an interventional aspect of CHAT, by engaging teachers from different schools in collaborative learning to transform their practices.

In the next chapter, I will explain the conceptual framework that guided my research.

Chapter 3: Theoretical Framework

This chapter is organised under eight sections. Section 3.1 introduces the chapter. Section 3.2 discusses cultural-historical activity theory (CHAT) and the rationale for using it in this study. The key concepts relevant to this study are explained: the activity system (3.3), contradiction (3.4), expansive learning (3.5), agency in CHAT (3.6), common knowledge (3.7). Section 3.8 then provides a conclusion to the chapter.

3.1 Introduction

The main research question that guides this study is: how can barriers to pedagogic change be overcome in the context of science curriculum reform in Ghana? Based on the literature review, where I argued for the need to create conditions for change (rather than documenting challenges), the need for a relevant theoretical framework was identified. The intention was to involve teachers actively and collectively in working through problems. For these reasons, the study was conducted using CHAT. The theory enabled me to frame the teaching and learning of science in Ghana as a collective activity with different components shaped by its historical and cultural context. The interventionist aspect of CHAT conducted in a form of Change Laboratory (see Chapter 4) provided the teachers with an opportunity to collectively analyse, design and implement their own solutions to address the challenges they face in teaching science under the new curriculum.

3.2 Cultural-historical activity theory (CHAT)

In this section, I discuss CHAT, the theoretical framework applied in this study, by first distinguishing it from other theories with similar roots and articulating my rationale for selecting this theoretical framework. I then look at the historical developments in CHAT.

Activity theory rooted in the works of Russian founders such as Vygotsky, and Leont'ev is pursued in many variations around the globe (Engeström & Sannino, 2021), leading to multiple uses of terms such as cultural-historical theory (CHT), cultural-historical activity theory (CHAT) and sociocultural theory (SCT) (Stetsenko, 2024). In this study, I use the term CHAT to refer to a research approach associated with Finnish tradition represented by the works of Yrjö Engeström, Annalisa Sannino and others from the CRADLE Research Centre at the University of Helsinki. This approach is noted for ideas of activity systems with their representation by triangular models, emphasis on contradictions in and between activity systems, expansive learning and the use of Change Laboratories as interventional tools (Engeström & Sannino, 2021).

CHAT is an interventionist theory (Engeström 2014; Engeström & Sannino, 2010; Sannino, 2011). This means it seeks to understand and promote change, rather than understand the world as it is. This has been described as studying things 'in motion' (Chaiklin, 2012) referring to how things are changing, rather than simply comparing before and after as is common in interventionist research using experimental designs. Another key difference from quantitative experiments is that the intervention is not known at the outset: this is captured in the term 'formative intervention' (Engeström, 2011) and is discussed more in Chapter 3, which details the Change Laboratory approach used in this study. As an approach to studying and facilitating change, CHAT is distinctive in drawing attention to what happens between people, and between them and the tools they use in purposeful activities - rather than focusing on what is happening inside individuals ((Engeström, 2011). This guided my interest in how teachers could work together to develop and use new tools to change their pedagogic practices. Before further detailing the history and key concepts in CHAT, I will outline my main reasons for choosing CHAT.

There are three main reasons why CHAT was chosen as the theoretical framework for this study. First, the primary goal of this study is to facilitate change in teaching practices to ensure the successful implementation of the intended curriculum. CHAT is well-suited for this purpose because it is a powerful tool for reshaping and empowering research in science education and fostering collaboration to drive meaningful change (Roth et al., 2009). CHAT focuses on understanding and facilitating the transformation of activity systems, making it particularly effective for examining and promoting changes in educational practices, which aligns with the study's objective.

Second, this study is concerned not only with the learning outcomes but also with the learning process, unlike many studies on teacher professional learning that primarily focus on outcomes (Wei, 2017). The aim is to delve into the inner dynamics of teacher professional learning, exploring the driving forces and mechanisms that underpin it, as reflected in the research questions. CHAT was chosen for this study because it provides a "robust lens to help crack the inner mechanisms of teacher professional learning" (Wei, 2017, p.37). This theoretical framework allows for a deeper understanding of the complexities and processes involved in teachers' professional growth and development, rather than merely evaluating the end results. Thus, CHAT offers an appropriate framework to comprehensively understand teachers' professional learning as a process, not just a product or outcome of intervention.

Third, CHAT possesses integrative power through the combination of theoretical and practical tools – in the form of a Change Laboratory, offering new perspectives on both doing and understanding things (Roth et al., 2009). This framework provides researchers with methodological and practical tools to analyse human interactions and relationships within specific contexts (Wilson, 2014). The methodological aspect of CHAT, which is predominantly interventional, often takes the form of a Change Laboratory (Engeström et al., 2014; Sannino et al., 2016). Change Laboratory provides a platform for teachers to collaboratively identify challenges, develop solutions, and implement classroom changes (Botha, 2017). By integrating theory with practical intervention, CHAT enables researchers to not only understand the complexities of educational phenomena but also actively engage in transformative practices to address them. This aligns well with the aim of the current study to facilitate meaningful change in science teachers' practices.

Engeström and Sannino (2021) state that CHAT has undergone four generations (see Table 3.1). They indicated that the generations started from mediated action (1st generation) to a collective activity system (2nd), to multiple interconnected activity systems (3rd), and most recently to heterogenous work coalitions aimed at resolving wicked societal problems across different levels (4th). Engeström and Sannino indicated that all four generations share some key idea that "work needs to be analysed as object-oriented practice, mediated by instruments, and changing through its inherent contradictions" (p.5). Across the generations, formative intervention is key to studying work (Engeström & Sannino, 2021). My study is mainly located within the second generation, which focuses on collective activity (I will explain more in the next section). Additionally, it incorporates some conceptual elements from the fourth generation, drawing on contemporary CHAT. This includes insights from Annalisa Sannino's work on transformative agency by double stimulation and Anne Edwards' exploration of relational agency and its related concepts.

Table 3.1 Four Generations of CHAT, Modified from Engeström and Sannino (2021)

	First generation	**Second generation**	**Third generation**	**Fourth generation**
Object and problem	Individual learning or developmental challenge	Contradiction in collective activity requiring an expansive solution	Contradictions between and within an interwoven activity system	A crucial communal challenge or issue requiring multiple and cross-sectoral solutions
Unit of analysis	Individual mediated action	Collective activity system	Two or more interacting activity system	Combined cycles of expansive learning in different kinds of activities facing societal challenge
Concept of learning	Internalisation of knowledge and skills	Expansive learning: learning what is not yet there	Expansive learning cycle: boundary crossing and sideway learning	Horizontal and vertical interaction between different kinds of expansive learning
Concept of agency	Agency is seen as understanding the historically developing nature and liberating possibility of one's action	Agency is considered as an expansive move from the individual subjects towards the collective transformation of activity	Agency is seen as recognising and negotiating differences and complementarities	Agency is considered in terms of transformative agency by double stimulation

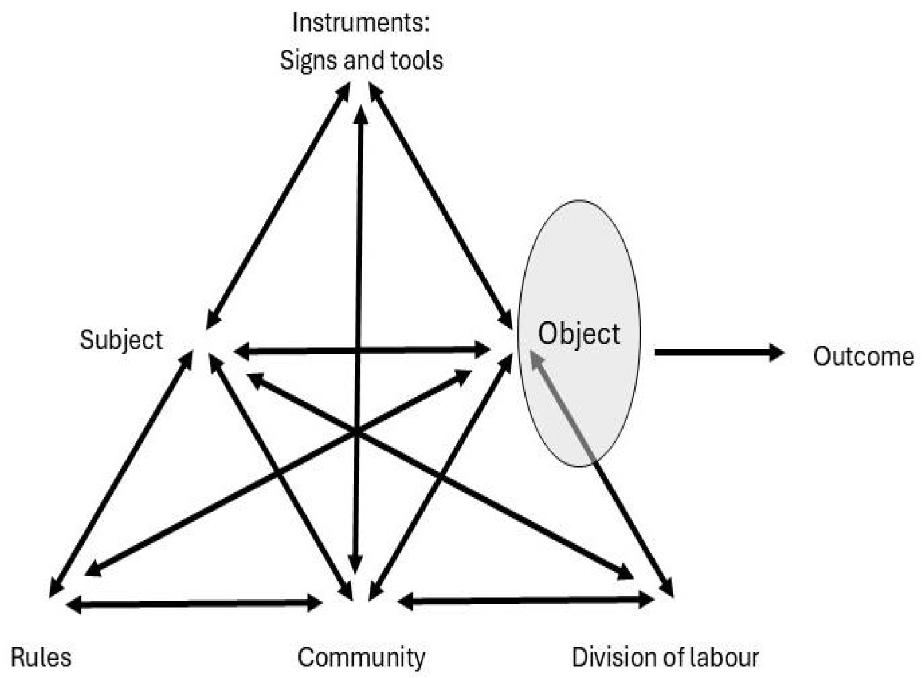
In what follows, I explain the theoretical concepts applied in the methodology, informing data generation and analysis. I will start by looking at the activity system, which can be applied to science teaching. I will then move to contradictions experienced in the activity systems, to be followed by expansive learning, which is a process of resolving those contradictions. The next section after this is devoted to discussing agency in CHAT focusing on transformative agency, double stimulation and kedge anchors. The final section will look at common knowledge and conclude the chapter.

3.3 Activity system

In this section, I explain the concept of an activity system, rooted in the second generation of CHAT. I begin by introducing the concept of activity and then further discuss the activity system's various components.

An activity is " an evolving complex structure of mediated and collective human agency" (Roth & Lee, p.198). This distinguishes it from a short event with a beginning and ending (that usually characterises school-based tasks). Activity is not something that can be completed once and for all, and as such is not oriented towards specific goals. Rather it involves an ongoing effort to satisfy the needs of an enduring object. The teaching of science in schools can be understood as activity. Activity is thus seen as a "relatively durable system" with different parts to serve a collective purpose (Engeström & Sannino, 2021). This can be represented in triangular form as shown in Figure 3.1 The double-headed arrows indicate bi-directional interactivity and dynamism between the components.

Figure 3.1 The Structure of an Activity System Adapted from (Engeström 2001, p.135)



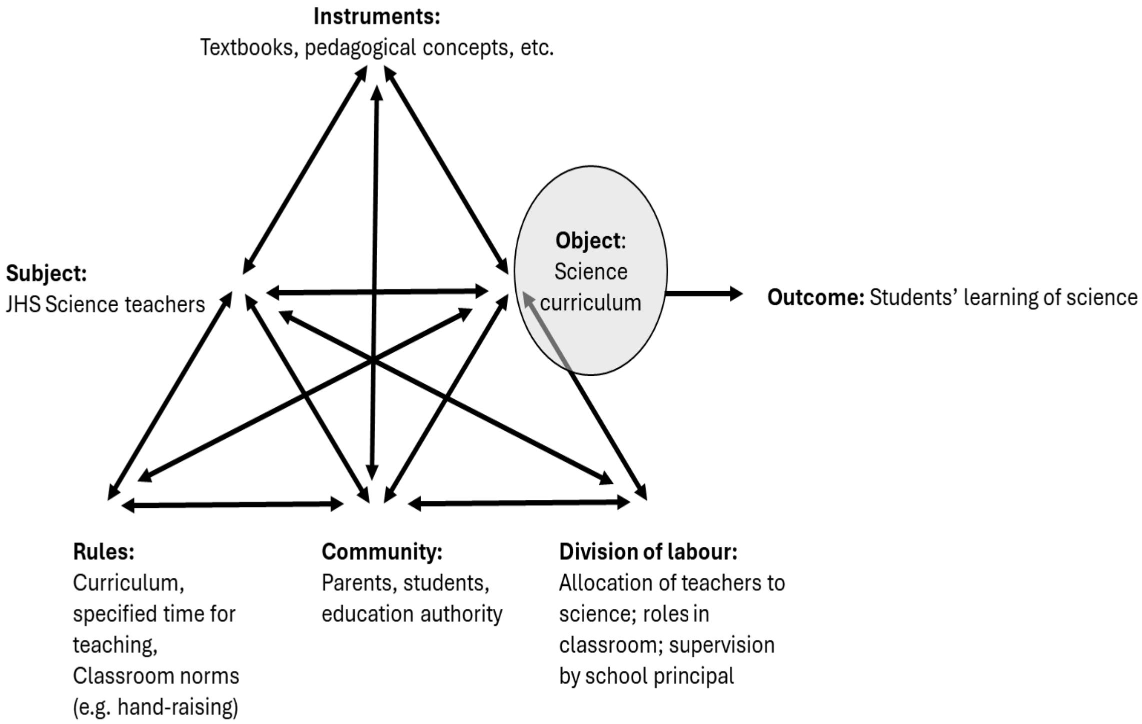
The top of the activity system takes first-generation understandings of mediation action, a triad of subject-object-mediating artefact (instrument) (Engeström, 2022). This represents a person working on a problem with the aid of mediating tools or signs. However, this component of the activity system is considered "the 'tip of the iceberg' representing individual and group actions embedded in a collective activity system" (Engeström 2001, p 134). The three components below – rules, community, and division of labour – were added to the development of the second generation of CHAT and clearly re-orientated from individual action to collective activity.

Subject refers to a group or individual whose positions and points of view are taken as the perspective of the analysis (Engeström & Sannino, 2021). The *object* of an activity is not the objective but rather what is being worked on or changed by the use of the tools (Edward, 2005; Lee, 2011). It is a moving target that cannot be reduced to short-term goals (Engeström, 2001). The object is what the activity is oriented towards. It is that towards which human efforts are directed, thus carrying the motives of an activity (Engeström & Sannino, 2010; Sannino et al., 2016). The object thus gives direction and identity to the activity (Engeström & Sannino, 2021). *Instruments* (also referred to as mediating artefacts) are tools or signs used by the subjects to transform the object into outcomes (Engeström & Sannino, 2010; Engeström & Sannino, 2021). This mediating role in changing the relationship between the subject and object is important in the CHAT concept of double stimulation (considered below).

The other parts of the activity system are the community, division of labour and rules (Engeström & Sannino, 2021; Engeström, 2020). The *community* refers to individuals or subgroups who have shared interest in the object or participate in the activity system. The *division of labour* can be thought of as roles, or who does what. *Rules* refer to explicit regulations, standards that govern the activity, and implicit and informal norms and conventions (Engeström & Sannino, 2021).

For example, in this study, science teaching is considered as an activity system with the teachers as the subject (see Figure 3.2). The objective of their activity is conceptualised as implementing the science curriculum with the outcome of students' learning (including but not limited to passing the national BECE examinations). To achieve this objective, the teachers use instruments such as textbooks, concepts and pedagogical principles. The teachers are part of a community of parents, students, and education authorities with a shared interest in science teaching. There are rules such as time allocated for the teaching and formal curriculum that govern the teaching activities, as well as informal norms such as students not speaking in class unless they put their hand up and are asked by the teacher to talk. The division of labour includes roles such as junior high school (JHS) science teacher, school principal, and the roles performed by teachers and students in everyday teaching and learning. Because of the interactions among the various components in the activity system, tensions in the form of contradictions can emerge over time. The next section will address this aspect in detail.

Figure 3.2 Activity System of the Participating Teachers



3.4 Contradictions

This section addresses the concept of contradictions. It explains the meaning and types of contradictions. In CHAT, contradictions are understood as forces that drive transformation in the activity system leading to change and development (Engeström, 2001; Roth & Lee, 2011; Postholm, 2020). They are "historically accumulating structural tensions within and between activity systems" (Engeström, 2001, p.137). Engeström and Sannino (2011) caution that contradiction must not be taken simply as problems or disagreements.

Engeström and Sannino (2011) indicate that contradictions are rooted in an activity's history, so their resolution must be traced to their historical development. This historicity informed the approach in this study, looking to the past to understand the present. Contradictions cannot be directly accessed; they must be addressed through their manifestations in the form of dilemmas, conflicts, critical conflicts and double binds (Engeström &Sannino, 2011). They further indicate that in an attempt to bring change with the use of intervention, contradictions are manifested in the patterns of talk and actions which the participants are helped to be aware of and resolve. In this study, contradictions in the science teaching activity were manifest in how participants talked about their work as science teachers.

Engeström and Sannino (2011, p. 7) summarise four main types of contradictions.

> (a) as emerging latent primary contradictions within each and any of the nodes of the activity system,
>
> (b) as openly manifest secondary contradictions between two or more nodes (e.g., between a new object and an old tool),
>
> (c) as tertiary contradictions between a newly established mode of activity and remnants of the previous mode of activity, or
>
> (d) as external quaternary contradictions between the newly reorganised activity and its neighbouring activity systems.

A key focus in the Change Laboratory conducted in this study was to enable participants to identify the contradictions in their practice by tracing the root cause of the challenges and disturbances they face in teaching science. This was important because identifying the contradictions in the teachers' activity system could drive their transformative practice (Engeström & Sannino, 2010). From an analytical point of view, it was important for me to identify the types of contradictions the teachers faced in their activity system, which was shown to be mainly secondary type (see Chapter 6), and how they were resolved (see Chapter 7).

3.5 Expansive learning

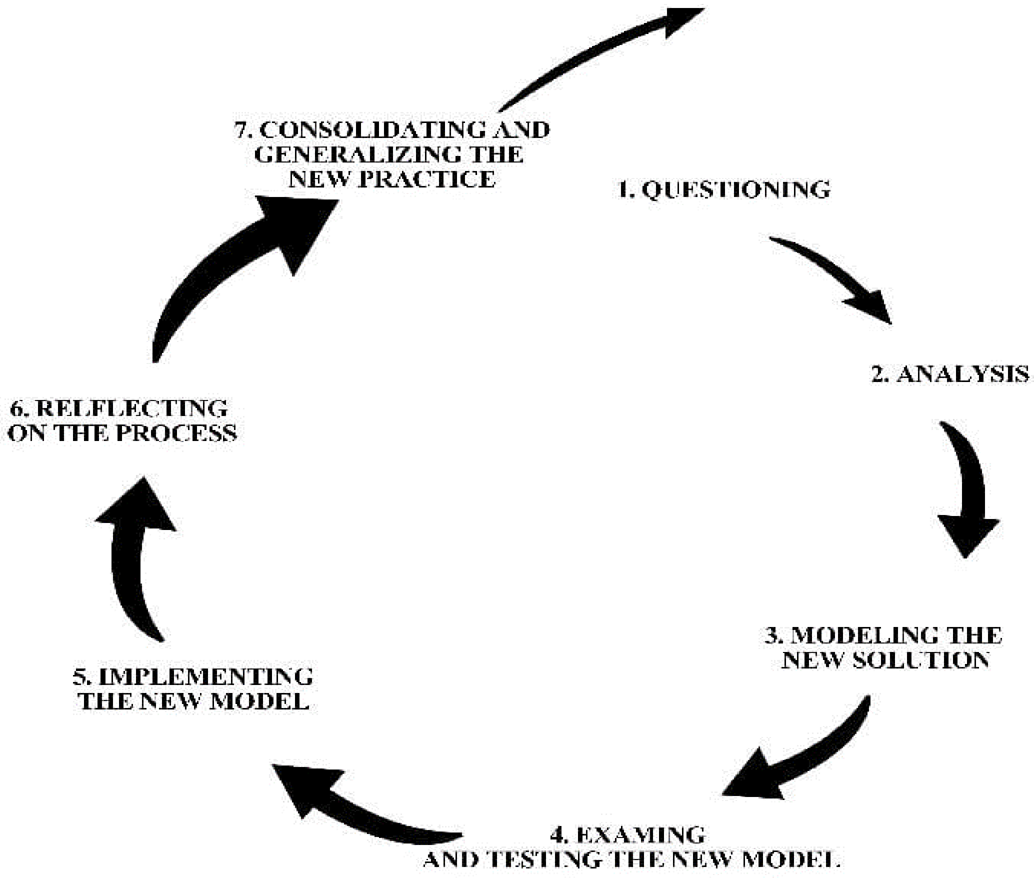
In this section, I discuss the concept of expansive learning. Engeström (1987, 2014) introduced the concept of expansive learning to understand learning processes within an activity system. Expansive learning, as described by Engeström and Sannino (2010), goes beyond traditional notions of acquiring knowledge; it involves learners actively creating and implementing a fundamentally new, broader, and more intricate object or activity. This type of learning is not confined to vertical growth, where existing knowledge is deepened, but rather involves a horizontal or sideways movement, where learning extends into unfamiliar territory to address what is not yet there (Engeström, 2001). By engaging with expansive learning, participants gain an enriched and expanded understanding of the object, transforming their thinking and practices. This transformative process allows for the redefinition of tasks, goals, and roles, ultimately contributing to innovative approaches that address complex challenges within the activity system.

Expansive learning is linked to the resolution of contradictions in an activity system (or between activity systems), and the "process of expansive learning should be understood as construction and resolution of successively evolving contradictions" (Engeström & Sannino, 2010, p. 7). Contradictions have the power to drive expansive learning when they are dealt with in such a way that the new object is identified and turned into a motive leading to the transformation of the activity (Engeström & Sannino, 2010). This expansive transformation occurs when the object and motive of an activity are reconceptualised to encompass a significantly broader range of possibilities than the activity's previous form allowed. A complete cycle of expansive transformation can be viewed as a collective journey through the zone of proximal development of the activity which is defined as "the distance between the present everyday actions of the individuals and the historically new form of the societal activity that can be collectively generated as a solution to the double bind potentially embedded in the everyday actions". (Engström, 1987, p. 174). This journey represents not just incremental improvement, but a fundamental shift in how the activity is understood and carried out.

Expansive learning emphasises communities as learners, transformation, and horizontal movement. It results in an expanded pattern of activity and a new type of agency, transformative agency (Engeström & Sannino, 2010; Engström et al., 2014). In other words, the learners construct a new object and concept for their collective activity and implement it in practice.

Expansive learning is achieved through specific epistemic or learning actions, forming the expansive learning cycle (Engeström, 2020; Engeström et al., 2012) as shown in Figure 3.3.

Figure 3.3 The Expansive Learning Cycle Reproduced from (Engeström & Sannino, 2010, p.8)



As can be seen from Figure 3.3, an ideal expansive learning cycle follows seven learning actions. This sequence is ideal-typical; in reality, the process is iterative and messy. The first expansive learning action of the expansive cycle is *questioning*, which Prokopis et al., (2022) cautioned, should not be taken literally as eliciting information. Questioning is necessitated by a "need state" concerning challenges or difficulties in the current activity system. This leads participants to question, criticise or even reject some parts of conventional ideas or ways of doing things.

From questioning, the process moves to *analysing* which "involves mental, discursive or practical transformation of the situation in order to find out causes or explanatory mechanisms" (Engeström et al., 2013, p.85). According to Engeström and Sannino (2010), analysis falls into two types: *historical-genetic*, where the origins and evolution of the situation are determined and *actual-empirical* in which explanation of the situation is sought by constructing a picture of its inner systemic relations. The analysis can lead to what Engeström calls "double bind" a situation where the participants face a dilemma in which all the outcomes are unsatisfactory. The situation can lead to rejection, from which a new direction may emerge. The actions of questioning and analysis can trigger one another (Augustsson, 2021). Questioning leads to a "deepening analysis, " leading to a sharper and more articulated questioning. These two actions aim to identify and define problems and contradictions in the systems (Engeström, 2001).

The third action of the expansive learning focuses on *modelling solutions*. Here, breakthrough ideas, which usually form part of the analysis of contradictions, are developed into a simplified model to offer solutions to the problems encountered (Engeström, 2001; Engeström & Sannino, 2010). Such a model is organised clearly using the activity system to address systemic contradictions (Tessier, 2022).

After modelling the new solution, the next action is *examining and testing the new model* to understand its dynamics, potential and limitations (Engeström & Sannino, 2010). A key feature of this process is critical discussion and rejection where new ideas or proposals could be rejected (Engeström, 2001). This can include stress-testing the model by anticipating how it might be implemented in practice and what stakeholders (community) perspectives might be.

The fifth learning action is *implementing the model* by "means of practical applications, enrichment and conceptual extensions" (Engeström et al., 2013, p. 85). This is not simply a one-off instance of putting the model into practice, but rather an iterative process through which experiences of enacting the model inform its further development, perhaps introducing new elements, refining others, or eliminating some.

The sixth and seventh actions are those of reflecting *on and evaluating the process* and *consolidating* its outcomes into a new stable form of practice. The latter involves steps taken to sustain new practices and spread them from particular instances to become features of wider activity.

Whereas these learning actions may be followed in a certain pattern, their cyclicity has been questioned by Engeström et al. (2013) arguing that "cycle is not to be found in pure form in practice; there are odd combinations, breaks, digressions and iterative loops" (p.86). Furthermore, expansive learning is in most cases intentionally designed and studied by an interventionist researcher via a method of formative interventions (Engeström & Sannino, 2010). These learning actions are not typically followed or observed in a sequence in real life as a naturally occurring process. The expansive learning cycle informed the design of the Change Laboratory (see Chapter 4).

Expansive learning is rooted in the method of ascending from abstract to concrete. This "is a method of grasping the essence of an object by tracing and reproducing theoretically the logic of its development, of its historical formation through the emergence and resolution of its inner contradictions” (Engeström & Sannino, 2010, p.5). The method involves starting with an abstract, simplified idea and gradually expanding it into a more detailed and concrete understanding. As the abstract idea is enriched with more details, it evolves into a complex, concrete system that reflects multiple and dynamic aspects of the object. The simple initial idea becomes a comprehensive understanding, integrated into a new form of practice. Ascending from the abstract to the concrete enables us to understand the core nature of an object by following logical development and historical formation to address the internal contradiction.

Ascending from the abstract to the concrete is achieved by means of a germ cell, which is enriched and transformed into a complex new form of practical application (Engeström & Sannino, 2010). A germ cell is a basic abstract idea that is the starting point for understanding a complicated whole. It is like a seed for which the understanding of the object begins. Engeström et al. (2012) point out that an important characteristic of the germ cell is that “ it carries in itself the foundational contradiction of the complex whole” (p. 289). This means the germ cell has an inherent contradiction of complex totality, the resolution of which leads to expansive learning. It is also worth noting that the “germ cell opens up a perspective for multiple applications, extensions, and future developments” (Engeström, 2020, p.36). It serves as a starting point that allows for various uses, expansions, and future advancements. In other words, the germ cell opens up possibilities for applying it in different ways, building upon it, and envisioning future developments based on this foundational idea. The germ cell thus carries the dynamic force for transformation.

A study of homecare encounters between caregivers and patients (Engeström, 2020; Engeström et al., 2012) illustrates how the germ cell enables people to ascend from the abstract to the concrete. The elderly encounter a contradiction of mobility between safety (demanding support from others) and autonomy (demanding they use their own strength). This is experienced by the patients as a conflict between the fear of falling and the motive to walk independently. The germ cell that enabled them to resolve this conflict was a simple deceptive action of standing up from the chair (Engeström, 2020; Engeström et al., 2012). It was important for me in the analysis to identify a germ cell that enabled the teachers to ascend from the abstract to the concrete in transforming their teaching practice, in a way that addressed their personal experience of the systemic contradictions, in the form of conflicts of motives (see Section 7.3).

3.6 Agency in CHAT

In this section, I begin by looking at agency development in CHAT. I then move on to discuss how agency brings about transformation. I further discuss the agency and double stimulation and finally discuss the relationship between agency, transformation and double stimulation focusing on forward anchoring, which is a recent idea in this area of scholarship.

Recent developments in CHAT have foregrounded the concept of agency (Hopwood, 2022). Hopwood (2022) identifies three prominent frames for understanding agency in CHAT: transformative activist stance, associated with Stetsenko (2017, 2019); transformative agency by double stimulation, as modelled by Sannino (2015a, 2015b, 2022); and relational agency, as conceptualised by Edwards (2010, 2012, 2016). Agency has historically and dominantly been linked to individuals (Englund & Price, 2018; Sugarman & Martin, 2011). CHAT, however, conceptualises agency differently by moving the focus from internal psychological properties towards individuals and collectives in dynamic, dialectic relations (Edwards, 2016; Haapasari et al., 2016; Hopwood, 2022; Sannino, 2015b). This avoids both inner psychological properties and what Stetsenko (2020) calls “reductionism upwards” where individual contributions are lost. Agency in CHAT is identified in object-oriented activity. CHAT grounds agency in social interactions, placing it at the intersection of the individual and the social

(Hopwood, 2022; Hopwood et al., 2021). Agency is seen in discourse and action (Haapasari et al., 2016).

The concept of agency within the framework of CHAT has evolved over recent decades. Engeström and Sannino (2020) identify this evolution as comprising four distinct generations of CHAT, as outlined in Table 3.1. As shown in Table 3.1, under the first generation, agency is seen as understanding the historical developing nature and liberating possibility of one's action. The individual is seen as one who can take his or her own actions thus limiting the "social relations and organisational embeddedness of work action" (Engeström & Sannino, 2020, p. 7)). In the second generation, agency is considered an expansive movement from individual subjects towards the collective transformation of activity, emphasising collaboration and social relations at work. Agency in the third generation emerges through acknowledging diverse expertise and the complementarity of different perspectives. A more advanced and nuanced perspective on agency incorporates the concept of double stimulation, particularly through Sannino's (2015) model of Transformative Agency by Double Stimulation (TADS), representing a fourth-generation understanding of agency, alongside Edwards' (2012, 2016) notion of relational agency.

3.6.1 Transformative agency

An appropriate understanding of agency is crucial for understanding transformative change (Hopwood et al., 2021). This is because agency and transformation are linked together (Lund & Vestol, 2021). Transformative agency is defined in CHAT as breaking from a given frame of action and taking the initiative to transform it (Haapasari et al., 2016; Virkkunen, 2006). "Transformative agency is a dynamic, long-lasting process of learning and development which evolves in interaction" (Haapasari, 2016, p.257). A key educational challenge is understanding how transformative agency is developed (Sannino, 2015b) and how it can be facilitated pedagogically (Engeström et al., 2022).

Transformative agency is developed when practitioners are given the opportunity to collaboratively analyse, envision and implement new ideas to change their activity system (Haapasari et al. 2016). Sannino (2015a) argues that researchers interested in change should analyse how transformative agency is exhibited in social engagement and change efforts. Therefore, an important part of the data analysis was to find out how the teachers demonstrated transformative agency during the process of the Change Laboratory, where they were provided an opportunity to collaborate and envision new ways of teaching science under the new curriculum.

3.6.2 Agency and double stimulation

Vygotsky (1978) introduced the concept of double stimulation as a process to understand higher mental functions, focusing on "the means and methods that subjects use to organise their own behaviour" (p.74.). Double stimulation involves two stimuli: first and second stimulus. The first stimulus can take the form of a problem, task, contradiction, or conflict of motives, which is addressed using the meaningful artefact referred to as the second stimulus. Double stimulation is thus the application of a mediating artefact which is referred to as a second stimulus to address a problem, a task, contradiction, or conflict of motives referred to as a first stimulus (Thorne, 2015).

Double stimulation is the means people use in everyday life to gain control of their own behaviour, including the common practices of tying a knot in a handkerchief to remember something. Sannino (2015b) therefore, argues that double stimulation besides being a method is a principle of volition. This means double stimulation is not just a step to be followed in an experimental setting, but a means of understanding how humans influence their situation to bring about change. The volitional action, one which overcomes problematic situations by breaking out of conflict of motives, results in transformation (Engeström et al., 2015). The principle of double stimulation has been applied in formative interventions such as Change Laboratory to foster collective agency (Sannino, 2015b) explaining how people intentionally change the cause of events (Morselli, 2021). A key aspect of double stimulation is that the basis for transformation does not come from 'inside' of people by some magical insight, but rather from using and developing appropriate instruments.

The basic notion of double stimulation refers to instruments an individual uses to solve a problem. To link double stimulation to volition, it must be linked to the idea of conflict of motives. Conflict of motives denotes a clash between opposite aspirations or tendencies, which occurs in uncertain situations and requires courage to make deliberate choices (Sannino, 2015b). It plays an important role in double stimulation as it is how individuals take volitional actions to change their situation (Morselli & Sannino, 2021). Conflict of motives increases in an activity system that is facing transformation because of the introduction of new tools and implementation of new practices as the participants struggle to resist or embrace the new possibilities (Engeström et al., 2015). Therefore, a key aspect in the data analysis was to search for conflicts of motives experienced by the teachers when implementing the new science curriculum.

3.6.3 Transformation agency by double stimulation (TADS)

Sannino (2015a, 2015b) developed a Vygotskian model of double stimulation that takes the principle of volition in situations characterised by conflicts of motives further. This TADS model represents a significant development in CHAT and is linked to the fourth generation (see Table 3.1). While this study draws on second-generation CHAT in the sense that it explores contradictions within one activity system, the fact that I use TADS in understanding the emergence of agency in the Change Laboratory means the study also draws on this fourth-generation theoretical aspect.

In an attempt to understand the process of collective transformative agency or what Virkunnen (2006) calls "shared transformative agency", Sannino (2015a, 2015b) proposed a model that shows the emergence of TADS. The model comprises two phases*: a decision-making phase and implementation phase*. The beginning point of the model is that a problematic situation creates a paralysing conflict of motives (first stimulus). In an attempt to resolve the conflict, the learner resorts to mediational means (second stimulus) by attaching a new meaning to the second stimulus. The second stimulus thus acquires the force of an auxiliary motive providing a means to resolve the conflict. In the implementation stage, the learner puts the second stimulus into use, which enables them to take control of the situation and transform it.

"TADS is a process by which individuals or collectives can intentionally break out of conflicts of motives and change their circumstances by forming auxiliary motives (also called second stimuli) and implementing them systematically" (Sannino, 2022, p.10). It is thus a process whereby people take wilful or volitional action when faced with a conflict of motives in order to change their situation.

TADS has been taken up as an analytical framework to trace the emergence of agency in diverse contexts. These include parenting (Hopwood & Gottschalk, 2022), children development (Chawla-Duggan et al., 2022), student leadership (Grant, 2022) and in-service training of teachers (Morselli & Sannino, 2021). Sannino (2022) extended her idea of TADS by using a metaphor of warping, a situation where anchors are pulled on the ground to move a vessel from a problem area, where it is stuck or otherwise unable to move in the desired direction.

Warping or forward anchoring: Whereas anchors are usually thought of as stabilising devices to prevent a vessel from moving, there are types of anchors called kedge anchors that are used to *move* a vessel from troublesome areas. This process is called warping. According to Sannino (2022), the metaphor of warping illustrates how change can be collectively achieved in the midst of difficulties, helping understand collective transformative agency. This extension helps to make TADS clear beyond the model outlined earlier and illustrates how people, especially the collective, develop agency (Sannino, 2022).

A kedge anchor needs to hit the ground, and catch on something solid, so that people can pull on it to move their vessel away. A second stimulus that has been successfully implemented can be considered as a forward anchor which 'hits the ground' (finds a stable and solid condition to function) and enables people to move forward (breaking away from their problematic, conflicted situation). Second stimuli understood as forward-oriented kedge anchors are instrumental in the elaboration of new meaning which may be stabilised to the point of supporting transformative actions in problem situations for which there are no known solutions (Sannino, 2022) "Forward anchoring involves the formation of novel representations emerging through personal sense-making, social interaction and experimentation embedded in the materiality of a problem situation" (Sannino, 2022, p.12).

Kedge anchors can take different forms. They can be material, digital or discussive entities (Lund & Vestol, 202; Sannino, 2022). In a Change Laboratory on homelessness, a history wall of collective memory and a four-field diagram constructed to analyse the past and present activity of the unit served as a kedge anchor for the participants (Sanino, 2022). Hopwood et al.'s (2022) study of parents of children with complex feeding difficulties identified the idea of rapid tube weaning, a play-based program, and a list of pre-conditions for tube removal as some of the kedge anchors used by the parents to overcome the situation.

Sannino (2022) identifies three sets of actions which are essential in forward anchoring: *throwing actions* which involve searching for suitable ground; *taking over actions,* which enable the crew to gain control over the situation; *breaking out actions,* which enable the vessel to be pulled out of the problem area. When people are faced with a conflict of motives, they turn to kedge anchor as a second stimulus to search for a solution to the situation. Using the second stimulus enables them to gain control over the situation and eventually break out of the problem.

The concepts of warping and kedge anchors were applied in my data analysis to understand how the teachers developed agency in transforming their teaching practice. A key focus in the analysis was to identify secondary stimuli which served as kedge anchors and the associated anchoring actions which enabled the teachers to search and eventually move away from their established way of teaching, which they saw as problematic, and embrace new possibilities.

A key focus in the analysis was to identify secondary stimuli which served as kedge anchors and the associated anchoring actions which enabled the teachers to move away from their established way of teaching, which they saw as problematic, and embrace new possibilities.

3.7 Common knowledge

This section continues the discussion of agency in CHAT, now focusing on common knowledge. This is one of three concepts that are part of Edwards' (2010, 2016) relational agency framework.

Given that the Ghanaian curriculum reforms encouraged a shift towards more student-centred pedagogies, I wanted to incorporate into my conceptual framework an element that could help focus on students themselves, as well as teachers' understanding of students' perspectives. A relevant concept is *common knowledge*, developed by Edwards (2010, 2011, 2012, 2016) as part of a suite of concepts - the other two being *relational agency and relational expertise.* While all three could have been taken up in the analysis, it was sufficient in my study to focus on common knowledge as a complementary conceptual expansion to ideas of TADS and warping. Common knowledge offered a way to conceptualise how the teachers' understanding of *what matters* to students became a second stimulus linked with auxiliary motives. While my focus was on common knowledge, I briefly outline its other related concepts (*relational agency and relation expertise*) to provide a fuller account of the origins of this concept.

Relational agency is defined by Edwards (2005b) as "the capacity to work with others to expand the object that one is working on and trying to transform by recognising and accessing the resources that others bring to bear as they interpret and respond to the object" (p. 172). The concept of relational agency extends beyond the main focus of interactions between practitioners to include relationships with those who are connected to the object of the activity such as other professionals and clients (Edwards, 2010; Sannino & Engeström, 2017). Thus, relational agency describes how two or more people work with different motives as they deal with the same complex object of activity (Edwards, 2020). Exercising relational agency involves communicating with others, discussing one's motives, and being aware of *what matters* to others (Edwards & Fay, 2019). Common knowledge refers to this '*what matters*'.

Relational expertise is different from specialist expertise. It is an additional form of expertise that is shown in how to work with others (Hedegaard & Edwards, 2019). Relational expertise is the capacity for practitioners to elicit and hear *what matters* for other practitioners or clients, to be explicit about *what matters* for themselves as professionals, and to be able to draw on these understandings when needed (Edward, 2020). Edwards (2010) argues that recognising and incorporating the motives and resources of others into the specialist expertise does not dilute the core competence of the profession but leads to an enriched understanding of the problem or object being worked on. This means that the relational agency does not displace or replace specialist expertise but augments it. The ability to exercise relational expertise and relational agency is mediated by the creation of common knowledge (Edward, 2016).

Common knowledge (Edwards, 2010, 2011, 2012, 2016) consists of the shared understanding of the motives for each member working on a problem, otherwise phrases as '*what matters*' to people. Motive, rooted in Leont'ev's work on object of activity, is explained in terms of '*what matters*' to people in their practice (Edwards, 2016). Identifying object motive is key to building common knowledge (Hopwood & Edwards 2017). Hopwood and Edwards (2017) argue that common knowledge does not mean that *what matters* for the collaborators should be the same, but effort must be made to ensure that they are aligned to prevent conflict and confusion. Alignment of motives they suggest can be done when people listen, recognise, reveal and engage with each other's motives. Common knowledge is thus built when *what matters* or the motives of each person are disclosed and heard (Edwards, 2020). This can be done by asking for and giving reasons (Edwards, 2017).

Common knowledge is made visible in sites of intersecting practices where reasons are provided and taken seriously (Edwards, 2012). In this study, there was a distinctive asymmetry in the way common knowledge was developed and used as a resource or second stimulus. Rather than being shared between people actively working together, as in Edwards' (2010, 2011, 2012, 2016) original work, it was a question of teachers understanding *what matters* to students, and then using this as a resource in their collaborative work as they tried to change their own practices.

The absence of students as co-participants in the Change Laboratory may be seen as a limitation (see Chapter 4). However, it is important to remember that common knowledge is a supplementary concept added to the already rich notions provided by TADS. It provided an important part of the conceptual framework that informed the Change Laboratory, without which the orientation to students would have been less strong. While students were not present in these Change Laboratory sessions, their voices echoed in the sessions, as the teachers discussed *what matters* to students, responding to data from students themselves.

Common knowledge is linked to double stimulation. Common knowledge is considered a second stimulus that helps people as they work on complex problems (Edward, 2016). Hopwood and Edward (2017) suggest that common knowledge is a second stimulus that enables professionals and clients to work together. It has been shown that common knowledge is important for improving teaching methodology in school as “it has the potential to be developed as a resource for pedagogic engagement” (Rai. 2017, p.166). Woodrow and Staples (2017) argue that effective engagement of children is enriched when values, motives and intentions are shared (Woodrow & Staples, 2017). Common knowledge therefore implies putting the needs of the students at the core and responding appropriately to them in teaching (Rai, 2014). Walters et al. (2017) indicate that common knowledge can serve as a resource for “the development of flexible learning and teaching strategies” (p.121).

The idea of common knowledge has been used in various studies addressing different issues such as combating poor school attendance and transport by school teachers and parents (Rai, 2014, 2017); professional-client interaction in joint work on problems in services for families with young children (Hopwood & Edwards 2017); professional collaborations on a project of improving life conditions of children (Fleer et al., 2017); professional assistance for parents good relationships with children (Hopwood & Cleke, 2017); assisting young adults in residential social-psychiatric centre (Pedersen, 2017).

As indicated earlier, common knowledge was used as a supplementary concept to the TADS framework, as part of a framework for understanding how agency emerged in the teachers’ work through the Change Lab. It enabled me to orient aspects of discussion to students, leading teachers to identify *what matters* to students and how that can serve as a second stimulus for the teachers to transform the practice they inhabit. Therefore, it was important for me to elicit *what matters* to the students during preliminary focus groups and to encourage the teachers to find out *what matters* to their students so that they could develop common knowledge as a second stimulus. A key analytical focus for me was to trace how *what matters* to students was expanded in the Change Laboratory sessions and used to provide solutions to the barriers the teachers faced in implementing the curriculum.

3.8 Conclusion

The conceptual framework used for this study is CHAT. CHAT was the chosen framework because of its focus on transformation, which is consistent with the aim of this study, and because of its dual theoretical and practical components, which come together in the Change Laboratory formative intervention discussed in Chapter 4. This chapter has outlined and explained the key conceptual ideas in CHAT applied in this study. It can be concluded that science teaching is an activity system comprising different components in which contradictions can be experienced. These contradictions when resolved can lead to expansive learning and development of agency of the participants. In the next chapters, I will show how these concepts have been used in designing the formative intervention methodology and analysing the data generated.

Chapter 4: Methodology

This chapter is arranged in ten sections. Section 4.1 provides a brief introduction to the chapter. Section 4.2 presents the research questions that guided the study. Section 4.3 focuses on reflexivity and my position in this research while Section 4.4 discusses the philosophical foundation of the study. Section 4.5 presents the research design, and Section 4.6 details the context of the data collection and participants. Section 4.7 discusses data generation methods while Section 4.8 discusses ethical considerations. Section 4.9 explains how data were analysed, and Section 4.10 discusses trustworthiness in the research process.

4.1 Introduction

The main aim of this chapter is to explain and justify the choice of methodological approach and research design used in generating and analysing the data for the study. The research was undertaken in the Sefwi Municipality of Ghana, at a time when a new national curriculum was being implemented. A CHAT interventionist approach, Change Laboratory, was adopted to understand and facilitate science teachers' learning during this implementation process. The study involved six JHS science teachers from six different schools as the primary participants. Mirror data were also gathered from their students in JHS1 (equivalent to Grade 7 in Australia). The main data for the study were transcripts of six Change Laboratory sessions involving all six teachers, complemented by three classroom observations, two individual interviews for each teacher, and six focus group interviews with three students from each school. In all a total of 18 observations lasting 21 hours and 12 interviews were conducted with the teachers.

I begin this chapter by restating my research questions (4.2), discussing reflexivity (4.3) and articulating the philosophical foundations of my study (4.4). This is followed by research design (4.5), context of the data collection (4.6) and methods of data generation (4.7). I also look at the ethical considerations of the study (4.8), discuss the data analysis strategy (4.9) and take a look at trustworthiness (4.10).

The research design, methods and procedures were informed by the research questions that guided the study.

4.2 Research questions

The overarching research question for this study was how can barriers to pedagogic change be overcome in the context of science curriculum reform in Ghana? This was deliberately kept at a more general and abstract level as it was the main guide for the study.

Four sub-questions were asked to explore this question in more detail; these four sub-questions were:

1. What contradictions are present in the implementation of the new science curriculum?
2. What do teachers learn, expansively, when collaborating on resolving these contradictions in implementing the new science curriculum?
3. How does agency emerge as teachers collaborate on implementing the new science curriculum?
4. How can teachers' understanding of *what matters* to JHS students be used as a resource to expand interpretations and possible actions as they meet the demands of teaching the new science curriculum?

These questions were framed more theoretically to guide the data analysis.

4.3 Reflexivity: Positioning myself as a researcher and interventionist

My role as a science teacher educator and my experience in teaching science in Ghana is key to the design and conduct of this study. According to Olmos-Vega et al. (2022, p.3), "reflexivity is a set of continuous, collaborative, and multifaceted practices through which researchers self-consciously critique, appraise, and evaluate how their subjectivity and context influence the research processes." The interventionist researcher ought to make his or her ideological subjectivism open for "contestation and objection by others" instead of making it hidden under pretext of neutrality (Stetsenko, 2016). This calls for me to declare my values, beliefs, and commitments and indicates how these have become the core grounds for designing this research.

It has always been my aim to see that the teaching and learning of science is transformed to make it relevant to the needs of students and the country at large. I saw science teaching as lacking relevance, and focused on acquiring scientific facts that students could not apply. Having been trained in Geophysics, an applied science, I felt there is a need to emphasise the applied nature of science to enable students to solve societal problems and advance the development of my country. I am a science educator with teaching experience at Ghana's basic, secondary, and tertiary levels. These experiences influenced my decision to engage in this project. The curriculum reform in Ghana presented an exciting opportunity to explore how to rectify some of these issues that mattered to me – and were echoed in the policy documents themselves and wider literature (as discussed in Chapter 2).

In situating the study within my life experiences and positioning myself as someone who is interested in the transformation of science teaching and learning in my country, decisions pertaining to the whole research process, including the data generated, were shaped by my theoretical frameworks, values, beliefs and attitudes. I would therefore want to move beyond the idea of neutrality and objectivity as such position is inconsistent with the transformative methodology because it is carried out in "non-neutral, historically determinate ways in line with the ontological, epistemological and ideological commitments and goals that the researchers deem worthy and take as guide for action" (Stetsenko, 2016, p. 37). There was no way for me to extract myself from the situation by taking "a neutral stance of disinterested observer."

My commitment was to significantly contribute to knowledge in both theoretical and practical sense. My research questions were framed within a CHAT interventionist perspective to understand and foster the teachers' professional learning by considering *what matters* to students, in changing their practices as they implement the new science curriculum. This focus on students represented both a gap in the literature and a personal interest in students, borne of my own experiences in the classroom.

I was both an insider and an outsider to my study area and the school system in Ghana. I am a product of the Ghanaian school system and have taught at the basic and secondary school levels. Furthermore, as a tutor in the College of Education for over 11 years where I supervised preservice teachers in the classrooms in the study area, I consider myself an insider to the schools' system and their cultural norms. However, I was also an outsider, as I was neither a student nor a teacher in the schools involved, but a researcher with an agenda. The insider position helped me in the recruitment process as I knew the protocols to follow upon entering the schools. It also helped with accurate transcription of Ghanaian form of spoken English and assisted me in understanding what students and teachers meant, when local languages were used in the classrooms and during the interviews.

Before starting the study, I was predisposed to the nature of science teaching in the context of my study and needed to appreciate the challenges teachers go through in teaching science at the basic schools in Ghana. Being an interventionist researcher, I had to be aware of the need to balance my professional experience with the issue under investigation and my role as an interventionist researcher. I had to create space for participating teachers to develop their own visions and models and not impose anything on them.

4.4 The philosophical foundation of the study

Creswell and Creswell (2018) argue that philosophical ideas need to be articulated in research since they affect the research practice. The study is framed within what Cresswell and Cresswell (2018) broadly call a transformative worldview, specifically within CHAT's philosophical foundations. CHAT as a research model is founded on the commitment to social transformation where the researcher and the participants act as collaborative change agents to create and enact alternative solutions (Engeström & Sannino, 2021).

This agrees with other CHAT researchers' views, such as what Stetsenko (2016) calls "trans/formative onto-epistemology", which is "transformative collaborative practices aimed at changing the world"(p.35). The transformative onto-epistemology is an alternative to an objective model that sees knowledge as existing without the knower on the one hand and the postmodernist relativism on the other, "with pedagogical intervention representing its paradigmatic form" (Stensenko 2016, p.36) where the learner is given the needed cultural tools to address the problem in a collaborative manner (Engeström & Sannino, 2021). "[T]his model called for actively and intentionally creating artificial conditions to co-construct the very processes and phenomena under investigation in order *to study them in the acts of co-construction including via cultural mediation*" (Stetsenko, 2016, pp. 35-36, emphasis not mine). Here, instead of trying to copy reality, the researcher actively and consciously creates artificial conditions to enable him or her to construct and generate the objects of the investigation while studying and changing them.

The onto-epistemology is also embraced by the post-qualitative inquiry (St. Pierre, 2021). According to St. Pierre, post-qualitative research is not another type of qualitative research methodology, but it aims to “re-orient thought to experiment and create new forms of thought and life” (p.163). This implies that post-qualitative research aims at change which is consistent with CHAT. I therefore agree with Marcelli and Morselli (2022) who believe that “CHAT could act as a framework that provides epistemological legitimisation to post-qualitative inquiry” (p.213). Marcelli and Morselli (2022) believe CHAT as post-qualitative research aims at “promoting attention to the transformation and change of groups, organisations, and community” (p.213). They further argue that CHAT's “methodological soundness” qualifies it as a robust strand of post-qualitative research. To bolster their argument, they outlined three features of CHAT that they believe make it post-qualitative:

a) CHAT seems to be successful in dealing with challenges of “subject essentialism and individualism in favour of abidance by an extended mind paradigm” (p. 220).

b) CHAT's “materialist dialectics” nature makes it an alternative to empiricism.

c) CHAT can produce results that are not predictable which makes the results “non-transferrable”.

The study is grounded in a transformative worldview, framed within the philosophical foundations of CHAT, which emphasises collaborative social transformation through co-constructed and culturally mediated processes. The study's approach supports the creation of alternative solutions in educational research through a collaborative and transformative lens. The aim is to support the participants in bringing change to their practice.

4.5 The research design

The study was designed as a qualitative formative intervention. This is compatible with my conceptual framework because research based on CHAT applies formative intervention as its own methodology, serving as a bridge between the theory and data (Engeström, 2011). Formative intervention thus aligned with my research priority to take action to bring about change rather than seeking a universal truth. In this sense, my interest was not how science teachers are able to implement the curriculum but how to facilitate and support their learning to bring change in their practice in meeting the demands of the new curriculum – i.e. how they will be able to implement the new curriculum, particularly in relation to its more student-centred aspects.

Formative intervention combines practical transformation efforts with research to change practice in the workplace and education (Sannino, 2011; Sannino et al., 2016). It applies a set of theory-driven principles that guide the given method, starting from the data collection to the interpretation of the findings (Sannino & Engeström, 2018). Formative intervention provides a "social space where all participants can come together, safely and talk to collaborate… [take] decisions that are likely to move practice forward" by finding solutions to problems in their activity system (Ellis et al. 2015; p.46).

Intervention may be defined simply as "purposeful action by a human agent to create change" (Midgley, 2000, as cited in Engeström, 2011). While all interventions may aim at change, CHAT formative interventions differ from other interventions. This is because they are highly contextualised and involve collaboratively developing solutions that do not yet exist compared to design experiments (for example) where the researcher believes he/she has solutions and needs the participants to "test this out". Formative intervention aims to stimulate "a new critical consciousness" among practitioners to make "deliberate" and "systematic" efforts to change the status quo of their practice (Ellis et al., 2015).

Various interventionist methods have been developed based on CHAT including the Change Laboratory (Engeström, 2007); clinic of activity (Clot, 2009; Clot & Kostulski, 2011); learning laboratory (Bal, 2011; Bal et al., 2019; Bal et al., 2014; Bal et al., 2021); organisation workshop (Carmen & Sobrado, 2000 cited in Sannino et al., 2016); fifth dimension (Cole & The Distributed Literacy Consortium, 2006 cited in Sannino, 2011). The key idea behind these interventionist methods is that "social practices can be developed through collective, cognitive and material reconceptualisation of the object" (Sannino, 2011, p.593). In this study the Change Laboratory was chosen as the interventional method.

4.5.1 Change Laboratory as formative intervention

A Change Laboratory is a formative intervention method whereby practitioners collaborate with researcher-interventionists to develop solutions to challenging aspects of their work practice (Virkkunen & Newnham, 2013). Practitioners collectively transform their activities by breaking away from the given status quo through envisioning, designing and experimenting with new forms of practices (Augustsson, 2021; Kaup & Brooks, 2022; Virkkunen & Newnham, 2013). A Change Laboratory is typically conducted in an activity system that is undergoing a major transformation (Engeström, 2011). The main aims of a Change Laboratory are to reveal the general inner contradictions in the activity system facing challenges and to create an expansive local solution by envisioning new practices (Augustsson, 2021; Newnham & Virkkunen, 2013). It thus enables participants to design a new activity system from the old problematic or contradictory one (Augustsson, 2021; Morselli, 2021). The purpose of a Change Laboratory is for participants to analyse their activity system in a series of sessions planned to stimulate the desired learning outcomes without any prescribed solutions provided by the interventionist.

The Change Laboratory usually consists of six to ten sessions whereby participants in an activity system identify contradictions in their system and take steps to address them by designing and implementing new ideas (Engeström, 2022). Mirror material of critical incidents, troubles and problems, collected in the form of ethnographic data from the activity setting is typically brought into the session as first stimuli, functioning to help participants identify problems, articulate dissatisfaction with the status quo, and commit to the need for change (Engeström, 2021).

Conceptual tools either introduced by the researcher, usually a triangular model of the activity system, or models developed by the participants are used as second stimuli. Second stimuli redirect participants' attention from the problem to the nature of the solution (Engeström et al., 2014). The second stimulus is an analytical tool or method (conceptual and/or practical in nature) that can be employed by the participants in dealing with the problematic situation. The participants eventually construct their own second stimuli as the learning process proceeds. Engeström (2011) identified four characteristics of an effective second stimulus: 1) it is actively constructed by the participant 2) its construction is ambiguous in the initial stage but is progressively enriched 3) it becomes stable and serves as an anchoring device 4) it addresses the challenge of contradiction faced by the participants. Hopwood (2024) reviewed different materials that have been used as second stimuli in Change Laboratory interventions. These include representations of the activity system, participant models/visons, four field diagrams, prior Change Laboratory workshops summaries, ideas from other theories, participant presentations and narratives, lesson plans and research literature.

4.5.2 Strengths and weaknesses of formative intervention

Formative intervention was chosen based on a number of well-documented strengths that are relevant to the aims of this study. These strengths include developing the participants' agency and producing change in an activity system facing transformation.

Formative interventions are known to develop the participants' agency as they lead and own the transformational process (Engeström, 2011). The formative intervention process starts with problems in the participants' activity system where there are no already known answers, but the participants themselves generate solutions. Ellis et al. (2015) argue that formative interventions involve "working with" practitioners rather than "working on them". This working with participants enables them to support the change process. CHAT formative intervention research is very rigorous and "produce better research that answers difficult questions in complex situations" (Ellis et al., 2015; p. 45).

> Formative interventions are not just a tool to produce change, but their side effect is that of making knowledge possible—either through engagement between participants and their world or by fostering learning processes in a perspective that treats 'learning' as equivalent to a process of discovery that is appropriated by those who take part in it. (Marcelli & Morselli, 2022, p. 223).

Ellis et al. (2015) indicate that formative interventions are less likely to lead to participants' frustrations for not meeting the interventionist expectation.

Despite the strengths outlined above, Ellis et al. (2015) criticise CHAT and its interventional studies for over-relying and over-emphasising theory, especially the use of a triangular representation of participants' activity system to change people's perception, even though the triangular models have been shown to effective for collaborative analysis and design (Engeström & Sannino, 2021). They state: "We are not sure how it is as simple as that always"

(p. 46). They further argue that formative interventions create a "headache" for participants given the amount of time they had to commit to engaging in the process coupled with their busy schedules. Most importantly, the "headache" is created "when attempting to deal with some fairly abstract theoretical or conceptual tools (represented by the triangle) through which teachers are being asked to look at data representing current practice" (p.48). They believe this is hard work which is less emphasised by CHAT researchers. This point is supported by Morris et al. (2021) who also argue that it can be difficult for people to understand CHAT's conceptual and methodological tools. Ellis et al. (2012) further argue that it takes time to build relationships for formative intervention to have a chance of working well. However, this was not a problem in my study as teachers already knew each other well.

These criticisms notwithstanding, there is ample evidence in the literature about the impact of the Change Laboratory in bringing change into practice (see, Batane, 2017; Botha, 2017; England & Price, 2018; Wei & Sannino, 2024).

Considering the transformation that the new curriculum envisages in Ghana, Change Laboratory was thus considered to be a suitable and strong option to support teachers in analysing challenges they face in implementing the curriculum reforms and taking steps to address them. Change Laboratory was deemed an appropriate approach as it empowers participants to bring about change (Bligh & Flood, 2015). Change Laboratory was also chosen as the intervention because it has the power to bring collaboration and transformative agency among the teachers (Price, 2018).

***Adaption/variations made in the Change Laboratory in this study*:** Bligh and Flood (2015) explain that the Change Laboratory has methodological guidance, yet their implementation is flexible. Linked to this flexibility, Contreras (2021) argues in favour of adapting Change Laboratory methods. Various researchers have therefore made adaptions to Change Laboratory methodology to fit into the particularity of their context (Bal et al., 2019; Botha, Boje et al., 2022; Contreras, 2021; Donan et al., 2021; Englund & Price, 2018; Garraway, 2021, Gorman 2022; Jakhelln & Postholm, 2022, Kaup & Brooks, 2022). For example, Englund and Price, (2018) conducted a Change Laboratory without the use of the triangular models. In the same manner, Donan et al. (2021) also conducted a Change Laboratory without the use of the triangles; they however used the triangles in analysing and presenting their results. Gorman (2022) used a one-off online synchronous Change Laboratory to study students' lived experiences as they move from face-to-face- to online instruction. Contreras (2021) recorded an audio version of the Change Laboratory for analysis instead of using video.

Following the literature, certain adaptations were made in the Change Laboratory, addressing some of the earlier criticisms. An important adaption made from the usual Change Laboratory reported in the literature is using teachers from different institutions instead of one institution. This adaption was necessary, because in the context of the study, science is usually taught by one or two teachers in a school, and I needed a group of more science teachers to work with which called for the use of teachers from six different schools.

Consistent with typical Change Laboratory approaches, the activity system was introduced as a second stimulus. However, I realised that participants were struggling as it became a 'headache'(Ellis et al., 2015) for them to use it in articulating their views but were more comfortable with other second stimuli such as their own models, and data from previous Change Laboratory sessions. Therefore, its usage was discontinued. All the sessions were audio recorded, as the participants were not comfortable being video recorded, and were conducted at two-week intervals instead of one week as Virkkunen and Newnham (2013) recommended. This was to give me enough time to follow up with the teachers and give them some support in their lesson preparations. To address concerns raised in the literature about the time commitment for the participants, the sessions were reduced from ten meetings to an optimum number of six, and the duration of meetings was reduced to 90 minutes instead of the 120 minutes of meetings as recommended in the literature. These adaptions and variations are consistent with research on Change Laboratory, as a review by Hopwood (2024) has highlighted how Change Laboratory has been adapted to meet diverse contexts and logistical constraints.

4.6 Context of the data collection and participants

The data collection was carried out within the Sefwi Wiawso Municipality of Ghana. The Sefwi Wiawso township where the study was conducted is also the regional capital of the Western North Region of Ghana. The municipality is ranked 92nd (out of the total 216 districts in Ghana) in the educational sector in terms of gross access to kindergartens, Basic Education Certificate Examination pass rate, net enrolment at rate at basic schools, and completion rate at basic schools (National Development Planning Commission, 2021). The municipality was ranked 6th by the Ghana Education Service in the performance of students in the 2019 BECE. The municipality was chosen because, I had been a college tutor there for over a decade, and it was therefore convenient for me in terms of data collection.

4.6.1 Schools

There are 27 JHSs in the municipality of which nine are private and the rest are public. It must be noted that in Ghana, private schools are not always elite, expensive institutions, but many are low-fee private schools. Six schools in the municipality were selected to be part of the study. Five schools were public and the sixth was private (of the low-fee variety mentioned above). There were wide variations among the schools regarding their performance and populations. Two of the schools were among the top high-performing schools in the municipality and their populations were twice or sometimes thrice that of the other schools which were considered average in their performance. For example, in one of these schools, the population of students in JHS1 class was over 60 while in one school there were just 20 students in a class. All the schools had one class for each year group. The classroom desks were very heavy wooden desks with two or more pupils sitting together. The classrooms had no information and communication technology (ICT) facilities like computers or projectors. Blackboards were the main writing surfaces using chalks. The schools had no libraries or science laboratories.

4.6.2 Teachers

All science teachers in the Waiwso Municipality who teach first-year JHS students were eligible to participate in this study except those who were in their first year of teaching, as they were considered not to have enough experience teaching in the old and the new curricula. The participating teachers were selected based on purposive and convenience sampling. In the context of the study area, science is usually taught by one or two teachers in a school, and I needed a group of teachers to work together; I therefore considered teachers from more than one school. According to Virkkunen and Newnham (2013), the main principle in selecting participants for the Change Laboratory is that they are dealing with the same object in their workplace. While the teachers were in different schools, the new curriculum was the shared object in this study.

Convenience sampling was used in recruiting participating teachers in schools close to each other so that teachers could regularly attend the formative intervention sessions. However, I purposively chose the participants based on the class they teach and their willingness to embrace change in their teaching practice. After securing permission from the Wiawso Municipal Directorate of Education to conduct the study (APPENDIX 6), I had to walk to the various schools to discuss my intentions with the science teachers in the schools that are teaching under the new curriculum.

Being an insider of the school system in the context of the study, I knew I had to negotiate directly with the participants after seeking approval from the Heads of the schools. In the end seven teachers agreed to take part in the study but six actually took part. The effective sample of six teachers was a viable and robust number, consistent with Change Laboratories studies – which typically have 4-10 participants in the workshops (Hopwood, 2024). The participants were teachers who taught first-year JHS Science and were eligible to be part of the study because they had started with the implementation of the new curriculum. The teachers had a wide range of teaching experience, from a minimum of two years to a maximum of 21 years (see Table 4.1). The participants' different range of teaching experiences enriched the Change Laboratory sessions by providing different perspectives on issues. It is important to highlight that the participating teachers were all males. This reflects that the vast majority of JHS science teachers in Ghana are currently male. Four of the teachers had a first degree as their highest professional qualification, with one having a Diploma. One of the teachers also had a master's degree as his highest qualification. Table 4.1 summarises the participating teachers, their qualifications, and the number of years of teaching.

Table 4.1 Details of the Participating Teachers

Teacher identifier	Gender	Qualification	Age (years)	No. of years of teaching
T1	Male	First Degree	41	17
T2	Male	First Degree	43	16
T3	Male	First degree	47	21
T4	Male	First degree	44	14
T5	Male	Diploma	31	2
T6	Male	Master's degree	39	8

4.6.3 Students

Students were involved in this study because of my premise that matters to students could be a resource for improving teaching. The sampling of students flowed from the central sampling decision, which meant six groups of students (one for each teacher). A group size of three balanced diverse perspectives provides time for each student to explain their ideas and respond to others (Horbo, 2021; Rabie, 2004). The resulting sample of 18 students (six groups of three) provided a good breadth of student input overall. A quota sampling approach was used to select students for the focus group interview. This ensured the representation of both boys and girls in each focus group. All students were first-year JHS students with an average age of 13.

4.7 Methods of data generation

Data for the study were generated rather than collected. “Data generation refers to the theory and methods used by researchers to create data from a sampled data source in a qualitative study” (Garnham, 2008, p. 192). The term generation is meant to capture the ways in which the researcher, social world, and data interreact in a qualitative study. Garnham (2008) indicates that researchers who hold such a theoretical view do not accept the idea that the researcher is a neutral observer of objective reality. Rather “reality” is socially constructed, and the researcher’s role is to actively engage and construct knowledge of that social reality using research methods (see Section 4.4). Therefore, by using the term data generation, I want to indicate that data were not considered “out there” just waiting to be collected but were generated by my active engagement with the social world using various qualitative methods.

Data were generated in the study through the following processes:

1. My facilitation of six Change Laboratory sessions with teachers.
2. Prompting teachers to reflect on their daily activities in a journal.

3. Interviews with teachers and students to share their opinions on issues of importance to them.
4. Observing classroom interactions and writing field notes of relevance to the study.
5. Extemporaneous conversation with participants.

Table 4.2 provides an overview of the timelines for generating the data over 12 weeks.

Table 4.2 Timelines for Data Generation Activities

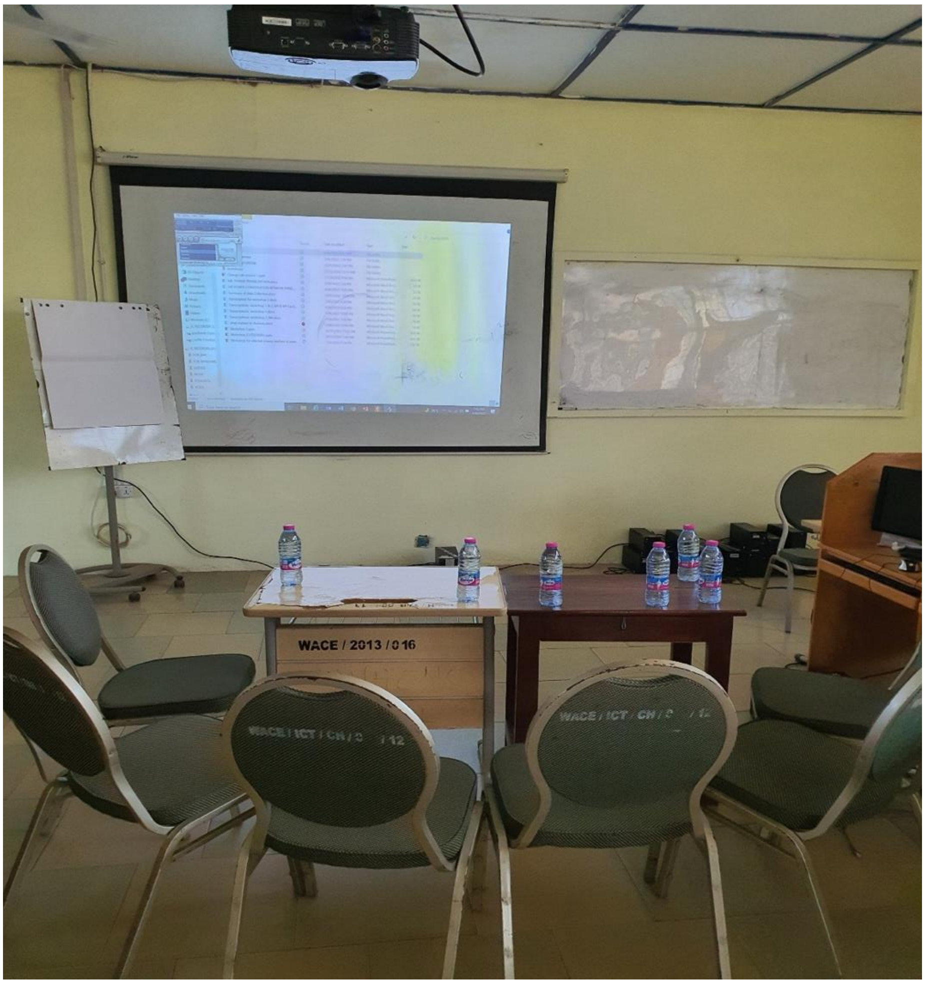
WEEK	ACTIVITIES	
	Observations and interviews Change Laboratory	
1	1^{st} round of interviews with teachers 1^{st} round of observation of science lessons	
2		Change Laboratory Session 1
4		Change Laboratory Session 2
5	Focus group interviews with students	
6		Change Laboratory Session 3
7	2^{nd} round of classroom observation	
8		Change Laboratory Session 4
10		Change Laboratory Session 5
12	3^{rd} round of observation 2^{nd} round of interviews	Change Laboratory Session 6

4.7.1 The Change Laboratory

Designing a Change Laboratory required that I consider certain factors. The guidance on the preparatory design was adapted from (Bligh & Flood, 2015; Virkkunen & Newnham, 2013).

Identifying a venue: The venue selection for the sessions was very important, and it was discussed with the teachers on a WhatsApp group platform I created for the participants. The criterion for choosing a venue was that it must be easily accessible by all participants, that means it must not be too far from each participant's school. Upon careful deliberation, all participants accepted the Wiawso College of Education. Since I was an insider there because I had worked there, I negotiated to get a convenient venue to hold the meetings (see Figure 1). Bligh and Flood (2015) advised that in choosing a venue for the session, certain factors like room size, furniture arrangements, technology, and ability to provide multiple writing surfaces must be taken into consideration. I made sure the place was equipped with materials needed for the three surfaces, (flip chat, projected screen and whiteboard), stationery materials (like large sheets, marker pens, etc.) and a table with snacks. The flip chat was used to draw abstract visions and models, the marker board was used to capture participants' ideas, and the projected screen was used to share mirror material.

Figure 4.1 Change Laboratory Set up



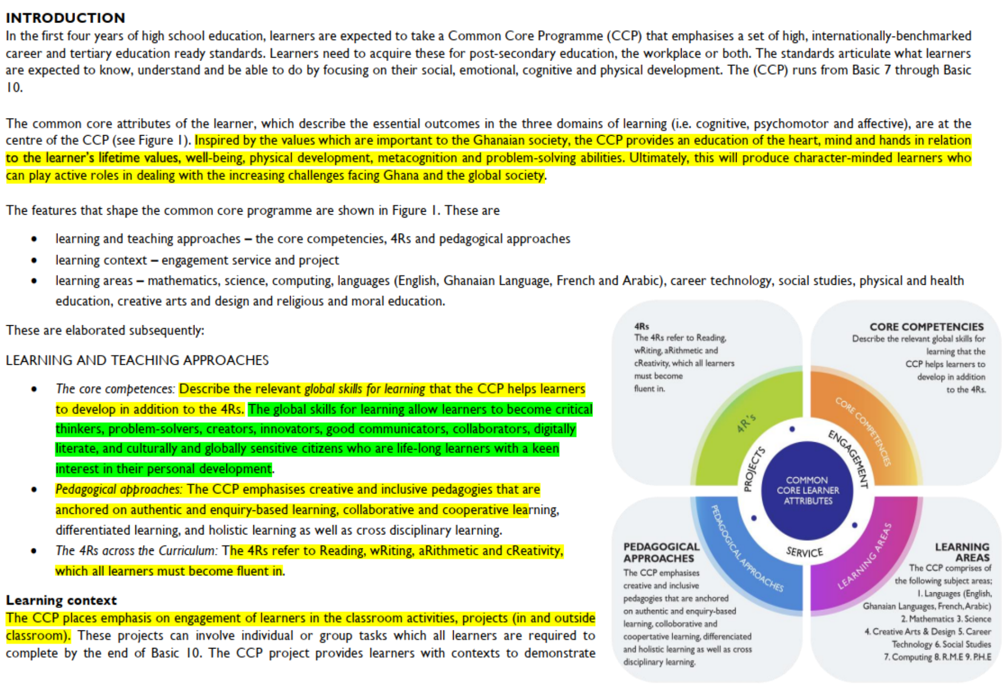
4.7.1.1 Timing and scope of the sessions

Virkkunen and Newnham (2013) indicates that for a Change Laboratory to be successful, the process needs to be continuous and intense which means the number of sessions must be decided and agreed upon before the session begins. To avoid distracting the teachers' timetable, all agreed that Wednesday morning was appropriate for all of them since the schools have morning worship at that time, and they could use the period for the workshops without interfering with their classes. Given teachers' busy schedules, where they must mark exercises and write lesson notes to prepare for class every day, coupled with challenging economic conditions in the country, the sessions were planned for 90 minutes six times within the term at least two weeks intervals between sessions. The two-week interval between sessions provided me with enough opportunities for reflection and preparation, such as listening to audio records of the sessions, taking note of important ideas, and collecting mirror data for the next session. More importantly, it enabled me to go around the schools to support the teachers in implementing ideas by helping them in lesson planning and trying out ideas discussed in the workshops.

4.7.1.2 Generating mirror materials

The main challenge in the Change Laboratory preparation was to ensure the process centred on current issues in implementing the new curriculum. To meet the challenge, mirror data, that is data that demonstrate challenging and problematic aspects of the current activity (Virkkunen & Newnham, 2013), were collected before and during the intervention for two main reasons. First, it enabled me to orient myself "to the developmental phase and central problems of the activity, to plan the Change Laboratory process, and to be able to discuss with the practitioners in the Change Laboratory session" (Virkkunen & Newnham, 2013, p. 70). It also helped me provide a mirror for the participants of "problematic aspects of their activity so that they can identify important problems in the activity and jointly analyse their systematic cause and search for solution" (p.70). The research orientation about the current activity was based on teachers' interactions with the students under the new curriculum. The mirror data were generated from interviews with teachers, classroom observations, lesson notes (plans) of teachers, and official documents (e.g. syllabus, see Figure 4.2 as sample with text highlighted by the researcher, curriculum framework). Students were also interviewed to find their perspective about *what matters* to them about the teaching and learning of science, and summaries and excerpts were presented as mirror data in the Change Laboratory sessions.

Figure 4.2 Sample of mirror material from curriculum document



INTRODUCTION

In the first four years of high school education, learners are expected to take a Common Core Programme (CCP) that emphasises a set of high, internationally-benchmarked career and tertiary education ready standards. Learners need to acquire these for post-secondary education, the workplace or both. The standards articulate what learners are expected to know, understand and be able to do by focusing on their social, emotional, cognitive and physical development. The (CCP) runs from Basic 7 through Basic 10.

The common core attributes of the learner, which describe the essential outcomes in the three domains of learning (i.e. cognitive, psychomotor and affective), are at the centre of the CCP (see Figure 1). Inspired by the values which are important to the Ghanaian society, the CCP provides an education of the heart, mind and hands in relation to the learner's lifetime values, well-being, physical development, metacognition and problem-solving abilities. Ultimately, this will produce character-minded learners who can play active roles in dealing with the increasing challenges facing Ghana and the global society.

The features that shape the common core programme are shown in Figure 1. These are

- learning and teaching approaches – the core competencies, 4Rs and pedagogical approaches
- learning context – engagement service and project
- learning areas – mathematics, science, computing, languages (English, Ghanaian Language, French and Arabic), career technology, social studies, physical and health education, creative arts and design and religious and moral education.

These are elaborated subsequently:

LEARNING AND TEACHING APPROACHES

- *The core competences:* Describe the relevant *global skills for learning* that the CCP helps learners to develop in addition to the 4Rs. The global skills for learning allow learners to become critical thinkers, problem-solvers, creators, innovators, good communicators, collaborators, digitally literate, and culturally and globally sensitive citizens who are life-long learners with a keen interest in their personal development.
- *Pedagogical approaches:* The CCP emphasises creative and inclusive pedagogies that are anchored on authentic and enquiry-based learning, collaborative and cooperative learning, differentiated learning, and holistic learning as well as cross disciplinary learning.
- *The 4Rs across the Curriculum:* The 4Rs refer to Reading, wRiting, aRithmetic and cReativity, which all learners must become fluent in.

Learning context

The CCP places emphasis on engagement of learners in the classroom activities, projects (in and outside classroom). These projects can involve individual or group tasks which all learners are required to complete by the end of Basic 10. The CCP project provides learners with contexts to demonstrate

4.7.1.3 The task of designing the Change Laboratory session

Even though the formative intervention process is expected to be taken over by the participants, Virkkunen and Newnham (2013) suggest that a preliminary plan be put in place. The plan needs to detail the task along the sequence by aligning the session with the expansive learning actions, identifying resources and how the sessions might build on each other in the process, (Bligh & Flood, 2015). It was therefore important that I had a plan of what is to be discussed in each session. The first step was to have a plan of activities that the participants would be engaged in, followed by a plan and schedules for the sequence of Change Laboratory sessions. The overall task design devoted to the expansive learning cycles was done using a framework by Bligh and Flood (2015) while each sessional planning was done using a template provided by Virkkunen and Newham (2011); see APPENDIX 1 for a sample.

The six sessions of the Change Laboratory were designed to progress through the cycle of expansive learning. Each session foregrounded one stage of the cycle, with the last workshop designed to focus on both reflection and consolidation as shown in Table 4.3. In reality, as with other Change Laboratories, stages of the cycle were not exclusively addressed in strict sequence in only one session. Rather, a more messy, iterative process unfolded as has been noted in the literature (Augustsson, 2021; Engeström, 2022).

Table 4.3 Change Laboratory Sessions and their Alignment with the Expansive Cycles

Change Laboratory session	Length of session	Number of participants present	Primary focus within the Expansive Cycle	Stimuli used
1	103 mins	6	Questioning	Mirror materials: lesson plans, quotes from teacher interviews, summary of observation data Activity system
2	92 mins	6	Analysing	Mirror materials: as above, plus curriculum documents, and key ideas from the previous session
3	90 mins	6	Modelling solution	Excerpts from student focus groups Teacher reflective journals Key ideas from S1 and S2 New ideas suggested during this Change Lab session
4	91 mins	6	Examining the new model	Second observation data, teacher reflective journals, key ideas from S1-S3, curriculum materials, teachers' model of student-centred teaching
5	91 mins	6	Implementing the new model	As above plus teachers' lesson plans
6	84 mins	5	Reflecting and consolidating	Teachers' lesson plans, reflective journals, and key ideas from S1-5

4.7.1.4 Session 1

Purpose: The session was intended to identify the nature of participants teaching practice and to questions those teaching practices. In the expansive learning cycle, it was questioning for the participants to recognise the need for change

The session was divided into two parts. In the first part, I formally welcomed the participants and introduced ourselves. I then presented my research project to the participants, giving them some background on the study, the nature of the study, how data will be collected, and most importantly, the study's purpose. This was to provide them with an opportunity and support to learn from each other and be able to effectively implement the new curriculum.

It was my intention that the "practitioners can feel safe to freely express their opinions and are allowed to experiment with new ways of acting" (Virkkunen & Newnham, 2013, p. xix). I took time to further explain their rights as participants, especially the right to withdraw their consent at any time during the process. The opportunity was given to the participant to seek any clarifications. An important question that was not part of my initial planning was whether I could provide them with a certificate after the program. This was important for the teachers because the sessions were for their professional development, and they needed evidence to support them and use it to build points for their promotion. I had to defer the answer and consult with my supervisors, who agreed to it. After the question-and-answer session, simple rules were developed as a way of working together. That ended the first part of that session.

The second part of the session officially opened the Change Laboratory sessions. Participants were given what Virkkunen and Newnham (2013) called "disturbance diaries" to write down their personal notes, thoughts, and reflections throughout the process. While the books were held as participants' personal records, they were made aware that some aspects like the classroom reflections may be collected for analysis.

Actions and interactions: The teachers were given the opportunity to share their experiences about a successful lesson they had delivered. The lesson could come from their experience with the old or new curriculum currently underway. After that, they were also given the opportunity to share experiences of very frustrating or challenging lessons they had experienced. From there, the discussion moved to the nature of the participants' teaching practice. The aim was to identify the cultural and historical basis of their teaching and show whether there has been any significant change in their teaching practice under the new curriculum compared with the old curriculum. The final issue for the session was on *what matters* to them regarding the teaching and learning of science. This session was facilitated using multiple stimuli (see Table 4.3) such as the teachers' lesson plans, summaries and selected quotes from their interviews, and summaries of observation data which served as first stimuli directing the participants to the problems in their activity. These also served as an appropriate prompt for the participants to question their practice and realise a need for change. The activity system was introduced as a second stimulus, but as indicated earlier, participants were not comfortable using it.

Preparation for the next session: The participants were tasked to find out what is demanded of teachers and students under the new curriculum. This was to let participants become familiar with the demands of the new curriculum. Participants were also asked to take a lesson plan from the old curriculum and rewrite it under the new curriculum. The essence of this task was to find out if they were planning their lesson differently under the new curriculum.

4.7.1.5 Session 2

Purpose: The purpose of this session was to enable participants to gain a reflective distance of their practice in relation to the demands of the new curriculum. In terms of the expansive learning cycle, the primary purpose was for participants to analyse their activity system, and specifically to identify relevant contradictions.

Actions and interaction: The second session began with the teachers sharing their impressions, and feelings and reflecting on the key ideas from the previous session. Their comments and suggestions were taken on board to improve the subsequent sessions. The participants shared their thoughts, concerns and questions about the new curriculum. They were given the opportunity to discuss what is demanded of teachers and students under the new curriculum. They also discussed student-centred teaching and provided key feasible and valuable ideas about it. To become conscious of these ideas and be intentional in applying them to the field, participants designed a lesson plan template as the last activity of the session. The main mirror materials introduced in this session apart from the previous ones were curriculum documents and key ideas from the previous session. These were used as a second stimuli to help the participants address the problems in their activity system.

Preparation for the next session: Participants were tasked to discover things that matter to their students in teaching and learning science. It was to let participants know what is important to their students regarding the teaching-learning of science.

4.7.1.6 Session 3

Purpose: To assist teachers in developing new ways of thinking about their practice under the new curriculum, considering *what matters* to students. This primary intention was to promote modelling in the expansive learning cycle.

Actions and interactions: The session started with teachers reflecting on the main ideas for the previous session. The teachers discussed some of the things that matter to their students in the teaching and learning of science, drawing on some differences and similarities between *what matters* to them and their students and how those ideas relate to the demands of the curriculum. The teachers committed to practice at least one idea that matters to students, which is related to the new curriculum. Multiple mirror materials were used to facilitate this session. These included new ideas and suggestions from the previous sessions, curriculum materials, teacher reflective journals, etc. However, the main mirror material from this session was excerpts from students' focus groups about *what matters* to them. This drove the discussion serving as both primary and secondary stimuli enabling teachers to identify problems as well and as think about solutions to address *what matters* to students.

Preparation for the next session: Participants were tasked to plan a lesson for week 10 or 11 considering *what matters* to students and try out an activity in their classroom taking into consideration *what matters* to students in meeting the demands of the new curriculum.

4.7.1. 7 Session 4

Purpose: It was for participants to examine student-centred ideas relating to *what matters* to students. This was primarily related to examining the model in the expansive learning cycle.

Actions and interactions: The sessions began with a reflection from the previous session, after which the teachers shared their experiences of trying out some of the ideas discussed in the previous sessions. The participants took time to examine some of the student-centred ideas developed previously that relate to *what matters* to students. They shared some ideas about a new understanding of the curriculum and committed to taking new actions based on the new understanding and *what matters* to students. The second observation data and teachers' model of student-centred teaching were the main mirror materials used in this session, in addition to teacher reflective journals, lesson plans, and key ideas from the previous sessions. These multiple mirror materials enriched the discussion by helping participants examine their collective models and visions.

Preparation for the next session: Participants were tasked to modify the lesson plan for week 11 based on the experience they got from the pilot testing and the day's discussion.

4.7.1.8 Session 5

Purpose: To experiment with new teaching ideas that consider *what matters* to students, related to the implementation of new models/ ideas in the expansive learning cycle.

Actions and interaction: There was a reflection on the main ideas of the previous session. The teachers shared experiences about the commitments and actions they took in their classrooms in relation to the ideas discussed. Teachers took turns to describe lesson plans they intend to teach in week 10 or 11 and how they intend to implement the ideas we have discussed in those lessons. They constructively critiqued the plans and made suggestions for improvement. Thus, the teachers' lesson plans were the main mirror data used in facilitating this session to enable them to implement their ideas and models of using student-centred pedagogies that take into consideration *what matters* to students. The teachers made commitments to implement their plans in the classroom.

Teachers were asked to reflect on their actions going forward using the following questions as a guide:

> What new idea(s) did I practise?
>
> Did it go well or not? Why and why not?
>
> What were the students' reactions?
>
> Is there any new understanding I got from the practice?
>
> Do I want to make modifications when I use the idea(s) next? Why or why not?

4.7.1.9 Session 6

Purpose: To stimulate participants to reflect on the learning process and consolidate their ideas. This is linked to reflection, consolidating and generalising in the expansive learning cycle.

Actions and interactions: The session began with sharing experiences about the teacher's planned lessons and their evaluation. The teachers reflected on the whole process by discussing the benefits they obtained from the workshops in terms of understanding the new curriculum, lesson planning and delivery, and collegiality. They also discussed the future implications of the workshops for their practice, that is, the vision of the future form of activity they want to have, what they want to do and why.

Most importantly, they also discussed how to sustain those practices in the future and how they will share the knowledge they have acquired to generalise and consolidate those ideas. The participants concluded the session by looking at the unique nature of the workshop and made some recommendations and commitments to practice what they have learned to improve the teaching and learning of science in their schools. The mirror data used in this session included teachers' lesson plans, key ideas from the previous sessions, their reflective journals, and the third observation data. These served to provide appropriate prompts to help the teachers discuss their experiences in the Change Laboratory sessions.

4.7.2 Semi-structured interviews

One-to-one semi-structured interviews were conducted with the teachers. Each teacher had two rounds of interviews (refer to Table 4.2 for timelines). The first interview was used to generate mirror data for the workshops. The second interview was to get feedback on what the teachers felt had been accomplished through the workshops. It was for the teachers to reflect on the entire process of the intervention from the discussion to commitments and actions they have undertaken and the impact it is having on their practice. Each interview was conducted at the teachers' workplace at their own convenient time and venue. This was to avoid interfering with teachers planned activities. As suggested by Sarantakos (2005), the environment was conducive and comfortable, and the talk was relaxed. I sat sideways with the teachers during the interview to avoid assuming a position of authority over them. The interviews were audio recorded. The audio recording of the interview afforded me the opportunity to listen attentively to the teacher's responses to the questions posed to them and ask for further clarifications without having to write any notes. My interview guide (APPENDIX 7) directed the interview questions, and I sought clarification on the responses through further questions.

The introductory question sought to find out about the teachers' background, which includes their qualifications and experience. The questions that followed were to find out *what matters* to the teachers and their students as well. There were questions seeking to find out the teachers' practices under the new curriculum. The second round of interview questions focused on the transformation that has occurred for the teachers since the start of the workshop. They were asked to share their change in understanding about *what matters* to students and how that has influenced their teaching practice under the new curriculum. To explore how teachers intend to use the knowledge acquired during the workshop in the future, they were asked to explain the new things they will continue to do in the future and why they want to keep on doing them.

I also used "prompting and probing" including non-directive probing like "I see", "how do you mean", "tell me more about that", "anything else you can share" (Sarantakos, 2005) to get the participants to give more and accurate responses. These strategies are very important because they determine the quality of a good interview and can encourage participants to go more deeply into the issues under discussion (Hatch, 2002). Guidelines on good interview techniques suggested by Hatch (2002) were also followed (see APPENDIX 3).

4.7.3 Focus groups

The purpose of the focus groups was to discuss *what matters* to students regarding the teaching and learning of science. Focus groups enable participants to engage positively with the researcher. It is suited for participants within the same age group and has similar characteristics (Rabiee, 2004). It can generate large amounts of data within a short period of time. A focus group was chosen because the group dynamics enable it to generate richer and deeper data than one-on-one interviews (Rabiee, 2004). These reasons made me choose a focus group over a one-on-one interview. Also, the focus group interview was chosen because it was less intimidating and less risky for the children because of the presence of their peers.

While the number of participants for a focus group may vary, 3-4 participants are considered optimum as the number should be small enough to be managed (Rabiee, 2004). From the literature, focus groups involving children have participants around 3-6 in a group. For example, in a study by Wiens et al. (2019) with adolescent girls, three girls were selected for four different focus group interviews. Horbo's (2021) study of school children's experience of pain had cases of 2-3 children in the focus groups. Three participants for each focus group were therefore considered ideal for the study.

A pilot focus group was conducted with three students in JHS2 after seeking permission from the head of a school and getting verbal consent from the participating students. The focus group conducted was in a classroom in the presence of a teacher from a primary school. This was to give the students security and freedom to express themselves without being intimated by the teachers they have direct contact with. The pilot focus group lasted for about 30 minutes which was audio recorded. The responses of the students during the pilot focus group made me modify some of the items in the guide I had prepared (see APPENDIX 7). I listened to the recorded audio several times and the main ideas that came out as *what matters* to students were written on cards (see APPENDIX 2) to guide the conversation during the actual focus group.

All the focus groups were conducted in an open space in the schools where the interaction could be seen by others. In some schools, the cards were introduced into the conversation immediately after the purpose and initial introductions were done, where the students were made aware of the nature of the interview and the rights, they have to refuse to answer a question or stop the process entirely. It was then followed by the questions in the interview guide. In some cases, the cards were introduced later into the conversation depending on the situation as I assessed the appropriateness of the time. I observed the participants carefully as the interview was going on, looking for verbal and non-verbal cues so I could identify if the participants were tired, bored, upset or embarrassed (Mason, 2002).

It was important for me to develop the trust and confidence of the students. The focus groups were conducted in a relaxed atmosphere as students were encouraged to feel free to talk about the issues. The students were provided with something to drink and eat while the conversation was going on. This strategy took their mind a bit off the conversation and made the place more casual. To sustain the conversation, I had to reach their level by building a good rapport. I actively listened to them by seeking clarification and sometimes summarising what they said. As with the teachers, I avoided an authoritative position over the students, by not sitting face-to-face with them. Rather, we all sat in the same line.

The entire discussion focused on *what matters* to the students regarding the teaching and learning of science. The students were asked to share when science lessons became interesting and important to them. Some of the questions focused on changes students would want to see in science teaching to make it interesting. Others focus on what they want to do in a science lesson.

I also used "prompting and probing", including non-directive probing like "I see", "how do you mean", "tell me more about that", "anything else you can share" to get the participants to give more and accurate responses (Sarantakos, 2005). The students were made aware that they could code-switch between English and Twi (a local language) during the interaction. This enabled the students to provide more information as they could change language at any time in the conversation without any difficulties. The focus group interview lasted between 30 to 45 minutes.

4.7.4 Classroom observation

Classroom observations provided a further data source that fed into the workshops as a first and second stimuli. The observation was non-participant and semi-structured because I knew what I was looking for but gathered data in a less "predetermined or systematic manner" (Cresswell & Cresswell, 2018). The observation allowed me to gather 'live' data from the teachers' classroom. The observation data was used as mirror data during the formative intervention session. It was also used to triangulate the data from the interviews and the Change Laboratory sessions.

All the teachers had three observation rounds (refer to Table 4.2 for the timelines). Each observation lasted for 70 minutes, which was the usual period for teaching science. The first observation was to gather data about the nature of participants' teaching. The observations focused on teacher-student and student-student interactions, the level of involvement and engagement of students in the teaching and learning process and *what matters* to the teachers in the classroom teaching of science.

The second and last observations were to find out any changes in teachers' practices regarding the ideas discussed at the workshops. The observations focused on how teachers addressed *what matters* to students in their classroom. Specifically, I observed how teachers used *what matters* to students in their lessons: the level of students' engagement in the lessons, how teachers involved students in collaborative learning, the use of resources in the lesson and students' interest in the lesson. The observation results were fed back into the workshops as a second stimulus.

In each class I was introduced by the class teacher who told the class my purpose for being there and asked for verbal consent from the students. Once the verbal consent was given, I sat at one side of the classroom towards the rear to observe. I did not teach the class, co-teach with the teacher, or contribute to class discussions. I made hand-written notes during the observation. These notes were both descriptive and reflective (Cresswell & Cresswell, 2018). They described what I saw and what sense I made of the situation and people. The sense I made of the descriptive data was mostly based on inferences made from the conversations with the teachers and students after the observations to understand the reasons, intentions or purposes behind participants' actions and behaviour. These were non-identifiable with respect to all students which means no notes were taken about a particular student other than in very general terms (e.g., the teacher asked a question to the whole class, a student answered...), and I used an alias for the teacher to link this data with the workshop data. No audio or video recordings were made.

4.7.5 Reflexive research diary

A reflexive research diary field note was used to collect data for the research. The diary served three main purposes. It was used to capture my thoughts and insights about the entire process. Before leaving the site after any data generation, I took some 20 minutes to write a few points into the diary about how the process went, what I remembered, what went well or did not go well and why, and what called for concern. This helped me to think beyond the past and plan well for the future in the next phase of the data generation process. Also, after each data generation process, I listened to the audio and wrote some notes in my diary about the main ideas in the data to have first-hand information about the data. The research diary therefore served as my first point of call in the data analysis process giving me an overview of the whole data. The research diary was also used as my observation field note in recording observation data “in situ”. The observation field notes written in the diary captured the lesson topics, the name of the participating teacher, the lesson topics, the dates and times, and the number of students present. It was also used to record important aspects of the classroom interaction that were not guided by any designed protocols. Finally, the diary was used to capture informal conversations with teachers and students.

Teacher reflective diaries: Teachers were also given reflective diaries and encouraged to use them to reflect on their lessons and to capture critical incidents in the classroom concerning the topic understudy. Some of the teachers used their diaries to record *what matters* to their students and brought them for discussion during the Change Laboratory sessions. Some also used the diaries to write lesson plans needed at the Change Laboratory session as they could not use their official lesson notebooks for such exercises.

4.7.6 Conversation

Informal conversations were held with students after a lesson observation to seek a clear understanding of what happened in the classroom. These conversations with the students were short, lasting about 5 minutes, and were used to seek their opinions on whatever happened in the classroom. Though informal in nature, I managed to record some critical information in relation to what I heard in my research diary by way of writing. This enabled me to offer a better interpretation of what I observed.

4.8 Ethical considerations

The study was conducted in accordance with the University of Technology Sydney (UTS) Research Policy and Procedures and was subject to approval by the UTS Human Research Ethics Committee with the approval number ETH21-6684 (see APPENDIX 5). The first step towards the ethics application process was to complete the two research integrity modules mandated by the Graduate School of the University of Technology Sydney for all Higher Degree Research students, after which a research data management plan was prepared in the university data research management program called UTS Stash. An approval letter was sought from the Municipal Directorate of Education at Sefwi Wiawso, where the study was conducted (see APPENDIX 6)

4.8.1 Informed consent

Written informed consent was obtained from all participants (see APPENDIX 8) with the additional safeguard of consent from parents, especially for those students who took part in the focus group, as verbal consent from students was deemed culturally appropriate for the students during the classroom observation. Students were informed that their decision to take part in the research would have no impact on their grades and would not affect the teaching they received. Written information provided to students was kept short and simple. However, it covered all key points such as the purpose of the research, reasons for being asked to participate, their voluntary participation, possible risks and the remedies to mitigate them, and their right to stop the discussion if they felt uncomfortable for any given reason. Before any data generation sessions, such as focus group interviews and formative intervention sessions, I reminded the participants of the facts on these information sheets and allowed them to ask any questions. For the classroom observation, I sought verbal consent from the student at all times I was in the classroom. I introduced myself and informed the students of my main focus, which was to be on the teacher's practices, and that I was not going to write down any of their names. I was visible but discreet and quietly wrote my notes.

4.8.2 Confidentiality and privacy

Confidentiality and privacy were considered important ethical issues as data were collected from participants' personal and professional lives.

Privacy and other ways of minimising risk were made clearly known to participants in the information sheets before they consented. I ensured that information was shared in a non-identifiable manner by using numbers for the participants. This was to ensure the privacy of the information shared was protected as stated in the information sheets of participants. Data security followed the UTS Research Policy and Procedures by ensuring data were stored in UTS's secure cloud storage system and on a password-protected hard drive while documents such as field notes were kept in locked a filed cabinet. A code of conduct was developed in collaboration with the teachers from the start of the workshops so that there were proper ways of working together where no one was embarrassed or intimidated, and discussions were to be kept secret.

4.8.3 Other consideration

I made clear to teachers that my research objectives were to support them in implementing the new science curriculum and not to judge or evaluate their professional competence. Also, I did not impose any ideas during the workshop for them to try but facilitated a collegial and collaborative discussion among the teachers to identify the challenges and find ways of making the implementation of the science curriculum better. This reduced the risk of teachers having to do things independently without any support as they tried new ways of doing things under the new curriculum.

4.9 Data analysis

The data analysis strategy for the study included data preparation, data management and the actual data analysis.

4.9.1 Data preparation

Most of the data collected were from the audio recordings of the Change Laboratory sessions and interviews with teachers and students, and therefore, transcription was needed. These were transcribed verbatim by me. Some of the data, especially student focus group interviews, contained a mixture of Twi, a local language and English as students were given the option to use both languages in the interview. Therefore, the transcription, in some cases also involved translating the local language into English. Being a native speaker of the language, I was in a good position to understand what the students said in the local language and translated it as accurately as possible. The transcription process allowed me to familiarise myself with the data in the first place. All names were anonymised during the transcription stage to ensure confidentiality in the data collected. These transcripts and the notes became the raw data for the analysis.

4.9.2 Managing the data

Qualitative data can produce large amounts of data (Gibbs, 2007) and this study is no exception, as a large amount of data was collected during the months of fieldwork. These data include transcripts of audio recordings of the Change Laboratory sessions, focus group data from students, interviews with teachers, observation data, and informal conversations. These files were all uploaded into one encrypted zip file on my computer. These files were then uploaded into NVivo software which was used for the analysis and served as a data management tool. The main data set used for analysis in this thesis is the transcript from the Change Laboratory sessions and the focus group from the student. Other factors, such as interviews and observations, were used as mirror data in the Change Laboratory session and partly for triangulation.

4.9.3 Data analysis

There was no clear separation between data collection and data analysis as has been noted by researchers (such as Gibbs, 2007). Analysis of data began in the field as I started to think about what I was hearing and seeing. In this study, using the Change Laboratory approach, analysis was an integral part of the data generation process. The analysis of one session informed the direction of the subsequent ones, and the data from one session was used as mirror material in another (Virkkunen & Newnham, 2013). Therefore, after every session, the audio recordings were immediately listened to and transcribed. The summary of the key ideas that emerged in the session was noted in my research daily.

Nonetheless, there was a need for much analytical work to be done after the data collection process. Data were read and reread, and summaries of each data set were produced through "selecting, focusing, simplifying, abstracting, and/or transforming... the corpus of data" (Mile et al., 2014, p. 12). Thus, I extracted summaries by creating synoptic units using my own words about how the data related to my interest in the analysis (see APPENDIX 4 for an example of synoptic units). As Hopwood (2018) indicated, the approach enabled me to identify patterns related to common ideas, differences and connections.

This part of the analysis was guided by the practical, interactive framework (Srivasta & Hopwood, 2009) focusing on these three questions:

1. What are the data telling me?
2. What do I want to know?
3. What is the relationship between what the data tells me and what I want to know?

As the transcribed data can miss out on some of the "feel" of the settings in the data collection, one strategy suggested by Gibbs (2007)) which I adopted, was to sometimes go back to the recordings and listen to them again. Hearing the participants' voices sometimes brought clear meaning and fresh perspective, leading to different interpretations.

Thematic analysis (Braun & Clarke, 2006) was used to analyse data from the focus group. The process began with coding, where nodes or codes were created using the NVivo software and linked to statements or phrases from the focus group data. These nodes were defined by providing a description of them.

The codes were later grouped to form categories, from which themes were developed. Three themes were developed from the categories as presented in Table 4.4.

Table 4.4 Theme and Categories

Themes	**Categories**
Support and attention	*Peer teaching* *Individual attention* *Collaborative learning*
Engagement and interestedness	*Active student participation* *Engaging lesson* *Experiential learning*
Applicability and connectedness	*Application of knowledge to real-life* *Doing well* *Local language* *Connecting with personal experience*

The data analysis from the Change Laboratory followed what Chaiklin (2012) calls *wholistic orientation* in CHAT, where specific CHAT concepts are applied in the analysis to understand what is happening. The following concepts in CHAT were applied in the analysis to provide insight into the data: expansive learning, contradictions, and TADS.

Expansive learning: The first step in the analysis was to determine the expansive learning actions in the Change Laboratory session**.** The analysis followed a method devised by Engeström et al. (2013), elaborated by Augustsson (2021) and applied in other studies (see Prokopis et al., 2022). The data was analysed using each speaking turn. A speaking turn begins and ends when a participant takes the stage to speak in the Change Laboratory. Each speaking turn was coded to identify expansive learning actions, and the frequency with which they occurred in each Change Laboratory session (see Prokopis et al., 2022) based on the following framework:

1. Questioning-a critique or rejection of aspects of current practice or suggested changes.
2. Analysing action taken to explore causes and to explain the problematic situation.
3. Modelling-ideation and construction of an explicit, simplified model that explains and offers a solution to the problematic situation.
4. Examining- running, operating and experimenting with the model in order to fully grasp its dynamics, potentials, and limitations.
5. Implementing-preparation and practical application of the model, enrichments, and conceptual extensions.
6. Reflecting-evaluation and reflection on the process of expansive learning.
7. Consolidating-generalising the outcomes and consolidating them into a new stable form of practice (Augustsson, 2021, p. 484).

To facilitate the analysis, these expansive actions have been broken down into sub-types (see Augustsson, 2021; Engeström et al., 2013). The subtypes were therefore applied in the analysis with some modifications to reflect the data (see Table 4.5).

Table 4.5 Expansive Learning Actions and their Subtypes

Expansive learning actions	Subtypes
Questioning	Challenging participants into questioning Criticising existing practice Questioning the proposed development
Analysis	Articulating needs and idea Historical analysis articulating problems or challenges Identifying contradictions Weighing alternative solutions Interpretation of rules and policies Explaining ideas or concepts
Modelling the new solution	Sketching the initial idea of a model Exploiting existing models Naming and defining the model Fixing the model in material or graphic form Varying and adapting the model
Examining and testing the new models	Discussing the model critically Enriching the model
Implementing the new model	Demonstrating the new model Preparing implementation Actual use of the new model Reporting on the use of the new model Evaluation of implementation Making commitment to implement new model
Reflecting on the process	Reflecting on activities in the process Reflecting on personal professional development Reflecting of future implications
Consolidating and generalising the new practice	Committing to future actions Coming to a realisation Admonishing to apply Identifying ways to support and sustain ideas Finding ways to spread ideas

Contradiction: The next analysis phase was to identify contradictions within the participating teacher's activity system**.** Contradictions are defined as historically accumulating structural tensions within and between the activity systems' activity systems" (Engström, 2001, p.137). These contradictions were identified through their discursive manifestation in the form of conflicts, dilemmas, double bind and critical conflicts (Engström & Sannino, 2011). These were identified using linguistic cues outlined by Engström and Sannino (2011) see Table 4.6.

Table 4.6 Types of Discursive Manifestation of Contradiction and their Linguistic Cues Modified from (Engström & Sannino, 2011, p. 375).

Manifestation	Linguistic cue
Double bind	"we", "us", "we must", "we have to" "we should" pressing rhetorical questions, expressions of helplessness like "we cannot
Critical conflict	"let us do that", "we will make it"
	Personal, emotional, moral accounts narrative structure, vivid metaphors "I now realise that[...]"
Conflict	"no", "I disagree", "this is not true" "yes", "this I can accept"
Dilemma	"on the one hand[...] on the other hand"; "yes, but" "I didn't mean that", "I actually meant"

The key focus was not to code these linguistic cues to determine the type of discursive manifestation but to serve as key pointers in the data to where contradiction could be identified. These cues themselves did not determine the occurrence of discursive manifestations but helped to locate them (Engström & Sannino, 2011; Lilley, 2020). For example, the expression of helplessness in statements like "unless they provide us" "we cannot" "we don't have" etc which were very common in the data helped in focusing on the potential manifestation of contradictions.

Different statements across multiple discussions were relied on and then analysed to get an overall sense of the contradictions faced by the teachers. After identifying these potential contradictions, they were then mapped into the activity system (subject, tool, object, division of labour, rule and community), and where they were related to enabled me to determine the type of contradiction being articulated. For example, issues relating to participants' training and the demands of the new curriculum were identified as secondary contradictions between the subject and the object.

TADS: To trace the teachers' agency in transforming the practice, I applied Sannino's (2015a, 2022) model of TADS in the analysis. I began by systematically identifying conflicts of motives that the participants encountered in their practice. This pertained to the problematic situation in the teachers' practice in which they were confronted with two alternative motives requiring a deliberate choice. For example, the motive for teachers to teach in a more engaging manner conflicted with the motive to finish the syllabus on time.

I then identified artefacts and ideas agentively taken up by participants as second stimuli to become forward anchors and traced how the teachers used them to overcome the conflict of motive and transform their practice (Sannino, 2022). These anchors were concrete actions or practices that participant developed, while others were statements that changed the direction of their actions and thinking. For a second stimulus to qualify as a forward anchor, it must satisfy the following characteristics: (1) the participants intentionally formulate it, (2) the initial formulation is ambiguous but is progressively enriched, and (3) it addresses the paralysing situation faced by the participants. Five main forward anchors were identified in the data (Chapter 7). As forward anchors are associated with three key actions: *throwing, taking over and break out action* (Sannino, 2022) it was important for me to identify these actions that were associated with the identified forward anchors. For example, actions like making suggestions were considered to be *throwing* action while exploring options was considered to be *taking over* action.

4.10 Trustworthiness

Many ideas relating to the quality of research have been developed based on quantitative research and focus on validity, reliability and generalizability. These mostly rely on approaches that cannot be applicable to qualitative research (Gibbs, 2007). However, this does not mean that qualitative research cannot ensure quality. There are frameworks for ensuring rigour and quality in the process (Shenton, 2004).

Credibility: Credibility is the attempt by the researcher to show that a true picture of the issue under investigation has been presented (Shenton, 2004). This study's credibility was achieved through triangulation, where data were collected from different sources such as observation, interviews and the Change Laboratory sessions. According to Gibbs (2007), respondent validation is one way to ensure credibility. I applied this principle in my study by presenting transcribed data to participants for member checking. I also provided summaries of each Change Laboratory session as part of my mirror data so that participants could check the accuracy of the interpretation. Credibility was also ensured by providing evidence in the work with quotations from participants.

Transferability: Transferability deals with the extent to which the finding of a particular study can be applicable in another context (Shenton, 2004). The findings of this study are specific to the context of the participants in the study; I do not claim the findings to be applicable to another context. However, I have given thick descriptions of the participants and the study context, providing good descriptions of issues for readers to make transferability decisions.

Dependability: To ensure dependability, Shenton (2004) suggests that the research process must be reported in such a way that it can serve as a "prototype model". I therefore provided a detailed description of what was planned and executed in this research regarding the methodological approach (see sections 4.6 and 4.7). I also provided a personal reflection to evaluate the process highlighting the weaknesses and strengths in the approach used.

Confirmability: This is "the qualitative investigator's comparable concerns to objectivity" (Shenton, 2004p. 72). To ensure confirmability, as outlined by Shenton (2004), I addressed my personal beliefs and assumptions and how they influenced my research decisions**.** I also ensured that the study's findings were the result of the experiences and ideas of the participants rather than my own preferences. This was done through data triangulation.

This chapter has provided a thorough description of the methodological approach and research design used in generating and analysing the data for the study. In the next chapters, the result of data analysis will be presented.

Chapter 5: Data Overview

This chapter has three sections. Section 5.1 introduces the chapter. Section 5.2 provides an overview of the Change Laboratory sessions. Section 5.3 concludes the chapter.

5.1 Introduction

In this chapter, I present a condensed summary of the data collected from the Change Laboratory sessions, in their relatively raw and untheorised form. Its purpose is to serve as bridge between the methodology chapter and the analysis chapters. I used *what matters* in the present tense because this reflects the fact that concept refers to something enduring - not a temporary motive resolved by accomplishing a goal, but something that is a more stable and lasting characteristic of how people relate to an object.

5.2 Change Laboratory sessions

As I explained in the methodology chapter, there were six Change Laboratory sessions spaced at intervals of two weeks. Here I present an overview of the purpose of each session before delving into the main issues discussed in each and the kinds of data that were generated. The descriptions are supported with excerpts from the discussions. The data are in chronological order to depict the progression of ideas throughout the sessions. Each session was designed to generally stimulate one or more of the expansive learning cycle steps; for instance, both sessions 1 and 2 were designed for questioning and analysis. However, the reality was messier and more complex.

5.2.1 Session 1: Questioning and analysis of activities

The purpose of this session was for each participant to question and analyse their teaching practice and thus identify the challenges they face in their activity system. The teachers discussed their experiences of both successful and frustrating lessons. They also explored the nature of their teaching, tracing its historical basis, in addition to *what matters* to them as science teachers.

The session began with the teachers highlighting instances of teaching they believed went well. This process allowed them to demonstrate their professional competence in delivering successful lessons. For some of the teachers, success in their lessons hinged on their ability to use practical demonstrations to dispel student misconceptions, thus fostering student interest. For others, it was when students could apply their knowledge to produce tangible results, or when students' contributions demonstrated the student-centred nature of their teaching. For example, teacher T3 noted:

> I was also teaching reproduction in humans, on the subtopic, the characteristics of adolescents. Because the lesson was practical and related to their lives, the students were able to contribute effectively, making it successful and student-centred experience. [T3]

The teachers also discussed some of their frustrating or challenging lessons. It was evident that the biggest challenge for these teachers was the lack of access to teaching and learning resources that would enable practical demonstrations in the classroom. The absence of science laboratories prevented them from conducting demonstrations effectively. T4 explained: "I was also teaching acids and bases, but because we don't have science lab it was very difficult for me to teach it very well. I had to teach it abstractly." [T4,].

It became clear that the ability to demonstrate concepts was crucial for effective science teaching. The lack of resources was identified as the primary reason the teachers struggled to engage students actively in lessons. In the absence of appropriate resources, they were compelled to use didactic approaches.

The teachers also discussed the nature of their teaching and the reasons behind their teaching methods. They described their teaching as focused on preparing students for tests, lacking active student engagement, relying heavily on didactic methods, and often characterised by "chalk and talk". They attributed these teaching practices to several factors, including the shortage of resources, limited lesson time, pressure to cover the syllabus, and students' lack of access to textbooks, which meant they would put notes on the board for the students to copy. Additionally, they acknowledged that the emphasis on test-driven teaching was influenced by their school's need to perform well in exam league tables. Some also pointed to the ways their own teacher education had shaped their teaching methods. While recognising the need for change in their teaching practices, they emphasised that changes in the curriculum alone would not suffice without the necessary resources. For example, T4 said:

> We want change but for it to be successful, it should start from the top so that we the teachers can follow suit. …Because they brought this new curriculum without given us the needed materials like textbooks and teachers notes books to be able to use to implement the new curriculum. So, if there is a change, that change must come with the needed materials to make it successful. [T4]

Despite these challenges, the participants articulated several things that mattered to them. They wanted science lessons to dispel misconceptions by being more practical; connect concepts to students' experiences; build on students' prior knowledge; be more tangible; address individual differences; and enable students to apply their knowledge in real-life situations. The following comments by T6 and T4 illustrate some of these teachers' priorities:

> I think what teachers want is that we want science lesson to be more practical, to occur in a friendly environment where students can relax and relate to things. I want my student to relate to whatever I am teaching so they don't see science as abstract. [T6]

> As teachers we should not base our teaching sole on making student pass exams, but we have to teach so that the children can apply what they have learnt in the nearby future. That for me is important. [T4].

5.2.2 Session 2: Questioning and analysis of activities

The purpose of this session was to encourage the participating teachers to question and analyse their practices in the light of the demands of the new curriculum and to reflect on whether they might need to change these practices accordingly. They shared their views about the new curriculum and what it demanded of them and their students. They also shared their understanding about student-centred teaching.

Some participants perceived little or no difference between the new and old curricula, while others questioned why certain resources were not included along with the new curriculum, asserting that its implementation would be effective only if the necessary materials were provided. Their comments highlighted the recurring issue of a lack of resources for curriculum implementation.

The teachers demonstrated their appreciation of the new curriculum's student-centred nature. However, it became apparent that many had not read the curriculum materials sufficiently to understand the demands it places on both students and teachers. In the workshop, they were able to read the materials and exchange ideas about their roles as facilitators in the classroom, as required by the new curriculum. While some had insightful ideas about facilitating learning, others said they felt challenged due to the lack of resources needed to fulfil this role effectively. As well, there was a consensus that if they were to meet the demand for developing problem-solving skills in students, timetable changes were needed to allow more time for them to explore issues and develop solutions.

Moreover, the teachers deliberated on how to foster critical thinking among students, unanimously agreeing that asking "why" was one effective approach. They emphasised that even when students provided incorrect answers, teachers should not dismiss them but instead encourage the students to explain why they gave those answers. The excerpts below are contributions to this idea from T2 and T6.

> You see, at times, teachers may not even know, so the wrong answer can help you find out and address some of the misconceptions students have. Yes, a child may give you a wrong answer, but you don't have to shut the person down and say sit down. We should let the person explain why he/she gave that answer. [T2]

> As I talked about misconceptions, maybe the child has a different or wrong mindset already formed, so that must be corrected to set the child free. If they have these preconceived ideas and they express them, and you, the teacher, say it's not correct, they may even dislike you. So, just ask "why did you say that"? and then continue to ask further and deeper questions so that the children can even discover the misconception by themselves. [T6]

The teachers also discussed student-centred teaching, acknowledging the gap between their theoretical knowledge and its practical application. They suggested and deliberated upon practices that might aid the transition towards teaching methods that are more student-centred. Their ideas included "think-pair-share", peer teaching, self-assessment, and individualised testing. During this discussion, the participants had the valuable realisation that resources were not the only essential element for actively engaging students. They collaboratively developed a lesson-planning template to ensure the conscious incorporation of student-centred teaching approaches into their instructional practices.

5.2.3 Session 3: Modelling solutions

The purpose of this session was to assist the participating teachers in developing new perspectives on their teaching practices, taking into consideration *what matters* to students. The workshop began with the teachers presenting their own findings and also listening to students' voices from the interview I conducted. They then identified ways they could meet the demands of the new curriculum and committed to practising at least one of these in the classroom.

The teachers discussed the various issues that matters to the students, namely, receiving support from their peers; active participation in class; involvement in projects and presentations; extending teaching science beyond the classroom; individual attention; and the practical application of science. They then discussed ways to engage with these ideas. For example, T4 said:

> I will speak on engaging in projects or presentations. So as teachers we should, now most of the time, allow students to present their own ideas about topics we teach, and we should also give them projects. There are some projects in the textbooks that we can allow them to engage in by guiding them either in the class or given them to take home so that they can present their project work to the whole class.

The teachers expressed surprise at some of the things that matter to students, such as connecting science to their environment and teaching science outside the classroom. They discussed strategies to address these priorities, as exemplified by T1:

> So now, whatever topic I teach, I will ensure that I relate it to their environment. For example, if I am teaching a topic like erosion, I will have them identify erosion in their areas and help develop solutions. That is what we will be doing now. [T1]

A significant point of discussion that surprised the participants was the idea of educators doing research instead of relying solely on textbooks. Students had expressed concerns about their teachers not researching and merely delivering textbook information, sometimes even having students copy directly from the book. The participants analysed why delivering textbook information might be problematic for their students, citing incorrect or shallow content in some textbooks. T1 commented: "some teachers come to class and put the textbook there and read from it directly or copy the note directly from it. Some even give it to the students to copy directly." [T1]

The teachers were also surprised that students had perceived them as rushing to complete the syllabus without giving proper attention to whether the students understood its content. They attributed this rush to the expectations of supervisors, who evaluate teachers based on syllabus coverage. The teachers then explored ways to actively engage with students to ensure their understanding, including the benefits and challenges of students bringing materials from home for practical lessons. They also identified similarities between *what matters* to them, as teachers, and to their students, recognising that some of these aligned with curriculum demands, for example, collaborative learning, practical lessons, and experiential learning.

An essential part of the teachers' discussions focused on assessment and how to include students as active participants in the assessment process. One innovative idea was to have students contribute questions for examinations. To meet the demands of the new curriculum by incorporating ideas that matter to students, they committed in the coming weeks to make specific changes in their classrooms, for example, students setting their own questions, collaboration, providing individual attention, and student choice. T1 and T3 commented:

> Okay, then I will also give different evaluation questions to students for the purpose of differentiation. [T1].

> I will put students into groups for collaborative learning to provide support for their colleagues. [T3].

5.2.4 Session 4: Examining solutions

The purpose of this session was to explore how *what matters* to students could be used to address student-centred teaching when implementing the new science curriculum. The workshop began with the participants sharing their experiences of innovative teaching ideas and discussing how they were already incorporating some of these into their teaching practices with significant results. Some, for example, had developed problem solving and critical thinking among their students. The teachers said active student engagement had occurred through practices such as group presentations, think-pair-share, building on students' prior knowledge, and using improvised materials. These new teaching approaches resonated with students, making them happier and more interested in their lessons because they felt their teachers were addressing *what matters* to them. Remarkably, all the teachers tried to incorporate additional strategies, thus going beyond the initial ideas they had committed to trying in their classrooms.

The teachers also acknowledged the challenges they had faced when first implementing new ideas. Some had even abandoned their initial commitments due to the difficulties they encountered. For example, T4 explained how he had to abandon his commitment to giving students choices because he was not sure how to execute it, instead opting for practices that he felt more comfortable with. Others expressed concerns about the time-consuming nature of some activities, emphasising the importance of prior preparation and time management.

Despite acknowledging the challenges associated with implementing new ideas, the participants encouraged each other to take things slowly. For example, T6 said:

> What I think is that to be able to effectively implement the new curriculum using these ideas … we should do prior preparation. It is very important. In every lesson we need to think through it to find the best way of implementing an idea. As we are now beginning, we should take it lesson by lesson so by a year time they will be part of our practice. So for every lesson we need to think through by asking ourselves a lot of question like how can I make it child centred, what do I need to do etc. …. So I think it going to be challenging from the beginning but as time goes by we will be okay with them. [T6]

The teachers then delved deeper into some of the previously generated ideas, discussing their feasibility, challenges, prospects, and alternatives. Examples included improvisation, teaching science outside of the classroom, peer teaching, and self-assessment. In this way, they enriched their understanding of these ideas and how they could be implemented in the classroom. They also shared newfound understandings of the demands of the new science curriculum based on *what matters* to students, such as peer teaching, self-assessment, group presentations, and projects. The following comment from T1 exemplifies their commitment to these demands:

> What I have come to realise is that we can teach for children to understand science even if there is no science lab by actively involving them and relating things to their environment. [T1]

5.2.5 Session 5: Implementing and testing of ideas

In Change Laboratory session 4, the participants were encouraged to experiment with new teaching ideas that take into consideration *what matters* to students. In Session 5, the workshop began with the teachers sharing their experiences of trying out the ideas they had committed to implementing. They then evaluated the success of their lessons by measuring the level of student engagement, which they agreed was very high. They were also asked to share their lesson plans for the weeks ahead and discuss how they might incorporate into them the concepts discussed in the workshops. They took turns explaining how they intended to create student-centred lessons. The following excerpt is from T2's plan:

> I will be teaching agricultural tool in the week 11. In the introductory stage, think pair share approach will be used for students to come out with some of the tools their parents use or they know about. I will brainstorm with students to come out with the meaning of farm tool. Some of the students will be called to come to the front to describe and demonstrate how some of the common farm tools like cutlass, hoe etc are used. These farm tools which are my TLMs [teaching and learning materials] will be assembled by myself and the students. That means I will ask them to bring some of the common ones they can find in their surrounding and I will also bring some. After that, they will be taken to the school farm and I will put them into groups for them to practice how the various farm tools are used, based on the demonstration from the class. The next subtopic will be on the maintenance of these farm tools. Each group will be asked to come out with two ways of maintaining the farm tools. This is after they have gone to find out that information from their community. Here they will come and present to the class. I will then summarise the key ideas for them. [T2]

The teachers provided constructive feedback on their colleagues' lesson plans by questioning the feasibility of some and also identifying the strengths, weaknesses and challenges of others.

Thus, they drove the plans of their colleagues forward by critiquing them and suggesting improvements. The following excerpts exemplify the comments:

> I think he did well by planning to actively involve the students in the lesson. What I will suggest for him is to take the students out to see some of these domestic animals as some may be around the school. [T2].
>
> The plan is good but there is no mention of how assessment will be done. [T5]
>
> Do the animals cause problems in the community and what project can you give to them (students)? Since we want the students to be involved in solving community problem. [T4]

Many of the teachers' lesson plans incorporated ideas that matters to students, such as collaborative learning, students bringing materials, and engaging students in projects. Notably, the use of collaborative learning strategies such as group work and think-pair-share was common among all the teachers. This was contrary to their previous beliefs that they could not incorporate these practices due to large class sizes and the nature of student desks. The discussions also foreshadowed significant student participation in the teachers' planned lessons.

The participants also addressed the types of examinations the students might write at the end of the curriculum, thus revealing that their own focus on exams had not changed. Nevertheless, they demonstrated a new understanding of the curriculum based on *what matters* to students and also committed to implementing their plans in the classroom

5.2.6 Session 6: Reflecting and consolidating

Session 6 was designed for the participating teachers to reflect on and consolidate what they had learned during the period of the Change Laboratory. Despite a strike action by teacher unions that led to some of the teachers not teaching their planned lesson because they had to cover for lost lessons, the teachers still shared their experiences of how they incorporated into their teaching the ideas they had discussed in the previous session. They demonstrated how engaging their lessons had become for their students. The following excerpt is T3's description of teaching a lesson:

> Okay, so before the lesson, I asked the pupils to bring materials like bulbs, connecting wires batteries etc to class. During the lesson I put the students into groups and distributed the materials to them. They were guided to connect the wires and with batteries to produce light. The students were very happy because the lesson was very practical, and activity based. To engage them in critical thinking, I asked them how they could assembly the materials in some container to make it like a touch where they could easily carry it around and switch it on when needed. A lot of interesting suggestions were made by the students and so to make their ideas practical, I asked each group to put all the materials in one container as a touch and present it on the next lesson, which they all did. Some used bamboo sticks, paper cards, wood and other materials as their holders to produce the torch. The lesson was successful because the students were engaged in hands on activity. [T3]

The teachers emphasised how they placed students at the centre of their lessons by building on their previous knowledge, engaging them in collaborative learning practices, involving them in presentations, and helping them develop critical thinking and problem-solving skills, all of which were practices they had not employed before the change laboratory sessions. They also evaluated the success of their planned lessons, as reflected in the comments of T1:

> The lessons were successful, because I actively engaged students in the lesson, building on their previous knowledge. I also gave them opportunity to do collaboration and make presentations which made them happy and helped them to understand the lesson. The students were put at the centre of the lesson and each individual was given opportunity

> to contribute to the lessons as questions were fairly distributed. The students felt they were active participants of the teaching and learning process and they were able to answer the questions I asked them and they shared their ideas about what they have learnt. [T1]

During their discussions about their changed understanding of *what matters* to students and how this might affect their practices, the teachers admitted that they had never before asked their students about *what matters* to them. They agreed that considering *what matters* to their students had significantly improved the planning and delivering of lessons, which were now more student-centred. They discussed specific ideas that had shaped their teaching. These included teaching science beyond the classroom, providing students with foreknowledge of the topics to be covered, teachers doing research rather than relying solely on textbooks, involving students in projects and presentations, adjusting the language of instructions, and providing individual attention. T2's comments serve as an example:

> One of the ideas that matters to my students which has improved my practice is engaging in project and presentation. I used not to do that in my teaching as I was always using lecturing method but now that I know it matters to students, I used it in my teaching. Few weeks ago, I was teaching farming system in Ghana and I gave them assignment to find out the various farming systems use in Ghana, their advantages and disadvantages. They came to present and brought out some good ideas and it was very interesting to them. Since then, the students have been asking me to do that more often. So anytime you come to my class you will see that student participation in class has improved and they feel happy when they are asked to make group presentation.

The teachers indicated that understanding *what matters* to students had not only improved their practices, it had also led to enhanced student learning experiences, as students were now placed at the centre of the teaching and learning process. Interestingly, they also noted that implementing some of these ideas, such as providing students with advance knowledge of upcoming topics, had helped them complete their curriculum topics on time, contrary to their earlier experiences.

The participants also mentioned that the workshops had significantly enhanced both their understanding of the new curriculum and their ability to meet its demands. While they had initially seen no significant difference between the old and new curricula in terms of understanding and practice, they were now providing more opportunities for students in the curriculum implementation process than they had done previously. The following excerpts from T3 and T1 illustrate the benefits the teachers said they derived from the Change Laboratory sessions:

> The workshop has helped us a lot because previously we were teaching the children alright in the new curriculum, but we were not given them opportunities as we do now. For example, now I give my children the topic we will be doing in the next meeting, and I have seen a lot of benefit with that as most of the student go and read about the topic before the class, and when they come to class, they make contributions which make the lesson child centred. …It helps us to finish the topic within time as compared to last term. [T3]

> I will say this workshop has really helped me in a lot of ways in lesson planning and delivery. In planning my lesson now, I take into consideration how to bring in things that matters to student. For example, this week I am going to teach heat energy, I am thinking of how to make the lesson more practicals, engaging and relating to their environment and previous knowledge. I am also looking at what project to give to the students to make presentation as these matters to the students. This workshop has taught

me all these things and has gingered me to incorporate these ideas in the lesson that I am planning and at the same time when I am delivering. [T1]

The teachers also addressed the collegiality they had enjoyed in the sessions. The collaboration among themselves, together with their trust and tolerance for each other, had helped shaped the discourse in the workshops. They agreed they had learned many things from their colleagues, and they could now tap into the expertise of these colleagues to help in their teaching practices. T3 said:

> The collective sharing of ideas has been very beneficial in helping us to understand the curriculum. It has developed collegial relationship among us where we can call on colleagues for help. For example, last time I was going to teach electronics I called my brother here (pointing to T1) for help on some aspect I was finding it difficult because I could see he is very good in that aspect. [T3]

Finally, the teachers shifted the discussion toward the future, focusing on what they wished to continue doing and how they would sustain and consolidate their new learning. All participants expressed their unwavering commitment to practices such as collaborative teaching in the classroom, improvisation for teaching materials, engaging students in projects and presentations, teaching science beyond the confines of the classroom, and encouraging students to bring materials. These commitments are evident in T5's comments:

> For topics like diffusion and osmosis that I will be teaching next semester, I would want to make it more practical by letting students bring materials to demonstrate these ideas and also making improvisation for those that we cannot get. [T5]

The teachers brainstormed various ways of sustaining what they have learned. They emphasised the need for stronger collaboration to consult and share ideas. Additionally, they highlighted the importance of consistency, as illustrated by T6's comment:

> What can help sustain what we have done here is consistency of practice. We need to be consistent with what we do and try these one after the other. We can list the key issues that matters to students and so anytime we are planning to teach a particular topic we then look to them to see which ones we can incorporate into the lesson. That I think can help us to be conscious and deliberate in using these ideas in our practice. [T6]

It is worth mentioning that the teachers discussed not only how to sustain these ideas but also how to share them. Their most important recommendation was the extension of similar Change Laboratory sessions to colleagues who had been unable to participate in the current ones. Some teachers mentioned sharing what they had learned during their professional learning community sessions and even inviting their science-teacher colleagues to observe their lessons. T1 expressed this in the following way:

> For those colleagues I am close to, I plan to invite them to observe my lessons and learn from me because I know that *what matters* to my students also matters to theirs. By sharing with them, they will have the opportunity to enhance their teaching practices. [T1]

5.3 Conclusion to the chapter

This chapter has provided an overview of the discussions that took place during the six Change Laboratory sessions. The data were presented in chronological order to indicate the progression and content of these discussions. Chapters 6, and 7 present the results of the data analysis utilising CHAT.

Chapter 6: Expansive Learning and Contradiction

This chapter has two sections. Section, 6.1 presents an article submitted for publication. Section 6.2 discusses the contradictions in the participating teachers' activity system.

6.1 Introduction

This chapter is presented as the first finding section. The chapter has two main sections. The first section is an article which has been published. The article focuses on the participating teachers expansive learning. It must be noted that some of the ideas is this paper have already been discussed in the previous chapters and some of the subsequent chapters will refer to this paper as well.

The second section is added as an expansion to the paper based on the data analysis with a focus on the contradictions in the teachers' activity system which were briefly mentioned in the article. The chapter thus addresses the following research questions.

1. What contradictions are present in the implementation of the new science curriculum?
2. What do teachers learn, expansively, when collaborating on resolving these contradictions in implementing the new science curriculum?

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6.2 Science Teachers' Professional Learning and Changing Practices in the Context of Curriculum Reform in Ghana

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Abstract

Research on science education in Africa shows many teachers continue to use traditional lecture methods even when curriculum favours more student-centred approaches. This paper explores science teacher professional learning as a means to realise practice change at a crucial time of curriculum reform in Ghana. The study was a qualitative formative intervention involving six Junior High Schools. The aim was to explore possibilities of aligning the intended curriculum with the implemented curriculum, focusing on student-centred aspects. One teacher from each school joined six Change Laboratory sessions over three months. Transcripts from these were complemented by two interviews with each teacher, and 18 lesson observations early, during and after the Change Laboratory. Teachers' practices changed in four key areas that strengthened student-centred pedagogy: use of questions, assessment, teaching beyond the classroom, and designing a range of activities. Pedagogies that were initially seen by participants as impossible became viable as the Change Laboratory helped teachers see new ways to implement the intended curriculum despite challenging conditions. This paper contributes to knowledge of science education in relation to curriculum reform, showing how a Change Laboratory can support feasible change at the edge of what is possible in an African context.

Keywords: teacher learning; Change Laboratory; expansive learning; curriculum implementation; Ghana; science education.

Introduction

Curriculum reforms across African countries have encouraged shifts to more student-centred approaches, intending to address shortcomings associated with teacher-centred approaches and student passivity (Coffie, 2019; Nsengimana, 2021). This paper explores science teacher professional learning linked to practice change in the context of curriculum reform in Ghana, where the intended curriculum (van den Akker, 2010) envisages a fundamental change in teaching practice, not just taught content (Ministry of Education [MOE], 2020). This will require teachers to learn to practice differently.

Outcomes of curriculum reforms are often disappointing as workloads and pressure to cover content undermine changes in pedagogical approach This is particularly the case in African contexts where science curriculum reforms have been frustrated by constraints in implementation support, large class sizes and limited resources (Nsengimana et al., 2021; Ramnarain, 2014), meaning 'science curriculum is still implemented in traditional ways' (Nsengimana et al. 2020 , p.1). Across Africa there is a documented mismatch between the intended curriculum (the intention specified in curriculum documents), and implemented curriculum (actual process of teaching and learning) (Lelliott et al., 2013; van den Akker, 2010).

Rather than focusing on challenges producing this mismatch, this paper focuses on how the gap between the intended and implemented curriculum can be reduced, when this has often proved difficult in African contexts. It reports a collaborative interventionist approach through which teachers became able to enact significant changes in their practices, changes that have proved elusive in similar contexts, and which participants themselves initially deem unfeasible.

Studies have shown that the teaching and learning of science in Ghana faces many challenges. Key among these are the: lack of relevant resources; curriculum breadth leading to struggles covering the syllabus; lack of quality in-service training; students' struggles to understand science linked to the use of English language as a medium of instruction; excessive use of didactic approaches; and teaching to the test, where examinations overshadow what happens in classrooms (Boakye & Ampiah, 2017; s, 2018).

The new curriculum in Ghana reflects a view that pre-tertiary education has not been responsive to needs of the country (MOE, 2020). The intent is to shift from a focus on passing exams to building character, nurturing values, and raising confident citizens who can think critically. The reforms address not only taught content, but also the approach to teaching, outlining a change from currently dominant teacher-centred to more student-centred pedagogies (MOE, 2020).

Teacher professional learning in relation to curriculum reform in Ghana typically involves 3-5-day courses organized by the Ghana Education Service (GES), introducing teachers to key features of the new curriculum. This falls short of equipping and empowering teachers to implement intended changes in the classroom. A different approach to developing teacher professional learning is needed.

Learning that breaks away from established norms can be fostered when teachers are given the opportunity to analyse their own practices and develop solutions (Hopwood et al., 2023). This study adopted an interventionist approach, called the Change Laboratory (Change Lab) to help science teachers do so in a collective learning process (Botha, 2017). The Change Lab is an established methodology based on expansive learning theory (Engeström & Sannino, 2010). However it has not been used to change teaching practice during curriculum reforms in Africa (Winberg et al., 2023). The aim was to explore the possibilities of aligning the intended curriculum with the implemented curriculum through a Change Lab. The study answers the following research questions:

1. What changes in practice do teachers enact in their classrooms as they engage in professional learning through Change Laboratory
2. How does the Change Laboratory enable those changes?

Literature review: Curriculum implementation and teacher professional learning in Africa

Successful curriculum implementation is contingent upon relevant, high-quality teacher professional learning (Ogunniyi & Rollnick, 2017). However this has been identified as a key challenge facing African education systems (Gyimah & Ayinselya, 2022; Mabula, 2012). Developing countries, including those in Africa, witness poorly implemented educational reforms because of the lack effective professional development programs to achieve intended goals (Bantwini, 2009, 2010; Leu 2004). This has been confirmed in studies focused on teachers' perceptions and challenges faced when implementing the curriculum (Aboagye & Yawson, 2020; Coffie, et al, 2019). New research is needed to better understand what such learning needs to be so that the gap between intended and implemented curriculum can be reduced (Lelliott et al., 2013; Postholm, 2020; Rechsteiner et al., 2023). As a result, scholars have called for research that enables teachers to change their practices by providing them with opportunity to collaborate and reflect (Msimanga et al., 2019). The present study does precisely this, supporting science teachers to collaborate in professional learning, finding ways to bring intended and implemented curriculum into alignment.

Theoretical framework

The study applies the theory of expansive learning, part of Cultural Historical Activity Theory (CHAT). CHAT is an interventionist theory, aimed at changing the world, not just describing it as it is (Engeström & Sannino, 2010). The theory of expansive learning concerns how people learn what is not yet there, in this case referring to how teachers learned to implement the new curriculum when solutions to the challenges of doing so were not immediately available. Expansive learning involves in ‘constructing and implementing a radically new, wider and more complex object and concept for their activity’ (Engeström & Sannino, 2010, p.2). Expansive learning occurs when practitioners feel the need to transform their activity system because of problem they are facing. It concerns collective transformation not just for individuals, but for an activity system (Engeström et al., 2013).

The activity system includes the subject (the person or people working together, in this case, science teachers), the object (what they are working on, here implementing a new student-centred curriculum), and outcome (the result of their work on the object, here students’ learning of science) (Engeström, 2022). That effort is mediated by artefacts (physical and symbolic, including classroom resources and concepts), and is connected to rules (formal curriculum requirements and informal cultural norms), community (wider group of people who have a stake, including colleagues and parents), and division of labour (roles and responsibilities, including who does what in classrooms) (Engeström, 2022).

Expansive learning involves ‘ascending from abstract to the concrete’ (Engeström, 2020). Learners transforming their activity develop a ‘germ cell’, an abstract idea which carries the foundational contradiction of the whole system and the seeds for transcending the contradiction (Engeström, 2020). The germ cell is actionable, a starting point that can be systematically examined and translated into concrete practical applications. In a dialectical interplay, practical experimentation expands theoretical understanding, and theoretical understanding shapes the creation of new concrete practices and artefacts (Engeström et al., 2013).

An ideal-typical cycle of expansive learning follows seven learning actions (Engeström et al., 2013). The first is *questioning.* A need state concerning challenges or difficulties in the current activity system leads participants to question, criticize or reject some part of existing ways of doing things.

The process moves to *analysing* to find out causes or explanatory mechanisms (Engeström et al., 2013). Analysis falls into two types: *historical-genetic*, where the origins and evolution of the situation are determined and *actual-empirical* in which explanation of the situation is sought by constructing a picture of its inner systemic relations (Engeström & Sannino, 2010). Analysis and questioning can trigger each other (Augustsson, 2021).

The third action is *modelling solutions*. Here, breakthrough ideas emerge from analysis of systemic contradictions and develop into a simplified model solving the problems encountered (Engeström & Sannino, 2010). *Examining and testing the new model* follows, to understand its dynamics, potential and limitations (Engeström & Sannino, 2010; Engeström, 2020). The fifth learning action is *implementing the model* by means of practical applications, enrichments, and conceptual extensions (Engeström, et al., 2013). The sixth and seventh actions are *reflecting* on the process and *consolidating* its outcomes into a new stable form of practice.

The Change Laboratory Intervention

The interventionist thrust of CHAT has been developed into formative interventions to foster practical transformation, one of which is the Change Lab. The results of Change Labs are not known in advance (Prokopis et al., 2022). They emerge through joint activity between participants and researcher as facilitators (Morselli, 2021). A Change Lab enables participants to systemically identify challenges in their workplace practices and collectively design solutions to address them. The researcher's role is to provoke and support a process that is led by the learners/participants (Sannino et al., 2016). The intervention is thus 'formative', open-ended, focused on promoting agency and learning (Prokopis et al., 2022).

Change Labs use a process called double stimulation. Mirror materials of everyday practices are presented as first stimuli, helping participants identify problems, articulate dissatisfaction with the status quo, and commit to change. Conceptual tools either introduced by the researcher (e.g, triangular model of the activity system), or developed by the participants (e.g. templates to guide practice) are used as second stimuli. These redirect participants' attention from the problem to the nature of the solution.

Methodology

The study design was a qualitative formative intervention in a form of Change Lab. Six Change Lab sessions(S1-S6) were designed to foster expansive learning over three months (Table 1). Each session was design to provoke one or two expansive learning actions though in reality it involved a messier progression through the cycle. Consistent with Change Lab methods, these used three surfaces and relevant stimuli to prompt expansive learning (Morselli, 2021). The surfaces used were mirror surface, model surface, and ideas surface (Virkkunen & Newnham, 2013) which were represented on a projected screen, flip chart, and whiteboard respectively. Figure 1 shows how the room was set up, and Table 1 summarises the sessions S1-S6. The specific content of stimuli depended on what teachers suggested and decided in prior Change Lab sessions. Participants were less comfortable being video recorded, so sessions were audio recorded.

Figure 1: Change Lab set up

The first author facilitated the Change Lab with six science teachers (Table 2) from six junior high schools (five public, one private) in the Sefwi Wiawso municipality of Ghana. These teachers opted into the study based on their desire to change their practice and so may be regarded as a purposive sample. The Change Lab was conducted in the second term of 2022 academic year, one term after the introduction of the new curriculum. While Change Labs typically involve a group of participants from the same organisation, in this study participants were science teachers from different schools because junior high schools in Ghana often only have one science teacher. This exemplifies an adaptation of the Change Lab to specific contextual contingencies (see Spante, et al, 2022).

Table 1: Change Lab Sessions and their key Activities

Change Lab Session	Key discussion	Stimuli presented on each surface	Dominant expansive learning actions
1	Sharing experiences of frustrating and successful lessons	Mirror surface : lesson plans, quotes from teacher interviews, summary of observation data	Questioning and analysis

	Nature of teaching and why it is that way Historical and systemic analysis	Idea surface: key points emerging in S1 Model surface: Activity system	
2	What the new curriculum demands of teachers and students; how they understand student-centred teaching in relation to their current practices Historical and systemic analysis	Mirror surface: as above, plus curriculum documents, Idea surface: summary from the previous session Model Surface: Activity system	Questioning and analysis
3	What matters to their students	Mirror surface: excerpts from student focus groups; teacher reflective journals Ideas surface: key points from S1 and S2, emerging ideas in S3 Model surface: visual representation of new model	Modelling
4	How what matters to students can be used in more student-centred teaching to meet demands of new curriculum	Mirror surface: second observation data, teacher reflective journals; curriculum materials Ideas surface: key points from S1-S3, lesson planning template Model surface: teachers' model of student-centred teaching	Examining and testing the new model
5	Discussion of their own lesson plans to implement the model using more student-centred pedagogies	As above plus teachers' lesson plans on ideas surface	Implementing the new model
6	Experiences of implementing the model (enacting lesson plans) and how to sustain the new practice in the future	Mirror surface: reflective journals Ideas surface; key points from S1-S6; teachers' lesson plans Model surface: final model	Reflecting and consolidating

In between Change Lab sessions participants undertook activities such as consulting with students, designing lesson plans, and implementing new practices.

Each teacher was observed in the classroom three times for 70 minutes (a standard science lesson duration in the context of the study) – before S1, at the midpoint (after S3), and after S6.

The observations were unstructured and complemented by two semi-structured interviews with each teacher, one before and one after the Change Lab sessions. The first interviews and observations were used to generate mirror data to stimulate questioning and help participants gain reflective distance from their practices (Virkkunen & Newnham, 2013). Later observations and interviews were used to capture changes being implemented by teachers, excepts from which became stimuli to drive expansive learning forward (see Table 1).

The study was subject to approval by University of Technology Sydney (UTS) Human Research Ethics Committee with the approval number, ETH21-6684. Permission was given by the District to approach schools, and teachers were given information about the study by a local administrator. All participation was subject to informed consent.

Table 2: Biographical Information of Participants

Identifier	Gender	Qualification	Age (year)	No. of Years of teaching
T1	Male	First Degree	41	17
T2	Male	First Degree	43	16
T3	Male	First degree	47	21
T4	Male	First degree	44	14
T5	Male	Diploma	31	2
T6	Male	Master's degree	39	8

Data analysis

Audio recordings from the six Change Lab sessions totalling 551 minutes were transcribed verbatim. This created 60 pages of written text and was the principal data for the analysis, using observation notes and interview transcripts for triangulation. Transcripts were shared with participants for member checking, and summaries of interim analyses were shared with participants during Change Lab sessions as a further means of verification to enhance validity and reliability.

The analysis followed a method devised by Engeström et al., (2013), elaborated by Augustsson (2021) and applied in other studies (e.g., Prokopis et al., 2022). Each speaking turn was coded to identify expansive learning actions (Morselli, 2021; Prokopis, et al., 2022) using the coding framework by Engeström et al., (2013) see sample from Table 3. The framework comprises the seven learning actions: questioning, analysing, modelling the new solution, examining the model, implementing the model, reflecting on the process, consolidating, and generalising. Each of the learning actions were identified from a speaking turn and their frequencies in each session were tabulated; see Table 5.

Table 3: Examples of comments coded under each expansive learning action

Expansive learning action	Example comment	Session

Questioning	Our syllabus is too loaded. Why? I don't understand, so it makes the teacher rush through it.	S1
Analysis	We don't have teaching and learning materials to demonstrate and make things practical to the students which make teaching very difficult, so we normally resort to lecture methods	S1
Modelling solution	We can also undertake individualized test especially when they are given homework.	S3
Examining and testing new models	Teaching science beyond classroom especially embarking field trip is expensive but it possible and feasible for us to do it at least once in a year with proper planning in place…	S4
Implementing the model	I will be teaching agricultural tools in the week 11. In the introductory stage, think pair share approach will be used for students to come out with some of the tools their parents use or they know about.	S5
Reflecting on the process	There was collaboration among the teachers which helped the discussion	S6
Consolidating and generalizing the new practice	So now whatever topic that I will teach, I will make sure that, I relate it to their environment…	S6

To ensure validity and reliability, coding of data excerpts from all six sessions was done by Author 1 was then checked by Author 2 and Author 3 and disagreements were resolve until consensus was reached.

Findings

Changes in the teacher's practice

The first research question asked was: What changes in practice do teachers enact in their classrooms as they engage in professional learning through Change Laboratory? This section presents four key changes in the teachers' practice (see Table 4). These changes were planned and reflected on during the Change Lab sessions, discussed in the second interview with each teacher, and formed a focus of second and third rounds of observation.

Table 4: Teachers' Practices Before and After the Change Lab

Area of change	Before Change Lab	After Change Lab
Use of questions	Teachers' questions were generally low order	Teachers were asking high order questions, asking students to give reason for their answers, and distributing questions more equitably across learners
Assessment	Assessment was seen as activity to be done by the teachers at the end of teaching	Students became active participants in assessment process which became integrated into the teaching and learning process
Teaching beyond classroom	Lessons were always confined to classrooms	Teachers taught science beyond the confines of the classroom
Designing range of activities	Classroom activities were mainly dominated by teacher talk and chalk board illustrations	Teachers implemented a range of activities including group projects, presentations, practical lessons, debates etc

Use of questions:

Questioning was a common strategy used by all the teachers to get students involved in lessons. Initially these questions were of low order, demanding direct answers like "yes" and "no". During the Change Lab sessions, the teachers discussed the need to ask higher order questions as means of developing critical thinking among the students. As T2 indicated during Change Lab session 3, *"It is very important because the curriculum demands students to think critically so I believed asking such question will make students to think critically."*

Not only did the kind of questions change, but it was observed that teachers were distributing questions to students in a different way, rather than focusing on those who they expected to volunteer the answer (typically boys), they deliberately involved girls more, and began to ask lower achieving students questions, too. Interviews confirmed this was a deliberate part of their new practice: centring on all students not just a vocal, confident few.

One critical expansion to the idea of questioning involved asking students to give their reasons for a particular answer, especially when it was incorrect. This broke away from the culture of only acknowledging right answers (Ampadu & Danso, 2018) and was understood as an effective means of getting to know if students had misconceptions, and to activate students' knowledge as a shared resource in the classroom:

> *I wanted them to explain the reasons for their answers especially when the answer was wrong so if there is a misconception, I could address them. I also wanted to tap onto the knowledge they have and so by asking why they could explain further for others to understand as well. (T1, interview)*

Assessment:

Before the Change Lab, the teachers said they felt constrained by assessments, needing to teach to the test, understanding assessment as summative, happening *after* learning. Assessment involved set exercises used as evidence of teachers' output: the more exercises given to students the more the teacher was seen as working hard. From the first observations and interviews, it was clear that teachers set and marked all assessments. Through the Change Lab sessions, teachers came to use assessment to inform student learning, i.e., formatively. They expanded their understanding to include self-, peer and differentiated assessment. They also discussed the need to give more opportunity to students to shape assessment processes, including providing them with choices as to assessment format and focus. Some participants were observed giving students opportunities to award marks for their peers' presentations. This was discussed in interviews as an opportunity to foster responsibility while actively involving students in the assessment process as part of learning itself.

Another expansion relating to assessment was that the participants facilitated students to set questions for assignments, quizzes and exams. Through the Change Lab, it became important for teachers to make students part of the process:

> *… fostering their own interest and it will let them feel part of the process. For example, in a class test you can say write your own questions and answer them. Or even if we set the questions, we can give them the option to add their own and answer (T6, Session 4).*

Such practices were a radical departure from their established ways of working – often the first time they had approached assessment in these ways:

> *I have learnt how to solicit student ideas in assessment. I now involve my students in assessment, this is something I have never done before. This term for example, I have asked each student to set two questions for the end of terms exams and I will select some of the questions for the exams. (T4, Session 6)*

Teaching beyond the classroom:

Before the Change Lab all participants' observed science teaching was confined to the classroom, and they confirmed in interview that this was typical. During the Change Lab sessions, they discussed taking students out of the classroom to identify and respond to issues in the community, realizing the value of bringing students into direct contact with such problems to prompt their thinking about solutions, increase students' interest, and make lessons more understandable to students.

> *Most of them (students) were happy as for the first time they have been sent outside of classroom to learn and apply the knowledge. One student told me this is the first time he has seen a teacher doing that. (T5, Session 5)*

In the second observed lesson, T1 took the students to the school farm when teaching about farming systems. Beyond these direct observations, other participants reported similar activities in later Change Lab sessions, and in the final interviews.

Teaching beyond the classroom was seen as a way to address the lack of resources for teaching science. Participants realised that the surrounding natural and human environments provided rich funds of resources that were highly relevant to what they were teaching. Short field trips or nature walks nearby were seen as feasible ways to help students understand scientific content and concepts. In the final interview, T4 said:

I am not always teaching in the classroom. I sometimes takes my students out of the classroom to teach them science by using the immediate environment where I think I can have access to resources to make lesson more understandable.

Designing a range of classroom activities:

Initial observations and interviews showed classroom activities were dominated by teacher talk. As the Change Lab sessions progressed, the teachers designed various activities that engaged students in what they termed "hands and minds on" ways. Observations captured examples of these new activities including debates on key scientific issues, and research assignments to gather data from the community and make group presentations in class. As illustrated by T1's comment in the final interview:

Tomorrow I will be teaching electricity so if you walk into that class you will see that students will be debating on the negative effects of both thermal and nuclear electricity generation on the environment.

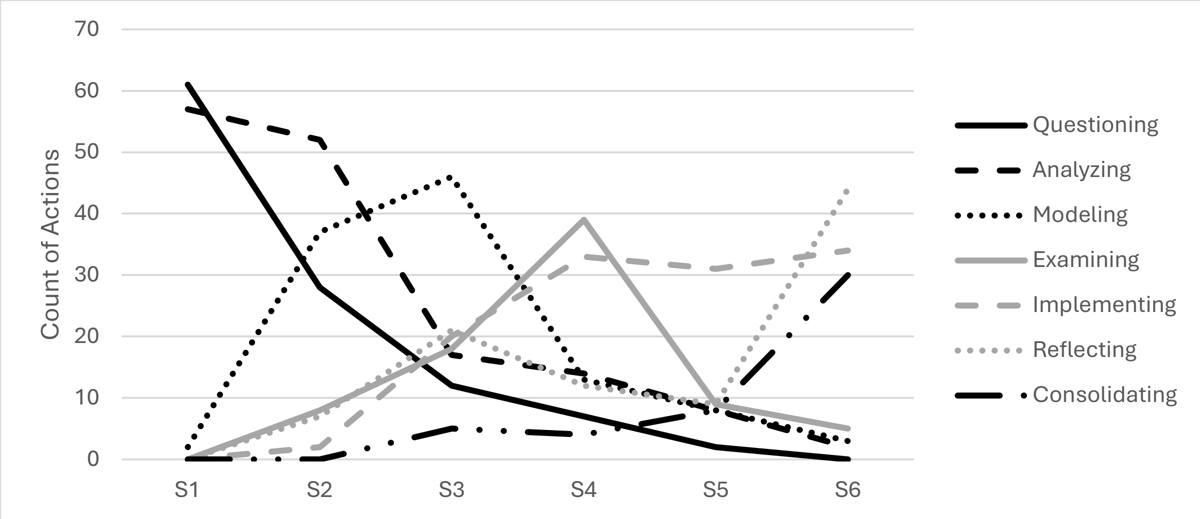
Expansive Learning Actions and Double Stimulation in the Change Lab

The second research question asked: How did the Change Lab enable teachers to make those changes? The theoretical stance frames this question in terms of the cycle of expansive learning, driven by the process of double stimulation. Table 5 presents the total number of comments coded under each expansive learning action across the six sessions, and this is represented graphically in Figure 2, clearly showing changes over time.

Table 5: Types and frequences of expansive learning actions in the Change Lab sessions

Expansive learning actions	**S1**	**S2**	**S3**	**S4**	**S**	**S6**	**Total**
Questioning	61	28	12	7	2	0	110
Analysing	57	52	17	14	8	2	150
Modelling	2	37	46	13	8	3	109
Examining	0	8	18	39	9	5	79
Implementing	0	2	20	33	3	34	120
Reflecting	0	7	21	12	9	44	93
Consolidating	0	0	5	4	8	30	47
Total	120	134	13	12	7	11	708

Figure 2: Evolution of frequencies of different expansive learning actions over the course of the Change Lab sessions



Questioning and Analysis

The teachers' expansive learning began with questioning and analysing, prompted by the mirror material comprising data from interviews and observations as first stimuli, along with an activity system presentation. Figure 2 shows these actions were predominant in the first two sessions.

Initially, the teachers were reluctant to change their practice even given the new curriculum: "*Yes the problems in our teaching is systemic and this curriculum can't change that. The fact that we have new curriculum does not mean our teaching will change*" (T5, S1). They felt that until problems such the lack of resources were addressed "*teaching will continue to be the same*" and "*no amount of curriculum changes will improv*e [practice]" (T5, S1).

Such comments manifest contradictions in the teachers' activity system. One was between tools and the object, as teachers felt unable to deliver student-centred approaches due to the lack of relevant resources. Second, a contradiction between the division of labour and the object, because teachers were doing nearly all the talking in classrooms and controlling the assessment process, while students were mostly listening – a far cry from the student-centred approach envisioned by the new curriculum.

Modelling solution and examining the models

After questioning and analysing, the teachers began to envision new ways to implement the intended curriculum. They proposed solutions and examined how they could be implemented. Modelling became a key focus in sessions two and three, with examining being the main expansive learning action in session four (Figure 2).

Their early visions for change were captured in ambiguous form as 'science lessons in which students are active and interactive'. This was progressively enriched and specified so that 'active' pointed to participating in ways other than listening to the teacher and writing notes, and 'interactive' pointed to both working with peers and with material resources. Four components emerged at an abstract level, as shown in the left-hand column of Table 6, with early ideas for how they might be realised presented in the right-hand column. Rough and changing versions of these were captured on the ideas surface as second stimuli during the session.

Table 6: Teachers Proposed Ideas for Effective Implementation of the Curriculum

Components of germ cell	Enactment
Active student participation	In lessons; high order questioning, given topic to student ahead of time, discussion and debates In assessments: peer assessment, giving students opportunity to set questions
Collaborative learning	Group presentations, think pair share, peer teaching, group projects and assignments
Hand on activities	Field work and practical lessons
Resource mobilization and utilization	Improvisation, use of technologies, use of environment and student bring materials to school

Implementing

Once the ideas had been articulated and examined, the teachers began to implement them – ascending towards the concrete. The resulting diverse concrete forms were detailed earlier in terms of the four key areas of practice change (Table 2). Implementation was a key focus of discussion in the Change Lab sessions, prospectively (planning) and retrospectively (discussing what had happened), spanning sessions four to six as shown in Figure 2.

A key participant-generated idea that served as a second stimulus was a new lesson planning template, making clear links to the elements listed in Table 6, and collaboratively developed on the whiteboard (Figure 1). Each teacher then added concrete details relating to the particular content they were teaching (they were all teaching different topics). These lesson-specific examples were shared with the researcher and were shown via the projector in subsequent sessions, driving discussion of implementation forward.

Reflecting and Consolidating

In the final session, participants reflected on the process of their learning in the Change Laboratory and planned ways to stabilise their new practices (consolidation; see Figure 2). Participants focused especially on two key features of the process that stood out to them: self-generation of ideas, and its collaborative and collegial nature; these were elaborated and confirmed in the final interviews.

The fact that the ideas for changed practice came from them, rather than from the researcher or another outsider, was key to the success of the process:

> *I want to add that this workshop [Change Lab] is better than all the workshops I have attended because in those workshops you go there, and someone comes to tell you what do but this one we generated ideas and decided what we were going to do. It means that we can do our own thing without someone coming to tell us (T1, Session 6).*

This is striking, given participants' initial stance that practice could and would not change until others outside their own classes and schools took action.

The participants further attributed the success of the Change Lab to its collaborative and collegial nature:

> *There was collaboration among the teachers which helped the process… I have also built knowledge from these colleagues. Their constructive feedback and criticisms have helped me lot in my lesson planning and delivery (T6, Session 6).*

Another participant also indicated *"I have learnt so much from my colleagues here. When we were discussing our lesson plans, they made a lot of suggestions which helped me in my lesson delivery"* (T4, Session 6). These comments are important given that in many schools, there can be only one teacher teaching science in the school. Hence the variation from typical Change Lab composition of people from the same institution (Virkkunen & Newnham, 2013) proved to be important. They worked collectively to understand and transform their practices, implementing emerging models in somewhat individualised ways based on what and who they were teaching at a particular time.

The participants discussed ways to consolidate their new form of activity. They framed this in terms of being consistent: *"What can help sustain what we have done here is consistency of practice. We need to be consistent with what we do"* (T6, Session 6). They each made commitments to keep implementing the new approach as they moved on to teach new topics, using the new lesson planning template.

> *I will keep on using collaborative learning approaches and peer teaching in my class. I will be teaching some of the topics that my colleagues have already taught like farming systems and tools next term and will adopt strategies like group presentation and project because I learnt from them that they made their lesson interesting (T3, Session 6).*

Interviews after Session 6 confirmed that these commitments were being upheld as teachers shared details of their planned lessons over coming weeks and months. Consolidation also concerns spreading the new form of activity. In this regard, participants outlined intentions to share and disseminate what they had learnt in the Change Lab. One said

> *I know what matters to my students also matters to other students in different schools, so I will want to invite my friends from other schools who did not get this opportunity to share with them what I have learnt here* (T1, Session 6).

He continued further by saying

> *I will do this by inviting them to observe my lessons or I can even go to their school…* (T1, Session 6).

Evidence of the impact of this lies beyond the scope of the present study, but such quotes do illustrate an intention to spread the new activity beyond the six schools involved and indicates the value participants saw in their new approach.

Discussion

This study sought to find out what changes teachers enact in their classroom when engaged in professional development though the use of Change Lab and how the approach enabled those changes. The participating teachers enacted four key changes in their practice. They questioned differently in class; assessed differently by given student an opportunity to be active participants in the process; took teaching beyond the classroom; and incorporated range of activities that are not traditionally employed in teaching. These teachers enacted changes they envisioned through the Change Lab. This in contrast to dominant cascading approach to teacher professional development many African countries where teachers are unable to translate their knowledge into practice (Bantwini, 2009; Gyimah & Ayinselya, 2022).

A key finding is that the Change Lab provided participating teachers with the tools to overcome a perceived lack of agency. A key finding is that the Change Lab provided participating teachers with the tools to overcome a perceived lack of agency. Many teachers feel conditions of their work and the need to cover extensive syllabus at the same time make it hard or impossible to change pedagogies (Adjibolosoo, et al., 2020; Boakye & Ampiah, 2017; Ramnarain, 2014). The Change Lab provided a context to transcend these perceptions, collaborating to produce significantly different forms of practice. Participants broke away from their initial stance that practice change depended first on resources changing, showing that commonly perceived barriers to implementation of new (science) curricula (Ramnarain, 2014) are not in fact insurmountable.

Winberg et al. (2024) identified challenges with Change Labs in Africa, including participants not completing the process due work and time constraints. This was addressed in the present study by limiting the number and duration of sessions but also ensuring that Change Lab helped teachers deliver their core job, rather than producing extra work.

Conclusion

The Change Lab approach fostered teachers' professional agency, enabling them to enact changes in their classroom, something considered by Pyhältö et al., (2012) as a key challenge in educational reforms. It shows how Change Lab can empower teachers to be actively involved in transforming their practice. Teachers want to be supported in innovating in their own practices rather than simply being asked to implement ideas imposed from the top down (Aldous et al., 2013). A collaborative and supportive environment that encouraged development of solution and experimentation with new practices was key to the study success. Through this, participating teachers realised valuable transformations in their pedagogical practices were within their grasp, despite the challenging conditions in which they worked. By providing opportunities for students to collaborate and actively participate in teaching, learning and assessment; carefully designing range of activities both within and outside of the classroom; being resourceful and using questioning practices differently, teachers can indeed bridge the gap between intended curriculum and classroom reality.

This study has broken new ground by focusing on producing conditions that make elusive change possible, responding and lending weight to arguments that interventionist research fostering collaborative approaches among teachers are valuable in reducing the gap between intended and implemented curriculum (Rechsteiner et al. 2023; Msimanga et al., 2019). Going beyond identifying mismatch between policy and practice, or explaining reasons for this, this study adds to the literature on science education in Africa by demonstrating how collaborative teacher learning can be an effective means to accomplish pedagogical changes envisaged in curriculum reform. The challenges in the African educational system preventing realisation of the intended curriculum are not insurmountable.

While the Change Lab may not be feasible in every school or context, there are valuable principles and conditions that can be adapted and applied to enhance teacher professional development more broadly. Creating opportunities for collaboration and idea development among teachers is crucial for fostering a culture of continuous learning and improvement.

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6.3 Contradictions in the activity system of the teachers

In the article, Coffie, et al. (2025) highlighted that the teachers faced some major contradictions in their activity system. This section is presented as a companion text to elaborate on these contradictions in the teacher's activity system; the next chapter will show how they resolved these contradictions. An overview of the structure of the participants' activity system is needed to understand the contradictions in the activity system.

The *object* of the activity is the implementation of the science curriculum. The *subjects* of this activity are the science teachers. The subjects apply some *tools* to achieve the object. These tools can be divided into three categories, namely:

i. *Curriculum materials* are tangible materials like textbooks, teachers' notebooks, and science syllabi.

ii. *Teaching and learning resources* are materials like the science laboratory and ICT tools teachers use in teaching science.

iii. *Pedagogical tool*s relate to the teaching and learning methods, approaches, techniques, and beliefs that the subject brings to the classroom regarding the teaching and learning of science.

The teachers' activity system also comprises a community, including students, parents, principals, and local supervisors. There is also a wider community of district and regional education officers and the Ministry of Education. There are *rules* in the classroom related to subject behaviours and activities like teaching periods and assessments. As a community, the school also has rules on attendance, etc. There is a *division of labour* among subjects and community members.

There were contradictions within the components of the teachers' activity system, some of which manifested themselves between other components and gave rise to secondary contradictions. These secondary contradictions were found between:

- The tools and the object
- The subject and the object
- Rules and the object
- The division of labour and the object

6.3.1 Contradictions between the tools and the object

Resources for teaching and learning: According to the teachers, resources for teaching and learning were very important in achieving the objective of the curriculum. Teachers believed that without basic science resources, teaching becomes very difficult as some ideas that could be easily demonstrated to students become impossible. For the teachers, showing or demonstrating ideas practically is a good way for students to understand and develop an interest in the subject. Their inability to have resources to demonstrate scientific concepts makes it very difficult for students to understand some concepts, as indicated by the comment of T5: "*I wanted to demonstrate..., I could not demonstrate, and the questions my students were asking me indicated they did not understand the lesson*" (T5, session 1). Physical demonstration, seeing science in reality, was more important for the teachers. The problem of lack of teaching and learning resources relates to the absence of science laboratories in the school. Without a science laboratory, the teachers are forced to teach in a manner contrary to the curriculum's expectations. "*It's because we don't have a science lab. If we had one, all these ideas would have been demonstrated easily for the pupils to understand, but because we don't have a science lab, we teach anyhow*" (T4, session 1).

The lack of resources led to the students' lack of active engagement. The students were passive recipients of knowledge in class. The only activities students were engaged in were listening, writing, and occasionally answering a few low-order questions. The teachers felt that they could not engage students in the lesson, creating a secondary contradiction between the tools and the division of labour. T6 affirms this point by indicating that

> *...actually many teachers have no choice but to resort to that (lecture method) because we don't have the facilities, there are no labs, and even where there are spaces, we don't have the materials to engage the students* (T6, session1).

It can be noted from the statement that the lack of teaching and learning resources affects student engagement and causes teachers to use teacher-centred approaches like the lecture method to teach students, which is usually "chalk and talk." The statement thus underscores the challenges faced by teachers. Without adequate facilities and materials to support active learning experiences, many teachers felt compelled to rely on traditional lecture-based methods as the primary mode of instruction. This reliance on teacher-centred approaches further reinforced the passive role of students in the learning process

To address the issue of lack of student engagement in science, the teachers initially believed there must be provision of teaching and learning resources like a science laboratory as seen in T4's comment: "*Something has to be done, and they should provide the schools with science labs so that we can engage students in activities*" (T4, session 1). Thus, teachers were of the view that having science resources to do experiments in the laboratory could engage the students. This idea is articulated by Marcourt et al. (2022) who indicated that for learner-centred pedagogy to be successfully implemented there is the need for the provision of teaching and learning resources.

The lack of resources also affected practical teaching, as teachers felt they could not engage students in hands-on or practical activities. As a result, the teachers felt that the only option was to lecture so that students could understand. T1 illustrates the issue clearly during the workshop by saying

> *...we don't have teaching and learning materials to demonstrate and make things practical to the students, which makes teaching very difficult, so we normally resort to lecture methods by explaining everything to them (students) because we have no option than to explain things to the students* (T1, session1).

The lack of resources affected every facet of the activity system. Teachers were trapped into linking the idea of resources to the ability to act as a facilitator as demanded by the new curriculum, and they felt they could not do that because of the lack of resources. In fact, "*acting as facilitators is not the challenge, but the material to use is the challenge to act as facilitators*" (T1, session 1). T3 shared this view by saying, "*Adding to what my colleague said, as a facilitator, if you want to deliver a lesson and you don't have teaching and learning resources, it makes the lesson very difficult to deliver*" (T3, session1). For the teachers, it was either they get the resources to be able to meet the demands of the new curriculum, or they continue with their teacher-centred teaching.

Curriculum materials: The conversation among teachers about the curriculum materials revealed tension between the materials themselves and the object (teaching and learning of science). The first issue raised was the loaded nature of the curriculum, which forces teachers to rush through it in order to complete it. They believed that this hinders their ability to engage students, as they focus on completing the syllabus rather than achieving the intended aims. They also attributed their rush to complete the curriculum at the expense of student understanding not to the loaded curriculum itself but to their supervisors who judge teachers' output based on the number of topics they have covered.

> *And here it is not our fault because our supervisors always come round looking for output of work, so we also want to reach there. So the supervisors should be advised on some of these things so that we will not always rush to complete the syllabus* (T4, sesion1).

Teachers were in a state of dilemma regarding the new curriculum. Some teachers did not see any difference between the old and new curriculum and questioned why it was introduced. For them, the only difference between the old and the new curriculum is just a change of names, as it was seen as "old wine in new skin." This means that, for them, there was nothing new in the curriculum to warrant a change in their practice. However, for some teachers, it is the best curriculum they can have, provided they receive the necessary support in terms of resources to implement it.

> *Although we have a lot of concerns about the new curriculum as teachers, I believe this new curriculum will help...students to become holistic learners and will be able to apply what they learn. So if they can provide us with materials, then this new curriculum will help our students become creators and innovators, and many good things will come to this nation through this curriculum* (T2, session 2)

Another tension experienced by teachers regarding curriculum materials is the lack of scope and information on some of the topics. While they believe that this can serve as an opportunity for them to do more research, they feel challenged by the lack of access to the internet.

6.3.2 Contradictions between the subject and the object

There was tension between the teachers' theoretical knowledge and practice in the new curriculum. Teachers' knowledge about the curriculum was not consistent with their practice. Although teachers shared a good understanding of the new curriculum at the theoretical level and understood what was demanded of them and their students, noting the student-centred nature of it, their practices were not aligned with their understanding as they were more teacher-centred in their approach.

For example, T4, in sharing his understanding of student-centred teaching, indicated that "*the child is at the centre, and most of the learning, for example, about 80%, is done by the child, with the teacher as a facilitator adding the 20%*" (T4, session 1). However, he later admitted that his practice was in direct opposition to the view expressed above, stating

> *my teaching has changed compared to before we started the workshop because previously I used to be at the centre, given the pupils just like 10% participation in the lesson because I was always given examples myself, just copying notes and performing experiments by myself* (T4, session 6).

Not only did the teachers' knowledge contradict their practice, but the things they espoused as important were not reflected in their practice either. The teachers articulated many things, either implicitly or explicitly, that mattered to them, some of which were in tension with their practice. Ideas like attending to individual differences, engaging students in collaborative learning, active student involvement in class, and making lessons practical were expressed as something that mattered to them. However, T6's comment later showed that teachers were not practising what they were saying: "*But in our schools, we don't even do these...which I believe does not help*" (T6, session 3).

Another contradiction that the teachers articulated was the tension between their training and what the curriculum demands. Teachers acknowledged that their training was quite different from what is demanded of them in the new curriculum. They believed their training was teacher-centred, and they were not exposed to student-centred teaching. This creates a critical conflict as the teachers recognise the limitations of their own training but continue to teach in the same manner that paralyses them in front of the contradictory motive of teaching in a student-centred manner.

> *We were taught in schools without activities and these student-centred things we are talking about. The teachers come and talk and talk and copy notes, so we learned rotely, and that is why we are also teaching like that* (T6, session1).

6.3.3 Contradictions between the rules and the object

Timetabling: There was a contradiction between the rules on the timetable for science lessons and the object. Teachers believed that the allocated time for teaching science is insufficient to achieve the new curriculum's objectives. One critical area where teachers felt the tension is in engaging students in practical lessons. They felt that allowing students to engage in practical work will delay them in completing the syllabus.

> *More so, our timetables are so tight that we can't even do practical works. If you try to do that, you cannot even finish your syllabus* (T6, session 1).

The teachers felt the need for extra time to do most of the things demanded by the new curriculum. Changing the timetable to have ample time to teach the required skills was seen as necessary.

> *We need changes in our timetable because it does not help the students to explore things for themselves...So we need to change our timetable to have ample time to teach them these skills* (T4, session 1).

Another tension arose between the rule and the object regarding the norm of positioning schools based on their performance in national examinations. Teachers believed that this goes against the spirit of student-centred teaching, as they are forced to teach students to the test to improve their schools' positions on the examination league table.

> *Because of the league table, it has been a problem for us when we are teaching, and so that is why some of us have been teaching to the test* (T1, session 1).

Language of instruction: A major tension experienced by the teachers is related to the language of instruction. In Ghana, English is the medium of instruction for teaching, including science. However, students often struggle to understand the concepts taught and struggle to express themselves in English when learning science.

> *I have realised that most of the things we teach are related to students' environment, and they see them every day, but they have scientific terms that make it difficult for them to understand in English* (T1, session1)

Furthermore, students' inability to understand science is attributed to using English as the medium of instruction.

> *When you ask them (students) if they understand, they will give you a chorus answer 'yes, sir,' but at the end of the day, some will tell you that they did not understand the way it was explained (because of the use of English language)* (T3, session 1)

This is an example of contradiction in the activity system, which created a double bind (Engeström & Annalisa, 2011) for teachers facing pressing and equally unacceptable alternatives to using either the local language or English to teach science.

6.3.4 Contradictions between the division of labour and object

Another secondary contradiction in the activity system of the teachers was found between the division of labour and the object. The curriculum demands students to actively participate in the teaching and learning process to construct their own knowledge. However, teachers admit that they end up doing most of the work, and students are just passive recipients of knowledge without any active involvement in teaching, learning, and assessment.

> *So based on the discussions, I have seen that students should be made to take an active part in the teaching and learning process, including assessment* (T2, session 2).

One reason why teachers tend to do all the work is their focus on students passing their examinations, which leads them to provide all the information they deem important without actively involving the students.

We were more concerned about exams in our teaching, so doing a lot of things for them (T3 session 2).

Another reason for not involving students in the lesson as demanded by the curriculum is the lack of materials.

Also, because we are not getting materials, we thought we could not involve our students in the lesson (T4, session 2).

Teachers express difficulties in implementing the curriculum and find themselves in a state of dilemma where, on the one hand, they want to change their practice under the new curriculum. Still, on the other hand, they feel that change is impossible.

This chapter has looked at the contradictions in the teachers, activity system and how they expanded their learning to bring about new practices. The next chapter will examine the teachers' agency in transforming the practice.

Chapter 7: What *Matters* to Students - A key to the Teachers' Transformative Agency

This chapter of the thesis presents the findings relating to the participating teachers' transformative agency. It is arranged in five sections. Section 7.1 introduces the chapter providing an overview of it. Section 7.2 presents *what matters* to students while Section 7.3 addresses how *what matters* to students became a resource for teachers' practice. Section 7.4 discusses the teachers' transformative agency and Section 7.5 deals with how they addressed the contradictions in their activity system.

7.1 Introduction

The previous chapter has shown explicitly that participating teachers expanded their interpretations and actions in bringing pedagogical changes in their practice in the implementation of the new science curriculum. The changes emerged in four key areas in teaching practice: questioning, assessment, teaching beyond the classroom, and designing various activities. The contradictions in the activity system mainly drove these changes. It must be noted that the changes before and after the intervention are not labelled as teachers-centred and student-centred respectively. As argued in the literature review (Chapter 2), this study takes a complex and dynamic view of teaching and does not categorise pedagogy into the binary of teacher-centred and student-centred. The emerging pedagogy is a complex and dynamic approach of teacher and student-centredness where there is an interplay of both student and teacher-centred methodologies acknowledging the complexity of the classroom to which the teachers must flexibly respond.

This chapter provides a theoretical explanation, based on data analysis, of what enabled the participating teachers to bring about the change in their practices and how they developed the agency in the transformation process due to the contradictions they faced.

This chapter addresses the following research questions:

1. How can teachers' understanding of *what matters* to JHS students be used as a resource to expand interpretations and possible actions as they meet the demands of teaching the new science curriculum?
2. How does agency emerge as teachers collaborate on implementing the new science curriculum?

The main argument from this chapter is that '*what matters*' to students became 'common knowledge', mediating teachers' agency as they transformed their pedagogical practices.

As previously mentioned, the emerging pedagogical change is a dynamic move between teacher-centred and student-centred pedagogies where the teachers use *what matters* to students as a resource to actively engage students in the teaching and learning process. As indicated in Chapter 5, I used *what matters* in the present tense to capture the lasting quality of how people relate to an object.

In what follows, I identify *what matters* to students (7.2) and highlight how they were used as resources by the teachers to change their pedagogical practice (Section 7.3). I then trace the teachers' transformative agency using two theoretical concepts: the germ cell and forward anchoring (Section 7.4). I conclude the chapter by looking at how the contradictions in the teachers' activity system were resolved (Section 7.5).

7.2 *What matters* to students

As explained in Chapter 3, this study draws on Edwards' (2012, 2020) concept of common knowledge to identify and understand *what matters* to students and how teachers can use it as a resource to transform their practice. Common knowledge is defined as the shared understanding of *what matters* to others in order to shape practice (Edwards, 2020). Common knowledge has been suggested as a crucial second stimulus enabling professionals to work with clients (Hopwood & Edwards, 2017).

In this study, *what matters* to students which is the motive that shapes their learning of science was considered to have the potential to transform teaching practice. It was considered a second stimulus to direct the teachers from the problem to a solution. Therefore, *what matters* to students was solicited through six student focus groups and the teachers' personal interaction with students (see Chapter 4). Three themes were identified in the analysis of students' focus groups in relation to *what matters* to students. These were:

- support and attention
- engagement and interestedness
- applicability and connectedness.

7.2.1 Support and attention

One key aspect of *what matters* to students from data analysis is support and attention. The key ideas in this theme relate to students getting support from teachers and peers, receiving individualised attention from teachers and engaging in collaborative activities.

According to the students, teachers must create a supportive environment where students feel valued and motivated to succeed in their learning. The participating students expressed *what* *matters* to them: the need for teachers to pay individual attention to them, understanding their challenges and providing personalised support. This will enable teachers to adapt teaching to students' needs (Bremner, 2021).

In addition to support from teachers, the students also expressed a need for opportunities to receive support from their peers as something that matters to them. Central to this perspective is the notion that getting support from their peers enhances their understanding and gives them a sense of belonging and confidence. They mentioned that sometimes they do not fully understand the concepts taught by teachers and would feel more comfortable approaching their friends for assistance. They emphasised the importance of peer interactions and how their friends can help them grasp difficult concepts, as they would be able to explain things to them in a way that they understand well.

> *I like to get support from my classmates because sometimes we do not get the understanding from our teachers, but we can go to a friend to help us to understand because they are our friends, we can ask them anything* (S3-FG1).

Interestingly, another student in a different focus group felt they did not get that support from their peers because the teachers may consider that as time-wasting "*I would like to get support from my mates, but the teacher will think we are wasting his time*" (S2-FG5). The students expressed a desire to receive assistance from classmates yet perceived a reluctance among teachers to facilitate such interactions due to concerns about time management. This contrasting view highlights the potential barriers to seeking support from peers within the science classroom, where teachers prioritise curriculum coverage over students' meaningful interactions (Agbene et al., 2023; Mabula, 2012; Qhobela & Moru, 2014). To address their concern about the lack of peer support, the students suggested that teachers should allow other students to answer if a student asks a question.

Most students expressed the desire for smaller class sizes in their science classes, believing it would enable the teachers to provide individual attention. However, they acknowledged the reality of crowded classrooms, with some having over 60 students. Large class size has been a major challenge to teaching science in Africa and Ghana in particular, where teachers are unable to implement certain pedagogies which are considered student-centred due to the large number of students in one classroom (Humprey-Darker et al., 202; Plessis 2020, Brobbey et al., 2020). Class size came up because *what matters* to students is support and attention - and they thought that large class sizes were often a barrier to attaining such support and attention. In such situations, the students believed that group work would be a suitable solution.

Collaborative learning emerged as a significant idea that matters to the students across all focus groups. The students emphasised the need for group activities during teaching and learning as they allowed them to share ideas and provide support for their peers.

> *In the class I want the teacher to put us into groups during teaching and learning to share ideas that can help us to get support from our mates and get more idea about what we are learning. I would want the teacher to polish what we have learn and add more to it* (S1-FG5).

Another student from a different school expressed a similar view by saying

> *If I am giving that opportunity [to teach science], it is not always that I will stand in front of the students and be lecturing them; sometimes I will put them into groups to go and do research and presents the findings to whole class. I will then add to what they have presented* (S3-FG6).

For the students, peer-to-peer interactions are very important as they facilitate collaborative learning, where they can teach and learn from each other. They believe it also provides opportunities for high-achieving students to take on leadership roles and share their knowledge with their peers. For most of these students if they were allowed to teach science, collaborative activities would be high on their teaching practice. "*I will put the students into groups, because some students are very good and so through that group interaction, they will teach their mates*" (S3-FG4). These ideas by the students reflect their recognition of the value of group-based learning activities and how they facilitate the sharing of ideas and gaining of mutual support thereby enhancing their learning outcomes. By providing opportunities for students to work together in groups, they can leverage their peers' diverse perspectives and insights, thereby enriching their understanding of the material and fostering a sense of collective ownership over the learning process.

7.2.2 Engagement and interestedness

The main ideas that emerged from this theme about *what matters* to students are active participation in lessons and engaging and interesting lessons.

An important idea that emerged from the students' perspectives about *what matters* to them is the active participation of students in science lessons. *What matters* to the students is not to be passive listeners in class but active participants in the teaching, learning and assessment processes. They believed that allowing students to actively engage in the lesson by asking and answering questions creates an atmosphere of engagement and involvement. Furthermore, when they witness their peers being acknowledged and appreciated for their contributions, it serves as positive reinforcement and encourages more students to participate. Therefore, active participation and contribution in the classroom were seen as key factors in fostering students' interest in science lessons.

> *For me what make science lessons interesting to me is when everybody contributes in class by asking and answering questions because someone may be there who does not*

know but when he/she sees that everybody is saying something, and they are being clapped for it will also motivate that person to say something. That makes the lesson interesting (S2-FG1).

Students explained that active participation matters to them because they believe it promotes understanding and critical thinking. They emphasised the importance of allowing students to engage in discussions and contribute their ideas during lessons. These reasons made active engagement and interest key things that matter to students as shown in a student's comments in focus group 5; "*we should do more discussion; students must be given the opportunity to contribute in lessons and if it is wrong the teacher can correct it*". Another student made a forceful statement in focus group 2 by saying "*yɛ pɛ sɛ yen so yɛ ka bi*" which literally means we also want to talk in class. This is because the students believed they had ideas about the topics taught in class but were not allowed to express them. "*It [science teaching] should be in discussion form, most students have ideas about the topic, but we don't have the chance to express our views in class*" (S2-FG5).

One key suggestion put forth by the students to enhance their active participation in class is for teachers to provide them with the topic ahead of time, allowing them to conduct their own research. This way, they can come prepared and actively contribute to the class discussion.

> *What I want is, if today we have learned about the environment and tomorrow will learn about the solar system, I want the teacher to tell us that tomorrow we will learn something about the solar system so when we go home, we should study that. When we do that and we come to school he can allow us to share what we know about it* (S1-FG1).

Another aspect that matters to the participating students is to experience engaging and interesting lessons. One key aspect that matters to students in achieving this is the inclusion of demonstrations and practical activities in the science curriculum. The students expressed that practical lessons are essential for providing them with hands-on experiences and making the subject matter more engaging.

> *When the teacher adds practical to the lesson it becomes interesting for example if we are learning about conditions necessary for rusting, we expect the teacher to bring materials to demonstrate practically these ideas because for some people just talking will not let them to understand…".* (S2-FG5)

The students complained about the predominant theoretical approach to teaching science, which focuses on teachers imparting information rather than involving them in practical lessons. They expressed frustration with the emphasis on memorising terms, definitions, and information without the opportunity to engage in experiments or practical tasks. "*When you go to most schools, science is more about books, learning terms or definitions, but they don't teach us how to do practical things or experiments*". (S2-FG4). The students viewed science as a subject that requires active engagement through practical applications rather than a mere accumulation of knowledge from textbooks.

The interesting thing is that the students showed an appreciation of the challenges their teachers go through in teaching science due to the lack of resources. They expressed a desire for their teachers to take them to the laboratory for practical lessons, but they acknowledged the absence of laboratories and the lack of resources. "*I think science lessons need to be practical; some topics need to be experimented but the schools, let me take our school for example, do not have the resources so that make the understanding of science difficult*". (S2-FG3).

An important aspect of *what matters* to students is for science lessons to go beyond the traditional classroom setting and incorporate experiential learning. They value exploring the environment and utilising the resources available outside of the classroom to enhance their understanding of scientific concepts. By taking the teaching of science beyond the confines of the classroom and directly engaging with the environment, they believe that it can become more interactive, memorable, and enjoyable.

> *If I am teaching science and the things relates to the environment, I will take them [students] out. For example, if I am going to teach living things, I will take the students out to observe some of these things outside and then I bring them to class to discuss what they saw* (S2-FG6).

7.2.3 Applicability and connectedness

Applicability and connectedness also matter to students. This refers to the application of knowledge to real life, doing well in science, experiencing lessons that can connect with students and using the local language.

The students articulated the importance of being able to apply the knowledge they acquire in science to solve real-world problems as a key thing that matters to them. They want to have a deep understanding of scientific principles and ideas that will enable them to apply their knowledge in various contexts. They expressed a desire for science to be relevant and useful in their lives, leading to developing inventions and technologies that can benefit society. They value the practical application of science and its potential to bring about positive changes and improvements. The students believe that it is not just about acquiring knowledge but also understanding and using that knowledge in practical ways. "*It was not just getting the knowledge but to be able to understand and use the knowledge that is important because we all know science talks about things around us so when we get the knowledge, we can apply it in our daily life*" (S2-FG1).

When discussing why interest matters to them in science lessons, students discussed applying the knowledge they learned to real-life situations. They shared various examples of how scientific knowledge was beneficial and practical in their lives.

> *There are so many things we learn in science which relates to our life which science can help us for example something like CPR(cardiopulmonary resuscitation), it is a science idea we learn in school so when someone is in difficult situation, we can use it to revive his/her life* (S2-FG4).

Another student shared how happy she was when she was able to apply the knowledge of science in school to solve societal problems. "*What made me happy is that the science I learned enabled me to solve a problem in the society by reducing the bleeding of mosquitoes which brought about the reduction in the cases of malaria in my area*" (S3-FG5).

One other thing which matters to students that connects with the theme of applicability and connectedness is doing well. For some students, doing well in science entails more than just academic achievement of getting good grades in examinations. It involves the ability to apply knowledge practically, contribute to societal needs, and make informed decisions based on scientific understanding. One student indicated "*At the moment I have not been able to use my science knowledge to do anything meaningful for the society so doing well will be the understanding I have in science and be able to get high marks in exams*". (S3- FG5). Another student in a different focus group said,

> *personally, doing well means I am able to apply my knowledge in real life, for example when we were learning water, our teacher said water is a natural remedy for headache so it is not every day that I will use paracetamol to treat headache. So, if I am sick or my mother is sick, I will tell her to use water instead of paracetamol because it has its own side effect* (S2-FG1).

Moreover, having science lessons that are connected to their personal experiences, future career and their environment also matters to students. For some of the participating students, teaching of science should go beyond simply teaching textbook material but rather finding time to understand *what matters* to them especially their future careers so that teacher can provide guidance and advice and support them on how to achieve their ambitions.

> *It not always that teachers should teach us books stuff, they must find time to know what is important for us especially our future careers so they can advise us and tell us more information about what we want to do [in the future] and how we can get to our ambition when they are teaching* (S1-FG2).

The students therefore called on teachers to create opportunities by setting some time to listen to them as they share their challenges in the science class so that teachers can better understand their needs in order to provide a supportive environment for their learning.

> *Most teacher do not do that; like sitting their students down to find out what is important to them… so if one day the teacher comes to sit us down and listen to us as we share our problems it will be helpful* (S1-FG4).

Another aspect that matters to students is for teachers to incorporate real-world examples or relate practical applications of science topics to their interests and aspirations to make science relevant and engaging. This is because they enjoy topics that relate to their future careers. For example, if a student's future ambition is to become a doctor, they believe that teachers incorporating medical examples or scenarios and discussing relevant scientific concepts can make their learning meaningful and enjoyable. As indicated by one student

> *I am interested in mining engineering, so if the teacher is teaching science and he/she can relate the topics to minerals and towns in Ghana where mining is done, I will be*

> *happy because I know Ghana is one of the top mining countries so I should be able to have the knowledge here to apply in my own country* (S2-FG4).

Another student in a different focus group shared how he enjoyed a science lesson which was related to his ambition.

> *I love technology especially computers so I was happy to hear how science can be applied in technologies like computers …So I was interested in what the teacher was teaching and especially when he was relating it to what we can do in the future…*(S2-FG6).

For the students, the key to connecting lessons to their personal experiences is using both the local and English languages in teaching science. This is because the students find it difficult to contribute in class even if the lesson is related to their personal experience because of the use of the English language. "*Somethings are better understood in both English and Twi [a local language]. The writing should be done in English but some of the explanation must be in Twi*" (S1-FG6).

This section has focused on *what matters* to the participating students. It was found that *what matters* to students relates to three key themes. The first theme was support and attention, where students wanted to get support from teachers and peers, receive individualised attention from teachers, and engage in collaborative activities, engagement, and interest. The main ideas that emerged from the second theme of engagement and interest were active students' participation in lessons and having engaged and interesting lessons. On the third theme of applicability and connectedness, *what matters* to students is applying knowledge to real life, doing well in science lessons that can connect with students, and using the local language. I will now move on to how teachers' understanding of *what matters* to students became a resource for their practice.

7.3 How *what matters* to students became common knowledge and second stimulus for the teachers

The previous section has outlined the key things that matter to students. This section will continue to elaborate on how *what matters* to students became common knowledge for the teachers in their pedagogical change. It shows how teachers came to understand *what matters* to students and used that knowledge as a resource to drive expansions of the object and actions relating to it. In this section, I present how the teachers came to know *what matters* to their students, articulate the teachers existing and new knowledge about *what matters* to them, and finally show the key ideas about *what matters* to students that became a resource for transforming the teachers' practices.

7.3.1 How the teachers came to know *what* matters to students

The students were explicit in articulating *what matters* to them. These ideas about *what matters* to students were obtained from the six focused groups that I organised. Summaries of these focus groups were presented in the Change Laboratory surfaces of Session 3 (as a lower level of abstraction, like mirror data) - function as first stimulus (problem identification) and second stimulus (as a tool in agency) when it became common knowledge - taken up in a particular way. Furthermore, teachers were also encouraged to find out what matters to their students. During the Change Laboratory sessions, teachers had access to written summaries and excerpts of student voices from the focus groups. They also shared their own findings, which aligned with the ideas expressed in the focus groups. Therefore, understanding *what matters* to students was derived from the focus groups and the teachers' interactions with their students. Through these two sources, teachers developed a shared understanding of *what matters* to their students, and this became common knowledge. This was very asymmetric in manner as there was no opportunity for both students and teachers to meet and share *what matters* to them. However, common knowledge was built when *what matters* to students was revealed and heard by the teachers.

While the teachers were aware of some of the things that matter to students, they did not necessarily consider them in their teaching practices. Other insights came as surprises to them, as they had not perceived them as important to students. For instance, ideas such as teaching science beyond the classroom, involving students in the assessment process, engaging students in projects and presentations, and connecting science to their future ambitions were unexpected for teachers, as they had not previously recognised their significance to students. One teacher said, "*I am surprised about the importance of relating science teaching to their future careers. Most of the time, we are not interested in those aspects... but now we can see that they matter to the students*" (T4 CL4).

The knowledge and discussions surrounding these ideas that matter to students brought about a new understanding, leading to fresh interpretations and new actions as was explained in the previous chapter. It was therefore not a simple “students said so we do it” but rather a process of expanding the object, relating those understandings of *what matters* to students to the purpose of teaching science under the new curriculum. Thus, common knowledge developed by the teachers mediated responsive professional actions to attune their practice with *what matters* to their students.

7.3.2 Aspects of *what matters* to students that teachers took up as a resource for transformation

Some ideas that matter to students became a resource that supported the emergence of the participating teachers' agency as they worked on resolving contradictions and changing their practices. The teachers dedicated time to exploring ways to actively involve students in their lessons, leading to an enriched understanding of the importance of involving students not only in the learning process but also in assessments. As previously highlighted, this newfound understanding became a significant aspect of the teachers' curriculum implementation efforts. In other words, their explorations of *what matters* to students expanded the object, producing new interpretations that opened up new possibilities for action. The teachers adopted new actions such as posing higher-order questions to students, engaging them in debates and discussions, and providing opportunities for students to generate their own questions based on the common knowledge which shaped their practice.

One crucial idea that matters to the students, which teachers reported to have positively impacted student participation in lessons, is providing them with foreknowledge of the upcoming topics to be covered. The teachers reported on how this approach allowed students to conduct their own research and prepare for the lessons, enabling them to contribute effectively. This shows how teachers created space in their teaching where children's motives were used as resources to ensure active participation in the lesson.

> *I want to involve them (students) in the lesson through discussion, by tapping into their thoughts. I provide them with foreknowledge of the upcoming topic and sometimes ask them to explore specific aspects before coming to class. This way, they can actively participate and feel like they are contributing to the construction of knowledge* (T6, Interview 2).

By giving students a preview of the topic, the teachers aim to engage them in meaningful discussions, encourage their active involvement, and create a sense of ownership in the learning process. Students were provided with the opportunity to research and familiarise themselves with the content beforehand, enabling them to make valuable contributions during the lessons.

Resource mobilisation and utilisation was another significant area in which *what matters* to students became a resource for the teachers' transformative agency. As the teachers became aware of the importance of practical lessons for students and their desire to explore beyond the confines of the classroom, efforts were made to address these concerns. New ideas for mobilising and utilising resources were discussed, aligning them with *what matters* to students. One such idea was teaching science beyond the classroom, which involved taking students out of the classroom to utilise the resources available in their immediate environment. Students were also encouraged to bring materials to class, enhancing their learning experiences. These ideas received considerable attention during discussions and subsequently led to actions by the teachers as seen in the comments of T2 in the second interview. This indicates how common knowledge informed the teachers' classroom activities to ensure students are engaged in the teaching and learning process.

> *For example, a few days ago, I was teaching about farming tools. In the past, I would have simply lectured them or, at best, asked them to mention some tools. However, this time, I asked them to bring some farm tools, and I also brought some to the class for them to identify and demonstrate how they are used. The students themselves conducted the demonstrations* (T2, interview 2)

The lesson plans developed by the teachers afterwards intentionally incorporated ideas that matter to students, demonstrating a deliberate effort to include elements that actively involve students in achieving the lesson objectives. Below is sample of a lesson plan shared by T3 in during Change Laboratory Session 5.

> *Yes, I will be teaching energy in week 11. In the introduction, pupils will use* ***think-pair-share*** *to revise the forms of energy by given at least four forms of energy. Pupils will be brainstormed to come out with the meaning of kinetic and potential energy through* ***discussion.*** *Pupils will be given the chance to* ***select their own group members of five to discuss and explain energy conversions****. Each group will be given a nail, hammer and wood. They will be instructed to hit the nail into the wood with the help of the hammer and discuss the energy conversion in the activity. After that different energy conversion situations will be given for each group* ***to select one to analyse*** *and come out* ***to present*** *the energy changes in the scenario. The lesson will be concluded by asking students some oral questions* (T3, CL5).

Here we see a deliberate effort on the part of the teacher to actively engage students in the lesson and to put them at the centre of the activity by emphasising on what they will do rather than what he will do.

The teachers described how they plan their lessons by considering *what matters* to students, ensuring that student-centred approaches are integrated into their teaching practices. They recognise the significance of incorporating ideas such as active student involvement, collaboration, projects and presentations, practical lessons, students bringing materials for lessons, improvisation, and providing students with more opportunities in the assessment process. This shows how *what matters* to students influences teachers' pedagogical decisions.

The teachers strived to consistently practice and incorporate ideas that matter to students, recognising the value of ongoing collaboration, project-based learning, practical lessons, engaging students in the assessment process, and other student-centred approaches. These considerations ensured that teaching remains responsive to *what matters* students in creating a more engaging and effective learning environment to meet the demand of the new curriculum.

The teachers engaged in discussions and embraced a student-centred approach to teaching based on *what matters* to students, which they believe provided them with a deeper understanding of how to effectively teach the new curriculum. Through these discussions, the teachers gained new insights into the curriculum, specifically in relation to *what matters* to students, and this understanding guided their implementation of the curriculum to better meet the needs of their students. Common knowledge was therefore used by the teachers as a resource for pedagogic engagement in meeting the demands of the new curriculum.

This section has shown how the teachers used *what matters* to students a resource to drive the expansion of the object creating a complex understanding and actions. It demonstrates how teachers' understanding of *what matters* to students in student-centred teaching provided them with strong roles and confidence to align their teaching with *what matters* to students. Thus, teaching was seen as a joint action between the teachers and students on the shared object of implementing student-centred pedagogies mediated by common knowledge of *what matters* to students.

7.4 Transformative agency by double stimulation (TADS)

In the previous section, I presented what I found about *what matters* to students and how it became a resource for the teachers' pedagogical transformation. In this section, I trace how the participating teachers developed agency in transforming their practices (see Coffie, et al., 2025). I base this on Sannino's (2015) TADS model. Within the wider framework of TADS, I will focus on two concepts that reflect recent developments in research using the TADS model:

the germ cell, and forward anchoring described in detail in the conceptual framework (see Chapter 3), which enabled the teachers to resolve the contradictions in their activity systems and addressed the associated conflict of motives.

I will now briefly recap key aspects of this framework to set the stage for the ensuing discussion. A problematic situation causes a paralysing conflict of motives that forms the first stimulus. To address the problems, people resort to neutral materials (secondary stimulus) and fill them with meaning to form an auxiliary motive to enable them to break out of the paralysing situation (Sannino, 2022). Implementing a student-centred curriculum in a challenging environment of lack of resources and crowded classrooms created a paralysing situation for the science teachers as they faced the conflict motive of teaching more engagingly or maintaining their old transmissive approach (I will discuss this in detail later). To address this problem, teachers need an auxiliary motive to help them practice pedagogies that meet the demands of the new curriculum. The purpose of this section is to show how teaching in ways that align with *what matters* to students became the auxiliary motive that enabled the teachers to overcome the challenges. The next two sections will trace the participating teachers' transformative agency from the germ cell approach and forward anchoring.

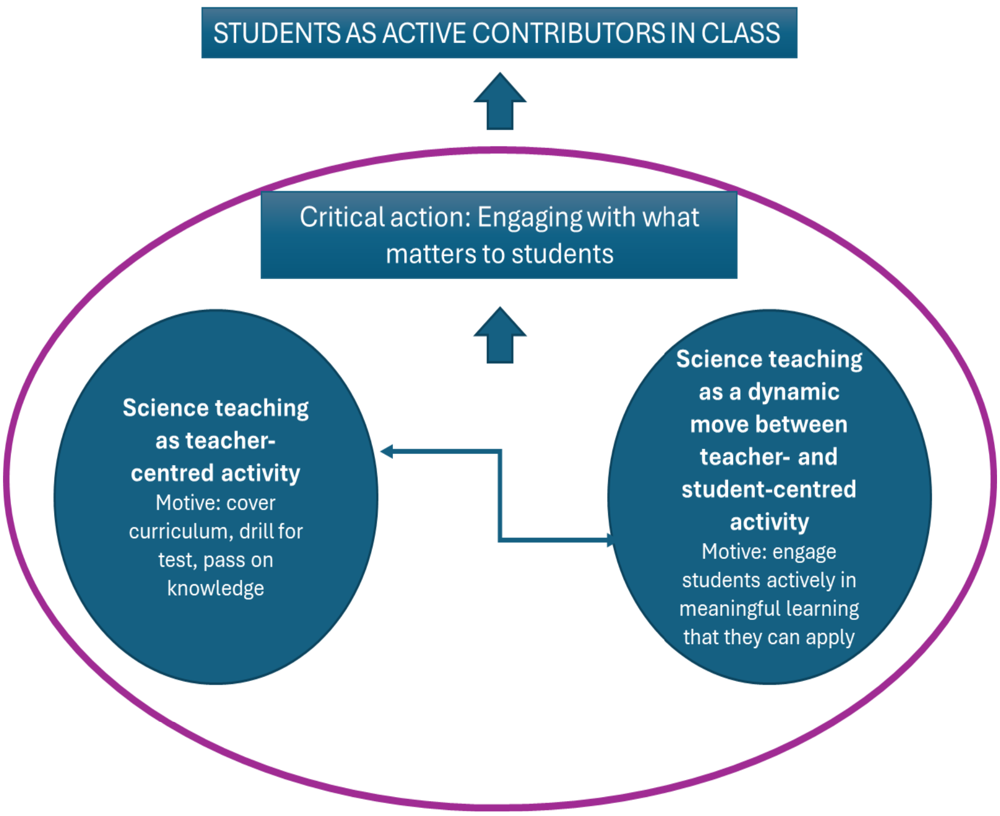
7.4.1 Transformative agency by double stimulation: The germ cell approach

It has been shown in the previous chapter that the teachers had to overcome some key contradictions as they sought to transform their practice in implementing the science curriculum in a student-centred manner. These contradictions were mainly secondary and were found between the tools and the object, the subject and the object, the rules and the object, and the division of labour and the object (see Chapter 6). The various systemic contradictions identified through the Change Laboratory were not distant from teachers' everyday experiences. Rather, they were present in their everyday work and were experienced as conflicts of motives that arose when planning and delivering lessons.

The transformation in the participating teacher's activity system can be understood using the concept of the germ cell, which serves as "seeds for transcending and overcoming contradiction" (Engeström, 2020, p.36). The germ cell is the smallest and simplest unit of a complex totality, enabling one to ascend from the abstract concrete (Engeström, 2020). In other words, the germ cell enables one to move from abstract ideas to concrete manifestations.

Figure 7.1 diagrammatically shows the internal contradiction of the germ cell for the teachers in the implementation of the science curriculum. Traditionally, teachers were expected to have control over everything that happened in the classroom, with students as passive recipients of knowledge. This made it difficult, if not impossible, to actively involve students in the teaching and learning process.

Figure 7.1 The Germ Cell for the Science Curriculum Implementation



I will discuss the conflict of motives that the teachers faced in trying to transform their practice, the critical actions they took in overcoming these conflicts of motives and the key concept that emerged from their actions.

Conflict of motives: Recapping from the theoretical framework (see Chapter 3), conflict of motives is defined as two alternative motives requiring a deliberate choice (Sannino, 2015). It plays an important role in transformative agency as it is the means through which individuals take volitional actions to change their situation (Morselli & Sannino, 2021). It is important to trace some of the conflicts of motives the teachers faced in transforming their actions. The teachers were torn between teaching in a more engaging manner that meets the demands of the new curriculum or maintaining the status quo of teaching in a very transmissive manner where students are passive participants. The teachers experienced this as a conflict between teaching science as a teacher-centred activity (motives to cover curriculum, drill for tests, and pass on knowledge) and as a dynamic move between teacher and student-centred activity (motives to engage students actively, in meaningful learning that they can apply, while attending to individual difference). See Figure 7.1.

The teachers had the motive to teach as the curriculum demanded but felt constrained by the lack of resources, resulting in abstract teaching approaches. This frustration is expressed by T3 in the first session of the Change Laboratory: "*As a facilitator, you want to deliver a lesson (in a student-centred manner), but you don't have teaching and learning resources, which makes the lesson very difficult to deliver...in order for the children to understand*" (T3, session 1). Other participants agreed to this point. For example, T4 also shared how he delivers his lessons in an abstract manner, explaining concepts and having students copy notes from textbooks by saying "*Oh I just explain things to them (students) and copy notes from the textbook for them* *to write which is very abstract*" (T4 session 1). This abstract teaching approach created disinterest in science among students because the lesson failed to account for student-centred pedagogies that interest students. "*I was focused on the lecturing method and most of the students were not interested in the lesson, so I just had to finish my topic and go…*" (T6, session1).

Furthermore, the motive for the teachers to engage in practical lessons conflicted with the motive to finish the syllabus on time, as they were constrained by a tight timetable that they believed did not allow for the freedom to engage in practical activities. T2 explains "*You see, we want to finish the syllabus, so we overlook some of the practical things*". (T2, session 1). Apart from ignoring the practical aspect of teaching science because the teachers want to complete the syllabus on time, active student engagement was affected by the teacher's bid to cover the curriculum on time. Thus, the teachers' motivation to cover the curriculum on time also hindered active student engagement in science lessons. The teachers felt that engaging students actively and completing the curriculum on time was impossible. For example, T4 questions the feasibility of actively engaging students while also completing the syllabus on time. "*I am looking at active student engagement and completing the syllabus on time; how feasible can it be?*" (T4, session 3).

Moreover, the motive for completing the syllabus did not allow teachers to pay attention to individual student differences. T4 states "*in our schools, we don't even do that. We just give them the same task, and they all do it, which I believe does not help. We need to pay attention to individual differences*" (T4, session 3).

The teachers expressed a motive to cover the syllabus and prepare students for examination, which led them to enact teaching as passing on knowledge. They also discussed motives, aligned with the curriculum, of helping students apply scientific knowledge to real-world problems. However, they experienced these motives as conflicting with one another, as satisfying the former left them feeling they had no time to do the latter. T1 explained: "*So I have to focus my teaching on examination, and in doing so, the students can't do anything because my focus is on how they can write and pass the exams*" (T1, session 1). The statement indicates a conflict of motive for the teacher whose primary aim is preparing students for exams and ensuring that they can write and pass as against other important aspects of the curriculum, such as application of knowledge, critical thinking, creativity, problem-solving and so on which the students cannot possess. T1 further explained that he would concentrate on the students who can perform well in exams, while neglecting those who are struggling to keep up with him saying;

> *as I indicated earlier, we are forced to teach to the test because of the [exam] league table. If I find out that two or three students are not concentrating, because I want most students to pass, I will leave them behind without attending to them. Because they will be wasting my time. I have to leave them and concentrate on those who are serious so that we can do well on the table* (T1, session 1).

The exams-focused teaching means that teachers are not paying attention to individuals, especially the weak ones. The motive for teachers to attend to individual differences thus conflicted with their motive to concentrate on good students who can perform well in exams.

In these conflicts of motives, the teachers faced challenges in aligning their practices with the curriculum's student-centred approach. However, these conflicts also presented opportunities for transformative agency to emerge as teachers navigated and transcended these conflicts of motives in their efforts to transform their teaching practice.

Critical Action: the germ cell: In breaking away from their established (teacher-centred) activity, towards a more dynamic activities aligned with the demands of the new curriculum, teachers had to establish new actions. These can all be linked to a critical action within the germ cell model that transcends and overcomes the conflicts of motives. For these teachers the critical action was "engaging with *what matters* to students" (see Figure 7.1)

When introduced in the workshop, the concept of *what matters* to students shifted the focus of the teachers' discussions and conversations and enabled them to address the problems in their activity system. They began to think and talk more deeply about things that matter to the students and considered what the implications were for their teaching. This idea became central in the Change Laboratory sessions and guided their understanding and implementation of the new curriculum.

> *It* [concept of *what matters* to students] *has helped me to realise that the demands of curriculum centres on what matters to the students, and I should consider that which motivates the students to also involve themselves in the lesson as expected* (T2, interview 2).

This is corroborated by other participants in the Change Laboratory sessions. For example, T3 also indicates that

> *I am implementing key ideas that matter to students to meet the demands of the new curriculum this time round. I am now giving students a choice and giving the pupils a chance to set their own questions. I am not teaching in an abstract way as I used to by bringing resources in my teaching. I am allowing students to participate in class by collaborating with others using think-pair-share. So, I think the change is about focusing on the children, knowing them and devising lessons around what matters to them* (T3, session 6).

This shows an increasingly complex forms of engaging with *what matters* to students in the teachers' practice. It led to pedagogies that disrupted the binary of teacher and student-centredness. In other words, there was a dynamic move between teacher-centred and student-centred teaching, with a strong role for the teacher and active participation of students in delivering curriculum in a manner that considers *what matters* to the students.

The teachers indicated new understanding of the curriculum based on *what matters* to students and believe it helped them to implement the curriculum in a way that meets the needs of their students.

> *There has been a lot of improvement in our understanding of the new curriculum compared to when we started the new curriculum. Getting to know what matters to student has brought a lot of improvement in our understanding and practice in the new curriculum. This time around I understand the curriculum as engaging with what matters to student than what matters to myself. I am engaging in a lot of practices like engaging in project, group works, presentations, etc but last term I was not doing that.* (T2, session 6).

This shows how understanding *what matters* to students afforded the teachers new interpretations and actions (Edwards, 2005) in meeting the demands of the new curriculum.

Students as active contributors in Class: Teachers implemented critical action (engaging with *what matters* to students) and other concrete solutions in diverse ways. This enacted a new concept of “students as active contributors”. This is referred to as ascending from the abstract to the concrete (Engström, 2020). The new concept of “students as active contributors” does not mean there were no teacher-centred activities in the classroom. In fact, this new concept involves a dynamic move between student and teacher-centred teaching with both aligning with *what matters* to students. Ways in which students became active contributors included: finding information by themselves and making presentations; taking active part in class discussion; asking and answering questions in class, setting questions for examination; constructing their own knowledge, awarding marks in presentations, and marking their colleague's work (Refer to Chapter 6). These activities enabled students to be "responsible for their own learning" as T6 puts it.

T2 provides a good summary of the outcome of engaging with *what matters* to students which illustrates the complex and dynamic pedagogical relationship between teacher-centredness and students-centredness that emerged from intervention.

> *If you walk into my class right now you will not see doing most of the talking, you will see that students will be actively involved in the teaching. You will see more student-teacher and student-student interactions as compared to previously* (T2 Interview 2).

T4 provided a vivid account of how his ascent from the abstract to concrete through active students' participation has generated students interest in his science lesson.

> *Students now generate more interest in my lesson and take active part in it. This time around instead of talking more, the opportunity is given to student to participate in the lesson based on the fact they want to be involved. Yes, so my teaching has changed compared to before we started the workshop…But this around the students are the main focus in the lesson, my lessons are pupil centred. Sometimes pupils tell me today your lesson was interesting because of the approach I use by engaging them, allowing them to come out with their own answers. One interesting thing I have observed is that student now rush to come and call me the moment it time for science because they enjoy it and when time is up you will see that they are not happy* (T4, Interview 2).

This section has provided evidence of how the teachers used *what matters* to students to expand their interpretations and actions in implementing the science curriculum. In what follows I trace the agency of the teachers through TADS using forward anchoring.

7.4.2 Transformative agency by double stimulation: Forward anchoring

As has been shown in the previous chapter, the teachers showed agency in transforming their situation during the Change Laboratory sessions. Following Sannino (2022), TADS can be used to trace both the means and outcome of these teachers' expansive learning and its connection to their unfolding transformative agency.

In this section, I explain how I used Sannino's (2015) model of TADS to understand the participants' transformative agency. Specifically, it will be based on her recent idea of forward anchoring in the model, which enables vessels to move forward when they are stuck (Sannino, 2022), explained in detail under the conceptual framework (Chapter 3). Kedge anchors are used as metaphors to explore the function of second stimuli in agency formation (Hopwood et al., 2022; Sannino, 2022). As explained in the conceptual framework, Sannino (2022) identifies three sets of actions that are essential in forward anchoring, which are summarised in Table 7.1.

Table 7.1 Essential Actions in Forward Anchoring Using Kedge Anchors

Actions	Meaning
Throwing actions	Actions that involve searching for suitable ground
Taking over actions	Actions that enable the crew to gain control over the situation
Breaking out actions	Actions that enable the vessel to be pulled out of the problem area

The participants in the study were stuck with their conventional teaching pattern, feeling that it was impossible to transcend the status quo, where classroom activities were dominated by teachers with students as passive recipients of knowledge. Throughout the Change Laboratory sessions, the participants explored, expanded, and implemented different ideas considered kedge anchors, which were instrumental in supporting the teachers' transformative actions.

Some of these ideas were concrete actions or practices they developed, while others were statements that changed the direction of their actions and thinking. What follows is a presentation of the five key anchors combined as multiple-second stimuli that enabled the teachers to address the problems and the conflict of motives they faced. These anchors were:

- Improvising learning materials
- Designing lesson planning templates
- Collaborative learning activities
- Attending to individual differences
- Active student engagement does not depend on material resources.

7.4.2.1 Improvising learning materials

The lack of resources triggered a paralysing conflict of motives for teachers as they felt unable to teach more engagingly due to lack of resources. In trying to cope with this problem, the participants began to search for solutions with statements such as "*but we believe activities will work but we don't know the how. Moreover, we believe we can make changes but when and how?*" (T6, session 1).

Immediately, T1 engaged in *throwing action* by making suggestion to provide a solution that can be considered as kedge anchor when he said "*Yes at the college they said as a professional teacher, you should be able to improvise*". However, that anchor did not hit the ground as he continued to criticise the concept of improvisation by saying that "*until they decide to bring resources and forget about this improvisation our teaching will continue to be the same*." The statement opened the way for the others to also criticise the solution or anchor he was trying to provide. Improvisation was again raised by T1 in Session 3 as he continued his search for suitable ground but this time, it was not supported by any other participant as the *throwing action* failed to hit suitable ground once again.

T1 continued the *throwing action* in the search for suitable ground as he raised the idea again in Session 4 as one of the solutions to address the lack of resources for teaching science in the classrooms. Even though it was met with scepticism and criticism when raised in the previous sessions, this time round, it hit the ground as it got the needed response from the participants by sparking a detailed discussion. This is because this time around, I questioned their understanding of improvisation and why they think it can help address the problem of lack of resources in their teaching. The excerpt below shows how the concept was taken up and discussed in Session 4. It is interesting to note that the discussion on the topic of improvisation when it was raised here took twelve speaking turns, and almost every participant in the room contributed to it. The teachers took time to explicate the concept of improvisation by looking at the benefits, challenges, feasibilities, and alternatives to improvisation. They explored how to create improvised materials, plan when using improvised materials, involve students in bringing materials, and utilise online resources like videos. These discussions can be analysed as *taking over actions* which enabled the teachers to regain control over their situation.

> T2: *It not always possible to get all the real materials you need for you teaching so you need to create your own alternatives to use in class...So I am sure if we do some of these things it will help the children to understand science so that when they go home they can use their ideas to create new things so that creativity will be part of them*
>
> R: *So how feasible is it to improvise? Can we always do it?*
>
> T5: *No not always*
>
> R: *So, at what point can we improvise, because the point is that it not all the time that we can use all the ideas we are talking about here*
>
> T1: *When the original items are not there but we feel we can get alternative in our community either by direct substitution or even constructing them. And it also depends*

on the topic you are teaching and the materials available in your environment. So, I think planning ahead is very key so that you can see whether there can be improvised materials to use to teach the topic if the original materials are not there.

T6: *What I think is that if we cannot improvise, we can show a video of it.*

R: *Yes, that is good. We are examining these ideas to look at when they can be applied and what alternatives are available*.

T2: *Making improvisation is time consuming sometimes because the real objects are not with you and so you need to plan in advance to get the alternative materials to use in the class.*

T3: *We can even ask students to bring materials so we can use in the classroom.*

T6: *But to make it advantageous to you, you have to learn prior, maybe days before because there are somethings you have to create and read a lot about it. So, what we can do is to go to YouTube and type how to improvise this or that we can get a lot of videos that we can learn.*

T1: *Actually, in our area here, as a teacher you may decide to improvise but may not get the materials so as my brothers have already said, the children may get some from their area. So, you asked a head of time to bring it and put it together and check whether it will work before use it.*

T2: *You have to practice it to make sure it works before you use it in the class otherwise you will disgrace yourself.*

The vignette above shows how the teachers collectively and constructively discussed the idea of improvisation. The teachers not only discussed the concept of improvisation but also implemented it in their teaching practices, thus pulling on it to *break out* of the problem of a lack of resources. The last comment by T2 concerns performativity, signalling the wider structures and pressures that teachers can feel. These can produce a defensiveness (Lilley 2024), which makes the conditions of the Change Lab even more important.

One participant, T4, shared an example of how he improvised in a lesson on fertilisers. He used sand as an improvised material and took the students outside the classroom to the school farm to apply the demonstrated methods of fertiliser application. By engaging the students in hands-on activities and critical thinking, the lesson generated students' interest and enthusiasm.

> *I was teaching fertilisers yesterday…. I was able to improvise for fertiliser by using sand and grouped the students into three for them to apply what had been demonstrated by taking them outside of the classroom to the school farm. Each group was made to practice two of the fertiliser application methods. I made them apply and think critically by asking them the advantages of each of the methods; which one of them is difficult, which is easy to practice, which is good for this type of crop and many more other questions. Most of them (students) were happy that for the first time they have been send outside of classroom to learn and apply the knowledge. One student told me this is the first time he has seen a teacher doing that* (T4, session 5).

The teachers decided to form auxiliary motives of building improvised materials and rely on them to teach science. The improvising of learning materials served as a kedge anchor that allowed the teachers to move forward from their initial perception of a lack of resources as a barrier to teaching that is more engaging. They recognised that improvisation provided a means to overcome resource limitations and create engaging learning experiences for their students. By embracing improvisation, the teachers transformed their teaching practices and empowered themselves to find alternative ways of delivering the curriculum within the constraints they found themselves. Overall, the concept of improvisation served as a powerful kedge anchor for the participants, enabling the teachers to navigate the challenges they faced and move towards engaging and interesting pedagogies to students. This illustrates purposeful pedagogical practice where there is a balance between teacher-centred and student-centred teaching.

7.4.2.2 Designing lesson planning template

The participants in the session recognised the need for a lesson template that would help them incorporate student-centred ideas into their science lessons. The idea of developing a lesson templated functioned as a kedge anchor in achieving that. When it was suggested, which is a *throwing action*, it immediately hit a suitable ground as the participants contributed to its development. Considering why this suggestion as a kedge anchor hit the firm ground so readily, it seems the teachers were eager for something concrete to guide their lessons more student-centred. Lesson plans were part of their established practice, so this did not feel like 'more' work but rather re-fashioning an existing tool to align with their new motives. The template aimed to provide specific instructions on the activities and methods to be used, so that the teachers could include student-centred pedagogies in their lessons.

The teachers discussed and developed a template together, intending to make them more conscious of how to engage students in their lessons. During the discussion, the participants highlighted the importance of being deliberate and intentional in choosing words and activities in the lesson plans. The excerpt below captures the moment in which participants were developing the lesson template. It is interesting to note that almost all participants were involved in developing the lesson template.

> T6: *I think now in writing our lesson plans, we must be intentional or deliberate in the choice of words or activities. I don't think we should stress on the core points and others. Our job now is the activities. It does not matter whether we are teaching in both old and new curriculum. In the old curriculum we normally write; teacher guide pupil*

but we don't tell how we do that. But this time we can be deliberate and specific like teacher uses think-pair-share to help student to brainstorm on this.

T1*: We usually write teacher assist pupils; what assistants are we given?*

T2*: Even in conclusion and evaluation we write those words. Does the process involve child and how?*

T6: *So, let us do something that can make it deliberate a bit, So, let say in our general lesson plan we start with introduction and ends with conclusion. In between these, we have activities so let say we have activity 1, 2 and so on. We are going to write what we are going to do under these sections. So, assuming we always say teacher guides students to revise their RPK (relevant previous knowledge). How are we going to that?* (T4: by collaborative method [meaning the application of collaborative teaching and learning approaches like think-pair-share]). *So that becomes our student-centred principle we are going to use.*

T1: *okay then we can write student-centred principle to use under introduction*.

T6: *So, I am going to write student-centred principles (SCP) to use under all the headings like introduction, activities, conclusion, and evaluation. In this case we can take for example the conclusion: under which SCP principles we can identify and how we can do that to involve the children. So, I think we can use simple template. It just a matter of putting in some of the ideas we have discussed here under the SCP.*

T3: *So, we can write the SCP under each of the activities we write in our lesson plans?*

R: *I think we can have this …to guide us.*

T1: *If we have time can we take a topic and go through it?*

It can be noted that during the discussion, the participants highlighted the importance of being deliberate and intentional in the choice of words and activities in the lesson plans. They emphasised the need to focus on activities rather than solely on core points, ensuring that the process actively involves the students. They suggested including student-centred principles under each lesson plan section, such as introduction, activities, conclusion, and evaluation. The student-centred principle would serve as a guide to identify and incorporate student-centred practices into each lesson phase.

While it looks like the discussion on the development of the template (*taking over action*) as kedge has provided a hook for the teachers to gain control over the situation, it was observed that in subsequent lesson plans presented, the teachers did not adhere to the template they had created as they continued to write lesson plans in the old format. It shows what Sannino (2022) refers to as critical moments in the TADS process where the conflict of motive is reactivated, and the second stimulus is either implemented or ignored. It was as if the teachers could not pull on the kedge anchor of the lesson template to move from the problem of dominant teacher-centred teaching. When asked about this, the teachers explained that they were required to follow the format approved by the Ghana Education Service (GES). However, they acknowledged that the template they developed during the session was useful and helped them think about how to involve their students during the planning stage.

> *But what I do is that when I am planning my lesson I do it along with the format we developed because that forces you to think along every step to involve your students especially what matters to them. Even though I follow the format of the GES in writing the notes but in teaching I use the format we developed here because that one makes the things easy to involve the students* (T1, Interview 2).

Despite following the GES format in writing their notes, some of the teachers mentioned that they still used the template they developed when planning their lessons. They found it helpful in ensuring student involvement and focusing on *what matters* to the students. Using the developed template during the planning process, the teachers could think through each step and incorporate student engagement strategies. This shows how the teachers pulled on the anchor during planning (*breaking out actions)* to help them pull out of their problem even when it seemed not to be working.

The lesson template served as a kedge anchor for the participants, aimed to move them from their traditional lesson planning approach to one that consciously incorporates student-centred teaching ideas. Although the teachers were required to follow the GES-approved format in their written notes, some acknowledged the value of the developed template and used it during the planning stage to ensure student engagement. The template thus provided a framework for teachers to be more intentional and deliberate in incorporating student-centred ideas into their science lessons to move them away from more teacher-centred pedagogies.

7.4.2.3 Collaborative learning activities

Initially, when the suggestion to engage students in collaborative learning activities, which was a potential kedge anchor, was made, it was met with resistance from the participants. They cited challenges such as large class sizes and the nature of the desks students sit on. The participants also expressed concerns that grouping students would consume a significant amount of instructional time, considering the number of students in the class. Additionally, some parents raised objections to assigning group work as part of homework assignments. As a result, the suggestion to incorporate collaborative activities was thwarted. These perceived challenges therefore made it difficult for the kedge anchor to find a suitable ground.

However, in a subsequent session, T6 continued the *throwing action* for the kedge anchor as he reiterated the need for the teachers to engage students in collaborative activities in the classroom, citing the specific example of think-pair-share, which got the anchor hooked. The reason why the anchor got hooked this time around may be because he illustrated the idea with concrete examples. The participants accepted the idea and discussed various approaches to fostering collaboration among students (*taking over actions*). They suggested strategies such as peer teaching, group assignments, and presentations. The advantages and disadvantages of collaboration were also explored, along with different methods of group formation. These discussions made the teachers confident enough to pilot test some of the ideas in their classroom, which enabled them to gain control over their situation. They shared examples of how they implemented collaboration in their classes and its positive impact on students. The recognition that collaboration was a key demand of the new curriculum and importance of it to students led the teachers to put these collaborative activities into action. They pulled on the kedge anchor in their classroom to *break out* from the lack of collaboration among students in the classroom.

Among the collaborative approaches suggested, think-pair-share was popular among the teachers. This may be due to the nature of the desks in the classroom, which facilitated this activity "*In the class, using think-pair-share approach I asked them to come out with their understanding of water cycle which they did, and I polished it for them*" (T1, session 5). Another teacher, T6 also explained how he used think-pair-share to introduce his lesson.

> *I was teaching them dentition. They do French so I started by writing the term dentition on the board and asked them the meaning of dent in French. So, I allowed them to practice think-pair-share to collaborate and come out with the answer* (T6, session 5)

The quotations illustrate how the teachers used the second stimuli of “think-pair-share” to gain control of their problem situation. This shows how the teachers pulled on the kedge anchor as they implemented the idea in their classrooms (*breaking out action*) to enable them to pull out from the lack of collaboration among students in the classroom, overcoming their initial idea that collaborative activities were impossible.

7.4.2.4 Attending to individual difference

Another kedge anchor thrown in while teachers were searching for solutions to address the problems in their science teaching was attending to individual differences. In the initial stages when it suggested, *a throwing action*, it failed to hit a suitable ground as the suggestion was met with resistance from the other teachers. They saw it as a burden requiring extra time and resources to support weaker students. However, it was later realised that attending to individual differences does not necessarily mean having extra classes for the weak students. Instead, it involves identifying the needs of all students and showing concern and care for those needs. The idea that individual attention does not solely imply extra time for low achievers resonated with the participants. They began to explore ways to pay attention to individual differences without overburdening themselves.

One suggested approach was utilising high-achieving students as peer teachers to assist their classmates. This way, the low achievers could benefit from the support of their more capable peers. T3 indicated this in the Change Laboratory session by saying *“adding to what my colleagues have said on attending to individual differences, in order to help the lower achiever, the brilliant students can be shared among the low achievers in groups so that they can assist these low achievers”* (T3, session 3).

Other suggestions were put forward to address individual differences, such as allowing more time for slower writers, providing different activities to address learner diversities, and implementing differentiated teaching. The idea of individualised tests and assignments based on students' abilities and pace were also discussed. The participants agreed that identifying students' strengths and weaknesses and tailoring tasks accordingly was a way to attend to individual differences effectively. These discussions where the participants, collaboratively thought of idea and examples, explored options are regarded *as taking over actions* that helped the teachers gain control in their practice. As evident from their discussions, paying attention to individual differences became a priority for the teachers. They realised the importance of not allowing the pace of the lesson to be solely determined by high achievers.

From the second observation, it was realised that the teachers began to give opportunities to low achievers, *a breaking out action,* ensuring that every individual achieved the lesson objectives, rather than relying on a few brilliant students to complete the syllabus on time thus breaking away from their problem area. Teachers were observed asking specific individuals if they understood a topic, rather than posing general questions. They also provided one-on-one assistance to students or asked their peers to assist them. Trying these ideas in their classrooms can be analysed as *taking over action* which the teachers took to gain control over their problem.

During the reflection stage, the teachers expressed the realisation that paying attention to each student, particularly the low achievers, was crucial. By doing so, the pace of the lesson could be adjusted to meet the needs of every individual.

> *…now I have come to realise that I need to pay attention to each student especially the low achievers so that the pace of the lesson is not determined by the high achievers. I give opportunity to the low achievers even if they are not willing to talk so that by the end of the lesson the objectives, I have set will be achieved by each and every individual*

rather than relying on few brilliant students to complete the syllabus on time (T3, session 6).

Overall, the teachers recognised the importance of attending to individual differences and began implementing strategies to address them. By doing so, they aimed to ensure that every student received the support and attention needed for effective learning.

7.4.2.5 Active student engagement does not depend on material resources

The participants made several statements which impacted the Change Laboratory sessions and helped move the teacher transformation agenda forward. One such impactful statement that became a kedge anchor to move teachers from the problem of lack of engagement in the classroom is a statement made by T6 that says that engaging students actively in a lesson does not mean having material resources.

> *What I think is that student-centred teaching is not necessary an activity methods or okay is an activity but does not necessarily mean it should have resources before it can be practised. We tend to think of these activities as those that involves practical works but there can be activities which do not involve practical works* (T2, session 2).

This statement came against teachers complaining about the lack of resources to engage students actively in their science lessons. As I have already shown earlier, the teachers believed that active engagement of students in science lessons involves having material resources. Without such material resources, students' active engagement in science lessons was not something the teachers felt they could practice.

When this statement was made, *throwing action*, it received no comments or contributions from any participants. It appeared the statement did not make any impact on the participants. In other words, that statement as a potential kedge anchor appeared not to have gotten hooked. At this point, T6's colleagues still associated active student engagement with resources that they felt were absent in the classroom. However, T6 did not give up as he continued his search for suitable grounds for the statement by reiterating the point.

However, recognising the significance of T6's statement, I used it as mirror data in subsequent sessions to prompt reflection and discussion among the teachers, *a taking over action*. This approach proved effective in helping teachers identify activities that do not require material resources to engage students actively. They suggested activities such as discussions, debates, presentations, and think-pair-share, some of which tie in with ideas that matter to students which they then implemented in their classrooms. Through these discussions the teachers began to realise that active engagement could be achieved without relying solely on material resources and began to apply these activities to actively engage their students illustrated by T2: "*Okay, I asked the children to go and ask or search for information about farming systems in Ghana and they use that information to debate on the merits and the demerits of these farming systems*." (T2, session 5).

The teachers referred to the statement as a key understanding in implementing the curriculum. They acknowledged that while student-centred and activity-based teaching had already been emphasised, their new understanding was that activities could go beyond practical work and material resources: "*I think we have already known that the curriculum is student-centred and activity-based, but for me the new understanding is the idea that activity does not only involve practical or materials. That is my new understanding*" (T4). This shift in perspective allowed the teachers to explore alternative active engagement methods and create meaningful learning experiences for their students. Overall, the statement played a crucial role as a kedge anchor in dispelling the misconception that active student engagement requires material resources. Teachers pulled on this kedge anchor to open up new possibilities to engage students actively, enabling them to *break out* of their problems.

In summary, the *throwing actions* identified in the data analysis included suggesting new ideas, dismissing ideas, and re-proposing or adjusting ideas to bring others on board. The *taking over actions* involved collaboratively thinking of examples, planning how ideas could be practically applied in the classroom, exploring options, receiving positive feedback from both students and colleagues, pilot testing of ideas, and presenting findings as mirror data for reflection. Lastly, the *breaking-out* actions encompassed implementing these ideas in classroom settings.

This section has shown that forward anchoring was made possible through the social interactions in the Change Laboratory where each individual teacher made personal sense of the conversation and experimented with those ideas in the materiality of the problem situation (Sannino, 2022). It has further been shown how *what matters* to students was used as auxiliary motives by the teachers to promote new understanding and new possibilities for action through various kedging actions summarised in Table 7.1 in implementing the science curriculum. The section shows how the teachers' knowledge of *what matters* to students enabled them to understand their classroom in a different way and act differently. It exemplifies how transformative agency, and expansive learning can be facilitated by kedge anchors in the Change Laboratory setting.

7.5 Addressing the contradictions in the teachers' activity system

Chapter 6 identified four main contradictions in the teachers' activity system. These were between the tools and the object where lack of resources affected the way the teachers were implementing the curriculum; the subject and the object in which for example the teachers' beliefs and training were in tension with their practices; the rules and object where loaded curriculum, timetabling, language of instruction and examination league tables affected the effective teaching science of the under the new curriculum; the division of labour and object where teachers were doing all the things contrary to the expectations of the curriculum.

This chapter has shown how these conflicts of motives were experienced personally, and how the teachers worked collaboratively to develop new motives and related means to break away from this conflict through transformative agency. This final section of Chapter 7 returns to the systemic level, connecting these processes with addressing the four conflicts.

The teachers could identify and analyse the contradictions in their activity system. They attempted to address these contradictions by formulating and modelling ideas. Some of these ideas were experimented, leading to concrete solutions and improved practices in their activity system. Others were still at the abstract level due to the lack of time to see their real applications in the classrooms. Through establishing new motives with *what matters* to students and using kedges anchors outlined above, the teachers not only resolved conflicts of motives but also addressed some of the main contradictions in their activity system.

The teachers addressed the contradiction between the tools and resources when they proposed and implemented ideas of improvisation and teaching beyond the classroom to use local resources to engage students actively in the lesson. Regarding the contradiction between the subject and the object, where there was tension between the teachers' theoretical knowledge and practice, they began to align their practices with the demands of the new curriculum using *what matters* to students as a second stimulus. This alignment brought their practices closer to what they espoused as important in teaching, thereby resolving some of the tension. Some aspects of the contradiction between the rules and the object were partially resolved. For instance, the tension between using the local language and the foreign language in teaching science was addressed by the teachers' proposal to use both languages where appropriate. This approach enabled better communication and made science lessons more understandable to students.

The participants also addressed the contradiction between the division of labour and the object. Previously, the teachers performed all classroom tasks, but this dynamic shifted by making students active participants in the teaching, learning, and assessment process. The key to resolving these contradictions was focusing on *what matters* to students, which became a second stimulus in addressing these challenges. By integrating student interests and perspectives, the teachers effectively engaged students and created a more collaborative and responsive learning environment.

It must be noted that not every aspect of the contradictions identified was addressed by the teachers. Some of them were not within their powers to address. For example, issues of time allocation for teaching science, positioning of schools based on their performance in national examinations, loaded nature of the curriculum, and nature of teachers' training were all issues that were beyond the teachers to address. The long-term impact of the solutions proposed and practised by the teachers is not known. It will be interesting to know how the teachers' attempt to engage students actively in science lessons will impact their completion of the science syllabus.

Chapter 8: Conclusion

This chapter of the thesis has seven sections. Section 8.1 introduces the chapter, while an overview of the previous chapters is presented in Section 8.2. In Section 8.3, I provide answers to my research questions. Section 8.4 discusses the study's contribution to knowledge, while Section 8.5 addresses the study's limitations. The implications of the study are discussed in Section 8.6 before concluding with some final remarks and reflections in Section 8.7.

8.1 Introduction

This study facilitated science teacher professional learning, transforming their practice in line with changing curriculum demands that require a more student-centred teaching approach in Ghana. The key expected outcome of this research was pedagogical change among a group of science teachers in Ghana. The study used an interventionist approach based on CHAT, called the Change Laboratory, to help science teachers from six JHS learn and develop their practice in light of these expectations of change. The study was conducted in Sefwi Wiawso Municipality of Ghana, where six teachers teaching science at JHS were recruited. These teachers were from six different schools: one was a low-fee private school, and the others were public schools. There were 18 JHS students selected from these schools, three from each school, to be part of this study.

The data generation process, which spanned three months, involved six Change Laboratory sessions with the participating teachers, two interviews with each teacher, six focus groups with students, and 18 lesson observations. The interviews with teachers were conducted in two phases, before and after the workshops, while the observation was conducted in three phases, before, during, and after the workshops. Data were analysed to answer the research questions.

The aim of this chapter is to conclude the study by answering the research question and highlighting the key contribution to knowledge. I begin this chapter by presenting the overview of the previous chapters (Section 8.2) highlighting their key arguments, after which I respond to the research questions and discuss these answers with the literature (Section 8.3). I then discuss the contribution of the study to knowledge in three key areas: empirical, theoretical and methodological (Section 8.4). I critically reflect on the study's limitations (Section 8.5) and then discuss the study's implications for policy, practice, and research (Section 8.6). I conclude the chapter and, for that matter, the whole thesis with some reflections (Section 8.7).

8.2 Overview of previous chapters

In Chapter 1, I presented the background of the study context, outlined the challenges within the education system in Ghana, and focused on science education. The rationale for introducing the new curriculum was also discussed, highlighting the need for reform to address these challenges. I provided the justification for my study arguing that despite implementing the new curriculum, teaching practices were unlikely to change without adequate support for teacher professional development. This recognition of the need to support teachers in their professional learning to effectively implement the curriculum and achieve the desired educational outcomes led to formulating the research questions and using CHAT as the theoretical framework.

In Chapter 2, I reviewed the literature on science education research in Africa, specifically focusing on Ghana. The aim was to identify the challenges confronting science education in the African context and to explore how researchers have contributed to addressing some of these challenges. The available empirical evidence indicated a tendency for researchers to predominantly highlight problems rather than offer viable solutions. I therefore argued for a solution-based approach to researching science education in Africa. It was also observed that science teaching was mostly dichotomised into teacher-centred and student-centred in the literature. I argued for a more dynamic view of science teaching that recognises its complexity rather than simple categorisations. In science professional learning, my research aligned with studies that emphasise the need for teachers to be supported in their professional learning to facilitate effective and impactful changes in their teaching practices. This is because the literature showed access to professional development among science teachers was limited, and the few ones they got access to were not effective. This made me support the call for different approaches to the professional development of science teachers in Africa. I, therefore, argued that professional development framed within CHAT could provide good support for teacher learning and enable transformative changes in their teaching practice.

Chapter 3 discussed my theoretical framework of CHAT. I argued that the challenges inherent in effecting changes to teachers' practices in Ghana are deeply rooted in historical and systemic structures and, therefore, require a theoretical framework capable of addressing these challenges from the appropriate perspective. CHAT was therefore considered as a suitable framework for understanding these challenges, as it enables the exploration of different components of the activity system shaped by historical and cultural contexts. I highlighted the importance of the CHAT intervention, particularly in the form of the Change Laboratory, which is able to provide opportunities for participants to analyse their activity system to identify the contradictions and then develop their own solutions to addressing these contradictions. Subsequently, these proposed solutions can be implemented to determine their impact. I located my study within the second generation of CHAT drawing on some conceptual aspects from the fourth generation. Specifically, features of contemporary CHAT ideas, such as Annalisa Sannino's work on transformative agency by double stimulation and Anne Edwards' work on relational agency and its associated concepts, were applied in the analysis to facilitate the interpretation of the data.

In Chapter 4, I presented the methodology for the study justifying the use of Change Laboratory intervention to address the identified challenges in the teachers' activity system. The Change Laboratory intervention was chosen to facilitate collaborative problem-solving among participants, enabling them to identify challenges within their activity system and develop tailored solutions. Six Change Laboratory sessions were conducted with the teachers, each lasting for a minimum of 90 minutes. These sessions were all audio recorded and transcribed for analysis. Additionally, three students from each participating teacher's school were selected for focus group to ascertain their perspectives on what matters to them with regard to the teaching and learning of science. The findings from these focus groups were presented to the teachers for further deliberation during the Change Laboratory sessions. Furthermore, each teacher was interviewed twice, and their lessons were observed on three separate occasions. The initial interviews and observations were used to collect data on the teachers' activity system which were presented mirror data in the Change Lab, while the subsequent interviews and observations were conducted to gather data on the teachers' learning and practice resulting from the Change Laboratory sessions.

In Chapter 5, an overview of the data collected, particularly from the Change Laboratory sessions, was presented in a relatively raw and unanalysed form. The data was presented chronologically, highlighting the key issues discussed in each workshop meeting. The aim here was to provide insight into the content and flow of the Change Laboratory sessions, allowing readers to grasp the progression of discussions and the emergence of key analytical ideas.

I presented the results of the data analysis in Chapters 6 and 7, which provided evidence to support my arguments that CHAT is a comprehensive framework for transforming teachers' practice and understanding their learning process. Chapter 6 presented the results of the teacher's expansive learning and the contradictions in their activity system. Chapter 7 discussed the transformative agency of the teachers in addressing the contradictions in their activity system. Here, I foregrounded *what matters* to students as key to transforming the teaching practice. In the next section, I will draw on the evidence from the results to answer the research questions.

8.3 Responding to the research questions

The overarching research question for this study was: how can barriers to pedagogic change can be overcome in the context of science curriculum reform in Ghana?

Four sub-questions were asked to explore this question in more detail. These four sub-questions were:

1 What contradictions are present in the implementation of the new science curriculum?

2. What do teachers learn, expansively, when collaborating on resolving these contradictions in implementing the new science curriculum?
3. How does agency emerge as teachers collaborate on implementing the new science curriculum?
4. How can teachers' understanding of *what matters* to JHS students be used as a resource to expand interpretations and possible actions as they meet the demands of teaching the new science curriculum?

In an attempt to answer the main research question, I answer the sub-questions first, discuss the answer in the light of the literature and consolidate them as a response to the main question.

8.3.1 What contradictions are present in the implementation of the new science curriculum?

We can recall from Section 3.4 that activity is a "relatively durable system" with different parts (tools, objects, subjects, division of labour, rules and community) to serve a collective purpose (Engeström & Sannino, 2021). Contradictions are "historically accumulating structural tensions within and between activity systems" (Engeström, 2001, p.137). The contradictions found in the teacher's activity system implementing the new curriculum were mainly secondary in nature and found between different components of the teachers' activity system. These contradictions were found between tools and objects, the object and subject, the rules and the object and the division of labour and the object. In what follows, I discuss these contradictions, focusing on the key ones to show that these contradictions identified are not isolated issues pertaining to the study context but something which is well documented in the literature as affecting the teaching and learning of science in Africa (Section 2.4.1).

It will be appropriate at this juncture to shed more light on the object of activity and put the discussion into perspective. It must be recalled that the object is that towards which human efforts are directed, thus carrying the motives of an activity (Engeström & Sannino, 2010; Sannino et al., 2016a). The object, as understood in this study, is more of a dynamic and fluid thing. The general objective was the implementation of science curriculums. Within this general object was the specific object of more student-centred teaching as articulated by the literature and the Ghanaian curriculum. As the study progressed, the specific object evolved based on the insights gained from the Change Laboratory process. The teachers came to understand student-centred teaching differently. The object came to have an expansive meaning. I will, therefore, refer to different aspects of the object as I discuss the answers to the research questions.

Even though the Ghanaian science curriculum advocates for student-centred teaching, it was realised that the emergent teaching practice of the participants was not binary opposition to teacher-centred teaching, but a dynamic move between these two approaches. The teachers were implementing a new science curriculum, which calls for a student-centred approach to teaching (MOE, 2018, 2020). It was the object of the teacher's activity towards which their efforts were directed, thus carrying the motives of the teaching (Engeström & Sannino, 2010; Sannino et al., 2016b). They needed tools such as teaching and learning resources to transform this object into the expected outcomes (Engeström & Sannino, 2021).

A major contradiction in the teachers' activity system was found between the tools and objects. The lack of resources became a key manifestation of contradiction in achieving the curriculum objectives. The identified contradiction between the tools and the object in the teachers' activity system highlights the important role of resources in achieving curriculum objectives, particularly in implementing student-centred teaching approaches. This challenge resonates with findings from existing literature on science education in Africa, where the inadequacy of resources has been consistently cited as a major barrier to effective teaching and learning (Brobbey, 2020; Humphrey-Darkeh et al., 2022; Ogunniyi & Rollnick, 2015). Specifically, teachers' inability to implement student-centred teaching in classrooms is often linked to the lack of resources (Mkimbili, (2018); Qhobela & Moru, 2014). The participants in my study, similar to findings in other research (Qhobela & Moru, 2014), associated student-centred teaching with engaging students in practical and hands-on activities. This underscores the importance of resources, including modern equipment, in facilitating active student engagement and effectively implementing student-centred pedagogy (Marcourt et al., 2022). Thus, resources were seen as a key contradiction to achieving the curriculum objective of active student participation and engagement in science lessons (MOE, 2020).

Another key contradiction in the activity system of the teachers was found between the rules and object where time constraints and the pressure to cover the syllabus conflicted with the objective of active student engagement. It was identified that teachers felt the time for teaching science was insufficient to complete the syllabus so they could not actively engage students in teaching. Their focus was completing the syllabus to prepare students for national examinations. The negative influence of national examinations on the teaching of science, where teachers use a less engaging approach to teaching to cover curriculum on time is prevalent in the literature on challenges of teaching and learning science (Boakye & Ampiah, 2017; Fletcher, 2018; Kalu-Uche et al., 2015; Ogunniyi & Rollnick, 2017). Teachers under pressure to cover the extensive curriculum within limited timeframes often resort to didactic teaching methods to ensure content coverage rather than foster active student participation and understanding. For example, Qhobela and Moru (2014) shed light on the challenges faced by physics teachers in their attempt to apply student-centred teaching approaches in Lesotho, where pressure to complete the syllabus within a limited timeframe, forced teachers to prioritise traditional teaching methods over more student-centred approaches. This pressure to complete the syllabus is attributed to the broad nature of the science curriculum (Adu-Gyamfi, 2014; Taylor et al., 2021; Coffie et al., 2020).

The use of the English language as a medium of instruction for teaching science was articulated by the participants as a major tension in achieving the curriculum objectives. The contradiction associated with the use of foreign language as the medium of instruction for teaching science, as expressed by the participants, reflects a broader challenge faced by science educators in Africa (Ogunnniyi & Rollnick, 2017; Singh & Singh, 2012), particularly in Ghana (Boakye & Ampiah, 2017; Quanah et al., 2011). The issue of language of instruction has been extensively studied and documented in the literature on science education in Africa, highlighting its significant impact on teaching and learning outcomes. For example, Singh and Singh (2012) reported about teaching science in South Africa, where teachers are forced to switch to the local language because students find it difficult to understand the use of English as a medium of instruction. In Ghana, similar findings were reported (Acquah et al., 2013; Quansah et al., 2019).

Several authors have therefore argued against the use of the English language for teaching science in Ghanaian basic schools because learning science in a second language makes understanding difficult (Anamuah-Mensah et al., 2004; Asabere-Ameyaw, 2012; Brown-Acquaye, 2004; Quansah et al.; 2019). These authors argue that using a second language acts as a barrier that prevents pupils from understanding scientific concepts, affecting their performance. This is because science teaching and learning is complicated by the need to have command over the English language. The teaching and learning of science are exacerbated by the use of the English language by teachers who are not good speakers of it (Brown-Acquaye, 2004). Students' inability to understand the lessons taught in science has been attributed to their poor knowledge of the English language, which is used in teaching (Boakye & Ampiah, 2017). It has been indicated that Ghanaian students' inability to read and understand contributed significantly to their poor performance in the TIMSS (Anamuah-Mensa et al., 2004). It has been argued that science concepts must be linked to a language that is easily understandable by the learner. It is therefore suggested that teaching science in the mother tongue may be the best alternative for children to learn science (Asabere-Ameyaw, 2012).

The literature thus shows the contradictions identified in this study are not locally situated within the context of the study but are issues that are widely documented in the literature on teaching and learning of science in sub-Saharan Africa. Often, these challenges remain at the point of identification rather than being folded into research about their solutions. This study is the first attempt to articulate these challenges as contradictions and map them into the activity system to help the participants resolve them.

8.3.2 What do teachers learn, expansively, when collaborating on resolving these contradictions in implementing the new science curriculum?

There were three main aspects of teachers' expansive learning as they addressed these contradictions. First, the teachers came to understand what was actually possible in their environment, linked this sense of possibility to concrete solutions and finally enriched their understanding of the object through *what matters* to students. The expansion of the object came through the enrichment of ideas, new interpretations, the development of new artefacts and new actions. The expansions were both material, such as designing practical solutions to the contradictions in their activity system and symbolic which is just a matter of recognising the complexity of the object, i.e. revealing more of the meanings inherent in it (Edwards & D'arcy, 2004)

One key expansion for the teachers related to their understanding of what was actually possible in their environment. The participants initially identified various challenges within their activity system. They used negative expressions like "*we do not have*", "*it is difficult*", "*we could not*", "*it is challenging*", "*we are not able*", "*it is frustrating*", "*we have no choice*", "*we can't*" to express their sentiments which reflected a sense of limitation and perceived barriers to change. Most of these statements were made during the analysis phase of the expansive learning cycle (Engeström & Sannino, 2010; Engeström et al., 2013)), during which they interpreted the curriculum (Augustsson, 2021). Through historic-genetic analysis, the participants could articulate their needs, challenges and problems (Augustsson, 2021; Engeström, 2020). Through the analysis, the teachers could explore the causes and explain the problematic situation in their current practice. They also identified and shared some of the origin or history of the situation. For example, they attributed part of the situation to their training that shaped their teaching practices (see Section 4.3.2. and 5.2.1).

However, a notable change occurred during their learning process, when they moved from an impossibility stance to one of possibility. This occurred when they started questioning and criticising their existing practice (Augustsson, 2021; Engeström & Sannino, 2010). The questioning triggered a need state (Virkkunen & Ahonen, 2011) where teachers realised the need for change in their activity system. It is important to note that at some point in their learning cycle, the teachers began to see themselves as agents of change, recognising that change was feasible and could be initiated by themselves. Therefore, instead of relying on external sources for change to happen, for example, waiting for government intervention to address resource shortages before altering their practices, they embraced the idea that change could start from within. This was when they started to model solutions to their problematic situation (Engeström 2020; Engeström & Sannino, 2010). The teachers' language, therefore, changed from negative to more positive and empowering items like "*we should*", "*we can*", and "*we must*". This shift in language from expressing challenges to embracing possibilities was a significant development observed in the teachers' expansive learning process, marking their transition from passive recipients of change to active change agents.

Another expansion was linking that sense of possibility to concrete and feasible local solutions designed by the teachers themselves in addressing the contradictions in their activity system. According to Engeström and Sannino (2010), the process of expansive learning should be understood as "construction and resolution of successively evolving contradictions" (Engeström & Sannino, 2010, p. 7). The teachers developed their home-grown solution to make science teaching interactive and participative. They critically examined and analysed their solutions by discussing, enriching and weighing alternative solutions (Augustsson, 2021; Engeström, 2020). They discussed ideas that matter to their students, like collaboration, students' engagement and how they can develop solutions to address those matters. They discussed solutions such as improvisation, teaching science beyond the classroom, group and presentation (see Chapter 5). By examining and testing the models, teachers could grasp the dynamics potential and limitations of their ideas (Augustsson, 2021).

To ensure active student participation in teaching, learning and assessment, the teachers proposed a range of strategies such as asking higher-order questions, giving students prior knowledge of the topic to be treated, facilitating discussion and debates among students and involving students in setting assessment questions (Coffie et al., 2025). In addressing the issues of lack of resources, feasible solutions such as improvisation, use of technologies, use of local environment and encouraging students to bring materials to school were explored. Activities such as group presentations, think-pair-share, peer teaching, group projects, and assignments were also suggested to promote student collaboration and enhance their learning experience (Coffie, et al., *2025*). The teachers did not only articulate solutions and ideas, but they also implemented some of these ideas by putting them into practice and reflecting on the process as well (Engeström & Sannino, 2010; Virkkunen & Ahonen, 2011), which resulted in some positive changes (see Coffie et al., 2025).

While some of these ideas and solutions might not be significant to people in other contexts, for these teachers, this was learning what was not yet there (Engeström, 2020) to practice their teaching differently. These ideas were geared towards making learning relevant to students' needs, interests, and situations while at the same time providing student-centred, active, and participative learning experiences as advocated by the new curriculum (MOE, 2018).

A third key aspect of teachers' expansive learning relates to their understanding of *what matters* to students, which provides an enriched and expanded understanding of the object. Through the concept of *what matters* to students, the teacher came to have a complex understanding of the curriculum enabling them to reposition themselves in relation to its implementation as a result of seeing more of it (Edwards, 2005). The teachers were able to make use of the concept of *what matters* as common knowledge, a second stimulus to engage students and contribute to better meaning-making of the curriculum. They took actions based on *what matters* to students in order to change their practice. These actions include teaching science beyond the confines of the classroom and implementing a range of activities such as debates, projects and presentations (Coffie et al., 2025). These activities represent a departure from traditional transmissive teaching methods commonly observed in African science classrooms where teaching is often characterised by extensive talk and note copying (Kalu-Uche et al., 2015; Marcourt et al., 2022).

While some of the ideas and actions were not new to the teachers and students, others were new and unheard of in the context, for example, students setting questions for assessment. In Africa, teachers view themselves as having absolute authority; students are therefore not involved in the assessment process; they hardly ask questions and are limited to responding to teachers' questions (Adu-Gyamfi, 2014; Qhobela & Moru, 2014). Therefore, for teachers in the study to think of allowing students to set their own questions, represents a departure from traditional teacher-led instruction and empowers students to take ownership of their learning. Introducing these new practices enabled the teachers to break away from the contradictions in their activity system and embrace innovative approaches to teaching and learning.

The participants' expansive learning was thus shown in the way they criticised and highlighted the need for change, explicated new possibilities, envisioned new models of the activity, committed to concrete actions aimed at changing the activity, and then took consequential actions to change the activity (Engeström, 2011). This transformation indicates expansive learning, as it is characterised by a shift in the activity system evidenced by changes in practice (Edwards, 2005; Engeström & Sannino, 2010). The actions undertaken by teachers to address the challenges faced in implementing the new curriculum show that these challenges in teaching and learning science (Section 2.2.1) which are historical and systematic, are not unsurmountable and the vision of the curriculum of making teaching students-centred where there is active engagement and participation of students (MOE, 2018, 2020) is achievable despite these challenges.

8.3.3 How does agency emerge as teachers collaborate on implementing the new science curriculum?

The teachers' agency emerged as they addressed the conflicts of motives they experienced as teachers trying to implement the new curriculum. They did this by responding to *what matters* to students, which became a new auxiliary motive that helped them escape those conflicts of motives. They also explored and implemented different ideas considered kedge anchors, which were instrumental in supporting their agency.

Addressing the contradictions in the activity system presented some conflict of motive where teachers had to make a deliberate choice between two motives. According to Sannino (2024), conflict of motives is the experience of contradictions and struggles that people go through in life. Lilley (2020) showed how Change Laboratory can create conditions in which conflict of motives is triggered. In this study, the discussions in the Change Laboratory provoked conflicts of motives, where the teachers had to make deliberate choices between two motives. These conflicts of motives were the participants' personal experiences of the systemic contradictions. They played a key role in addressing the contradictions the teachers faced in their activity system as it was the means through which the teachers took volitional actions to change their situation.

The conflict of motives became obvious because of the introduction of the new curriculum and implementing new practices as the participants struggled to resist or embrace the new possibilities (Engeström et al., 2015). For the teachers, the motive to teach in a more engaging manner to realise the intended curriculum crashed with the motive to maintain the status quo of transmissive teaching. Faced with this conflict of motives, they needed to take volitional actions to break out of the conflict of motives, which resulted in the transformation of their practice (Engeström et al., 2015). It was important for the teachers to experience this conflict of motives because, without them, they could not have engaged in expansive learning (Engeström, 2020).

The conflict of motives experienced by the teachers was addressed through TADS, (Sannino, 2022) where they took wilful action to face the conflict of motives they encountered to bring about a change in their teaching. As Sannino (2022) explains, "TADS is a process by which individuals or collectives can intentionally break out of conflicts of motives and change their circumstances by forming auxiliary motives and implementing them systematically" (p.10). For the teachers in this study, the auxiliary motive that enabled them to break off the conflict of motives they experienced as a result of implementing the new science curriculum was their response to *what matters* to students. Question 4, which specifically focuses on *what matters* to students, addresses this aspect in detail under the relational agency framework.

The teachers' agency in implementing the science curriculum was also manifested through forward anchoring or warping, a metaphor illustrating how change can be collectively achieved in the midst of difficulties (Sannino, 2022). According to Sannino (2022) "second stimuli understood as forward-oriented kedge anchors are instrumental in the elaboration of new meaning which may be stabilised to the point of supporting transformative actions in problem situations for which there are no known solutions" (p.12). Five key second stimuli were identified as kedge anchors. These kedge anchors were improvising materials, lesson planning templates, collaborative learning activities, attending to individual differences and active student engagement as not depending on material resources. What made these five stimuli kedge anchor is that the teachers deliberately took them up as auxiliary motives to face the conflict of motives triggered by the problem situation (Sannino, 2022). As described in detail in Section 7.2.2, the teachers carried out three sets of actions in taking up these kedge anchors (Hopwood et al., 2022; Sannino, 2022). They took some *throwing actions,* such as making suggestions and dismissing ideas to search for solutions. *Taking over* actions like collaboratively thinking of ideas, exploring options, and piloting testing of ideas were undertaken to regain control while they implemented some of these ideas to *break out* of the problematic situation (see Table 7.2).

The participating teachers were faced with the problem of a lack of resources in their teaching, which is a major issue affecting the teaching on learning of science in Africa and has been highlighted by various studies (Adu -Gyamfi, 2014; Annafo et al., 2018; Marcout et al., 2022; Ogunnniyi & Rollnick, 2017). They embraced the idea of improvisation as an auxiliary motive to address the challenge of lack of resources. While there are reported challenges with the use of improvised materials in teaching science (Adu-Gyamfi, 2014), improvisation has been recognised as a viable way of addressing the lack of resources in teaching science in Ghana (Marcourt et al., 2022; Quansah et al., 2019, Osei-Himah et al., 2018). It has been shown that improvised materials enhance students' understanding of science and sustain their interest in the subject (Osei-himah et al., 2018).

Creating a classroom environment that fosters interaction among students has been shown to positively impact student attitudes towards the study of science (Egbenya & Quayson, 2022; Shirazi, 2017). However, the lack of collaborative activities and active student engagement are recognised as significant challenges in science education in Ghana and Africa as a whole (Singh & Singh, 2012; Marcourt et al., 2022). In the study of Singh and Singh (2012), it was identified that lack of physical space due to overcrowded classrooms caused teachers to avoid collaborative activities like group work. A systematic study on student-centred teaching conducted by Bremner (2021) showed that the most frequently mentioned aspect of student-centred education is interaction where opportunities are provided for students to interact with each other. Through the Change Laboratory, the teachers understood collaborative activities as appropriate actions in designing student-centred lessons. As with Patchen and Smithenry (2014) study, the teachers created opportunities for students to collaborate. Providing opportunities for students to engage with each other enhances their learning experiences and promotes a sense of ownership and active participation in their education.

The teachers in this study demonstrated familiarity with concepts such as improvisation, attending to individual differences, collaborative learning, and active student engagement. However, they had not fully explored how to effectively implement these concepts in their classrooms. This limited implementation may be attributed to the teachers' superficial or theoretical understanding of these concepts, which often requires extensive probing to uncover (Hassler et al., 2019). During the Change Laboratory sessions, these ideas were revisited, clarified, and explored in greater depth. As a result, they became anchors for changing the teachers' practices. When the teachers faced conflicts of motives, they turned to some of these kedge anchors or second stimuli to search for a solution to the situation. When they used these kedge anchors, it enabled them to gain control over the situation and eventually broke out of the problem situation (Sannino, 2022).

8.3.4 How can teachers' understanding of *what matters* to JHS students be used as a resource to expand interpretations and possible actions as they meet the demands of teaching the new science curriculum?

The teachers came to understand *what matters* to students by eliciting students' views and by listening to summaries of interviews with students conducted by the researcher to align their practice with *what matters* to students. It has been argued that careful listening to students is a key to reforming teaching practices to improve student learning (Levin, 2000). As indicated by Hopwood and Edwards (2017), alignment of motives can done when people listen, recognise, reveal, and engage with each other's motives. Thus, through listening, discussing and engaging with students' motives explained in terms of *what matters* to them (Edwards, 2012), the teachers came to build common knowledge as *what matters* or the motives of students were disclosed and heard (Edwards, 2020). Through that, the teacher learned things that matter to students: engagement and interest, support and attention, applicability and connectedness.

Engagement and interestedness: Being actively engaged in a science lesson was a very important issue for the participating students. This was in line with the new curriculum which emphasises student engagement in classroom activities (MOE, 2018, 2020). Studies have identified active student engagement in teaching and learning as one important aspect of student-centred teaching (Bremner, 2021; Paris & Combs, 2006). In a study of the implementation of student-centred teaching in secondary schools in Tanzania by Mkimbili (2018), it was identified that students wanted science lessons with active student participation. However, the literature on science teaching and learning in Africa indicated that teachers do not provide students with opportunities for active engagement and participation in science lessons. Science teaching mostly involves copying notes and explaining without allowing students to express their ideas. Students are only passive recipients of information (Agbene, et al., 2023, Mabula, 2012). It is, therefore, not surprising the studies indicate that most students do not show interest in science (Buabeng et al., 2012; Kihwele, 2014).

Support and Attention: A crucial thing that matters to students is getting support from teachers and peers, receiving individualised attention from teachers and engaging in collaborative activities. Providing a supportive environment where students feel valued and motivated is very important for them to succeed in their learning. It is one of the most important and frequently mentioned aspects of student-centred practices (Bremner, 2021). Therefore, teachers are encouraged to provide opportunities for student interaction by creating collaborative activities to initiate such practices. (Lee et al., 2021). However, the literature shows that for science teaching in Africa, curriculum coverage is prioritised over students' meaningful engagement and interactions (Agbene et al., 2023; Mabula, 2012; Qhobela & Moru, 2014). It is, therefore, not surprising that support and attention become something that matters to students.

Applicability and connectedness: Applying knowledge to real life was very important to the participating students. They wanted science to be relevant to their life. The students find science more interesting and meaningful when they can apply the knowledge they learn in real-life situations. Similar results were found by Chetcuti and Kioki (2012), who studied girls' attitudes towards science in Kenya. The students in their study indicated that they find science relevant when they can apply knowledge to solve their daily problems for a better life. The findings indicated that the students find science relevant because it relates to their future careers. In Ghana, however, a study has shown that students perceived science to be difficult, boring and irrelevant (Baidoo-Anu & Mensah, 2018). This means that students do not see the real application of science in their daily lives. Students have, therefore, called for teaching to incorporate real-life examples and use resources from their environment to make science lessons more relevant (Mkimbili, 2018). It has been argued that students' disposition to learn science depends on whether they value the subject and think it is important for success in school and future career aspirations (Anamuah et al., 2004).

These things that matters to students became a resource, a second stimulus in Vygotskian terms (Edwards, 2020), enabling teachers to design purposeful pedagogy to encourage active participation and engagement of students in science lessons, a vision of the new science curriculum in Ghana (MOE, 2020). Understanding *what matters* to students enabled the teachers to sensitively calibrate their teaching practice to address the problems raised by students, which included the lack of collaboration, inactive participation of students in sciences, and lack of individual attention.

Teachers were intentional in relating science lessons to students' experiences and environment, engaging students in practical and hands-on activities, paying attention to individuals, building on students' knowledge, and helping students to construct their knowledge, which are key things that matters to students. Interestingly, some of these were the key principles the Ghanaian science curriculum articulated. The curriculum emphasises the need for teachers to support students in constructing knowledge based on their experiences as key to students' learning (MOE, 2020). The curriculum promotes learning that is "linked to the learner's background and to their prior experiences, interests, potential and capacities" (MOE, 2018). This study shows how common knowledge mediated teachers' "responsive professional action" (Edwards, 2011) towards achieving the curriculum vision.

While the curriculum envisions a student-centred approach, the teaching practice described and observed by the teachers after the Change Laboratory was a dynamic move between teacher-centred and student-centred approaches. In line with critical discussions of teacher- and student-centred teaching, the changes accomplished in this study were towards pedagogies that involved a dynamic move. Therefore, teaching that meets students' needs involves a dynamic move between teacher-centred and student-centred approaches with a clear understanding of how *what matters* to students can be used as a resource for pedagogic engagement. It has been shown that common knowledge is important for improving teaching methodology in school as "it has the potential to be developed as a resource for pedagogic engagement" (Rai, 2019, p.166). *What matters* to students directed teachers' interpretation of student-centred teaching and their responses to the challenges they encountered in the implementation process.

This study provides evidence that student's engagement and participation in lessons can be enhanced when their motives or *what matters* to them are elicited and carefully considered in teaching. Teaching in a student-centred approach is not a neutral process. It involves what Edwards (2012) describes as "a dialectical engagement in activities" where *what matters* to students is highlighted and responded to by teachers in the task they encounter. Therefore, to aim for an effective student-centred teaching requires paying attention to *what matters* to students. If teachers can take time to listen and elicit *what matters* to their students, this knowledge can become a resource to help teachers in their pedagogical engagement. Common knowledge, therefore, implies putting the needs of the students at the core and responding appropriately to them in teaching (Rai, 2019).

The study adds to the concept of common knowledge in two ways. First, it extends the application of common knowledge from collaboration among professionals to student-teacher interaction to show how it mediates that interaction. The study showed how teacher agency could be revealed by examining how students' motive orientations or *what matters* to them "are pursued and negotiated into new practices through building and using common knowledge" (Edwards, 2020, p. 5). Second, it links the concept of *what matters* and common knowledge to the TADS framework (I will discuss this issue under contribution to knowledge in Section 8.4).

8.3.5 How can barriers to pedagogic change be overcome in the context of science curriculum reform in Ghana?

The answers to the four research questions enable me to answer the overarching question of how barriers to pedagogic change can be overcome in the context of science curriculum reform in Ghana. Based on my data and the literature review, the main barriers to pedagogic change stem from the lack of resources, overloaded curriculum, and use of foreign language as a medium of instruction. These barriers are understood as historically accumulated systemic contradictions related to the tools, the object, the subject, the division of labour and the rules in the activity system. Following CHAT, they were understood as driving forces for change.

While the curriculum may have a set of expectations and requirements for novelties that teachers are supposed to follow, this will not be enough to overcome the contradictions that they will face. There needs to be a process where things that are not yet understood are developed. Teachers will need effective professional learning that does not provide existing knowledge but one that enables them to learn what is not yet there. Overcoming systemic barriers to pedagogic change therefore requires a multifaced approach: creating conditions for expansive learning, encouraging and supporting the collective agency of the teachers, recognising the conflict of motives and breaking away from them, and linking expectations with *what matters* to students.

Creating conditions for expansive learning: Overcoming barriers to pedagogic changes requires creating conditions for expansive learning where teachers learn what is not yet there. This process begins by providing opportunities for teachers to identify and analyse the contradictions within their activity system, enabling them to understand the nature of their challenges. The participants must detect and address historically evolving contractions within activity systems, as these are the driving force behind transformation (Engeström & Sannino, 2010).

The process should build on the initial questioning and analysis to empower teachers to develop solutions that are contextually relevant to their challenges. This bottom-up approach ensures that the teachers create the solutions, giving them ownership and a deeper commitment to implementing these changes. This means that addressing systemic barriers does not involve obeying rules and solutions given by others. Instead, it involves producing new, relevant, and contextualised understandings by the teachers themselves that can be practically applied. This approach requires the creation of new artefacts and concepts that enable teachers to expand and realise these ideas in their educational settings.

Encouraging and supporting the collective agency of the teachers: The collective agency of teachers is very crucial in addressing the barriers to pedagogic change. The results of this study revealed that while teachers acknowledged the challenges within their activity systems, they also recognised their capacity to address some of these challenges. This agency became evident when teachers could collaboratively share ideas and experiences and learn from one another. Through the process of sharing, discussing what matters to them and their students, and collaborating in a mutually supportive manner, they collectively constructed solutions to the barriers hindering pedagogic change enabling them to move away from the status quo. Thus, to overcome systemic barriers and bring about pedagogic change in teaching practices, it is essential to encourage and support teachers in forms of collaboration that foster their collective agency. Even as they may implement specific ideas in their own classrooms, the possibility of doing this relies on collective processes of questioning, analysing and generating ideas together. The collective agency of teachers is vital in addressing the challenges they face and fostering meaningful change in their classrooms.

Recognising conflict of motives and breaking away from them: Another crucial aspect of overcoming barriers to pedagogic change involves recognising and addressing conflicts of motives. Conflicts of motives often arise because teachers' familiar, comfortable, and habitual practices may conflict with new expectations and demands for change. The participating teachers in this study faced a conflict of the motive of teaching in a more engaging manner that meets the demands of the new curriculum or maintains the status quo of teaching in a very transmissive manner where students are passive recipients of knowledge. They took volitional actions to change their situation. Therefore, if teachers are going to break the barriers to pedagogic change in their practice, then they must be supported to recognise and address the conflict of motives by forming auxiliary motives and implementing them systematically.

Linking intended and implemented curriculum with *what matters* to students: Overcoming systemic barriers to pedagogic change involves linking the intended and implemented curriculum with *what matters* to students. This study has shown that the key to teachers overcoming the contractions in their activity systems lies in understanding *what matters* to students and linking that with curriculum expectations, which emboldened them to do things differently to overcome the barriers in their practice. In other words, the results presented in this study show how understanding and integrating student perspectives into teaching can drive meaningful change and overcome systemic barriers in education.

Therefore, teachers must deeply understand *what matters* to their students. This involves recognising students' interests, concerns, and perspectives on learning. Teachers who grasp these elements can tailor their teaching to be more engaging and relevant. Teachers' motivation and effectiveness are enhanced when they see their actions as aligning with *what matters* to their students. Educators can break through systemic barriers and create more effective teaching practices by fostering an understanding of student perspectives and integrating these into curriculum expectations. This approach supports pedagogic change and strengthens teachers' commitment to their students and their roles as educators. Therefore, by linking curriculum expectations with student needs, interests and expectations teachers can find the motivation to change their practices. This alignment acts as a crucial stimulus for change.

8.4 Contributions to knowledge

Based on the answers to my research question and the literature review, I can suggest I made three main contributions to knowledge: empirical, theoretical, and methodological.

8.4.1 Empirical

A lot of studies have been conducted in Africa on students' perception of science (Amponsah & Mohammed, 2019; Baidoo-Anu & Mensah, 2018; Kihwele, 2014; Singh & Singh, 2012) attitude toward science (Chetcuti & Kioki, 2012; Egbenya & Quayson, 2022; Jebson & Hena, 2015; Reddy, 2019; Sakariyau et al., 2016) and interest in science (Buabeng et al., 2012, Kihwele, 2014). This study contributes to knowledge by being the first study to link students' perceptions, attitudes and interests to teacher professional development and practices through the idea of *what matters* to students. It thus adds to the scholarship on science education in Africa by highlighting the role of *what matters* to students as a catalyst for improving teaching practice. The study empowered students to share their views on things that matter to them in teaching and learning science, which served as feedback on teacher practice, making them aware of the impact of their instruction. The process encouraged the teachers to evaluate their teaching approaches by adjusting them based on students' input, which helped improve their practice. There was co-construction of knowledge in the process where teachers and students (indirectly) contributed to shaping the learning environment, leading to a deeper engagement and motivation for learning. Exploring *what matters* to students and surfacing that for teachers' professional development offered valuable insights into fostering meaningful engagement and learning experiences in the science classroom. The benefit is that students' perceptions and interests did not just become something that was described from a distance but actually became part of how teachers implemented the curriculum to effect changes in their classroom practices.

Research that uses CHAT in designing, implementing, and analysing professional development in science, especially in Africa, is almost non-existent. This study is the first to apply Change Laboratory in Ghana and in science teacher professional learning in curriculum implementation, thereby extending the application of Change Laboratories in African educational settings, particularly science teacher professional learning. It thus adds to a growing body of literature that applies the interventional aspect of CHAT to study teacher professional learning. The value of this is that it addresses the gap in literature where professional development tends to provide teachers with information that they cannot apply in their classrooms. The literature highlighted the limitations of the prevalent cascading model of teacher professional learning, which impede classroom practice (Abaka, 2023; Gyimah & Ayinselya, 2022; Hassler et al., 2018; Vhurumu, 2021.) The intervention supported the development of participants' agency and expansive learning to their own activity breaking away from the status quo. The literature indicates that science teachers in Africa are rarely provided with professional development programmes that allow them to author their own responses to challenges and complexities in their activity (Abreh, 2018; Bantwini, 2018; Sodangi et al., 2022). The intervention provided opportunities for teachers to collaborate and learn from each other, enabling them to transform their classroom practices, something which has proven difficult to achieve by the dominant approaches to teacher professional development in Africa. Ongoing support and collaborative efforts are recognised as beneficial for enhancing teachers' teaching strategies and lesson planning (Ogegbo et al., 2019).

The study further contributes to knowledge in science education in Africa by going beyond describing the problems in science teaching in Africa (Benson et al., 2020; Brobbey, 2020; Mabula, 2012; Humphrey-Darkeh et al., 2022) to show how viable solutions can be reached by the teachers themselves when they are given the needed platform and support. It addresses the concerns that research has been helpful in only highlighting challenges and that the impact of research on science education policy implementation in Africa tends to be unsatisfactory (Engida, 2002).

8.4.2 Theoretical

TADS is a relatively new framework in CHAT but has been applied as an analytical framework to trace the emergence of agency in different contexts, including parenting (Hopwood & Gottschalk, 2022) and children's development (Johnson et al., 2020). This study adds to a nascent but growing number of studies that apply the TADS framework in analysing data from Change Laboratory (Grant, 2022; Morselli & Sannino, 2021; Sannino, 2022). In particular, this study is the first in a school setting to draw on the idea of kedge anchors to see how it might work with Change Laboratories in schools, which proved successful.

According to Hopwood (2022) agency in CHAT has been discussed under three key frameworks: transformative activist stance by Stetsenko (2017, 2019); TADS by Sannino (2015a, 2015b, 2022) and relational agency by Edwards (2010, 2012, 2016). Despite all these frameworks rooted in the work of Vygotsky, “there are limited cross-references between them” (Hopwood, 2022, p.1). Hopwood, therefore, calls for more dialogue among these frameworks, arguing that “we lose out on valuable insights that can be gained by bringing different CHAT approaches to agency into view alongside one another" (p.1). This study responds to that call. It demonstrated that one key idea of relational agency, which is common knowledge, could work coherently with the idea of a second stimulus from the TADS framework, and that common knowledge can be crucial in addressing the conflict of motives in the TADS framework, which had not been done before.

Many Change Laboratories, especially in schools, have theoretically focused on contradictions, expansive learning, and double stimulation in a general way, with few focusing on TADS (Hopwood, 2023). One of the few studies, though not in a school setting, includes Lilley (2020), where conflict of motives and systemic contradictions are linked together. However, to the best of my knowledge, no study has tried to work with TADS and relational agency frameworks as an extension to understanding contradictions and expansive learning, which this study did. This was done through careful consideration from both practical and analytical perspectives. The Change Laboratory sessions utilised the concept of *what matters* to students as a second stimulus. It was imperative to carefully consider how teachers could develop common knowledge of their students in the first place. Two options were considered: bringing students and teachers together to directly share their perspectives, or indirectly incorporating student voice into the Change Laboratory sessions to foster the development of common knowledge among teachers. After careful consideration, the latter option was chosen as the preferred approach, with the reasons for this decision being discussed in the study's limitations section. From an analytical standpoint, it was necessary to trace how the concept of *what matters* to students evolved into a second stimulus to enable teachers to implement the new curriculum. Therefore, working with these two frameworks was not so simple and straightforward, but it was done carefully to bring it into practicality and in a wide, complex analytical process.

8.4.3 Methodological

This study's small but significant contribution is methodological, even though it was not originally intended to develop a new methodology. The specific contextual circumstances and how the Change Laboratory was organised in this study necessitate a discussion of this aspect.

Traditionally, Change Laboratories have a very specific theoretical foundation and have been conducted in a somewhat prescriptive manner. However, there have been variations in recent years, such as the learning lab (Afacan et al., 2021; Bal et al., 2021) and the change room (Thorgeirsdottir, 2019). Moreover, within the framework of the main Change Laboratory, aspects of their design and execution have been evolving to better suit contextual circumstances.

In this study, as discussed in the methodology section (Chapter 4), the key methodological aspects of the Change Laboratory, including its processes and principles, were carefully upheld. These processes involved collecting mirror data from the participants' workplaces, utilising different surfaces for analysis, and recording the sessions for further examination (Hopwood, 2024; Virkunnen & Newnham, 2013). Data was gathered from the participants' activity systems through interviews and observations, which served as the first stimulus. The three key surfaces traditionally used in Change Laboratory interventions were applied in this study. However, the triangles representing activity theory, which are higher abstraction surfaces, did not work as effectively as anticipated. Some participants struggled to engage with these abstractions, making them less effective as a second stimulus.

To address this challenge, I improvised by introducing alternative second stimuli that resonated better with the participants. These included summaries and excerpts from interviews about *what matters* to students, teachers' reflective journals, and lesson plan templates designed by the teachers. These contextually relevant second stimuli proved to be more effective, functioning organically within the process by enriching the discussion (see Chapter 4s). The improvisation with contextually relevant stimuli in the Change Laboratory process highlights the adaptability required when theoretical tools do not work as expected in practice.

Change Laboratories have typically focused on a single institution, with only a few involving multiple school sites (Hopwood, 2014). This study marks the first instance where a Change Laboratory has brought together teachers from the same subject area—science—from multiple institutions to collaboratively develop common ideas for improving their practice in that subject. This approach fostered an interplay between teachers working together to create solutions and models that could be applied in different institutions. The solutions developed by the teachers to address contradictions in their activity systems were implemented individually in their respective schools, rather than by the entire group. This approach is particularly well-suited for the Ghanaian context, where most JHSs have only or tow science teachers. Instead of collaborating with teachers from the same school who teach different subjects, this study involved science teachers from different schools; it also represents an extension of the work in adapting and evolving Change Laboratories to fit specific contexts.

There has been a call for greater inclusion of students' voices in Change Laboratories, as a review by Hopwood (2024) highlights the low involvement of students in these settings. While this study did not directly involve students as participants in the Change Laboratory, their voices were indirectly conveyed to the teachers involved. The indirect inclusion of students' voices in the Change Laboratory process, is a valuable step towards addressing the call for greater inclusion of students in these settings. Although students were not direct participants, ensuring that their perspectives were considered in the discussions significantly impacted the outcome of the process. This approach helped bridge the gap between teachers' efforts to improve their practices and students' actual needs and experiences, which was crucial for meaningful pedagogical change.

Discussing how the study's specific context influenced the organisation of the Change Laboratory contributes to the ongoing conversation about how Change Laboratory can be tailored to different settings. This not only enriches the methodological literature but also provides practical insights for future researchers working in similar contexts.

8.5 Critical reflection on the limitations of the study

Change Laboratory interventions are time-demanding, and the sample for the study consisted of teachers who were motivated and willing to go the extra mile to bring change to their practice. Not every science teacher may be willing to spend some extra time on their professional practice. However, the solutions identified are very feasible and can be applied by any science teacher faced with a similar context in their classroom.

Student voices about *what matters* to them were indirectly conveyed to teachers. Given another opportunity, I would bring teachers and students to the Change Laboratory session. This might have changed the dynamics of the Change Laboratory by further enriching the sessions. By facilitating direct interaction between teachers and students within this collaborative space, teachers would gain even deeper insights into *what matters* most to their students and how they perceive the learning experience. This direct engagement could foster greater empathy, understanding, and co-creation of solutions tailored to meet the specific needs and interests of the students. Moreover, they might have contributed something significant to the teachers' expansive learning process as they might have questioned, analysed, or helped build solutions in different ways.

However, it must be noted that there are good reasons why an indirect approach was used in the study. First, there could be complications in the process as the teachers and students could experience different conflicts of motives. Also, there are contextual reasons why students may not be willing to voice out their opinions in the presence of their teachers because of hierarchy. Power is present in schools, and teachers usually hold the power. In my opinion, through interviews, students' voices were heard without the fear of being unable to articulate their ideas.

To address the seventh phase of expansive learning, which involves consolidation and generalisation, it can be argued that I could have involved headteachers. They could have provided additional perspectives and insight into the issues. They will also have help to sustain and support some of the ideas. Their involvement could have been valuable in the implementation phase or in subsequent discussions about how to scale up the interventions in their schools, as it has suggested that the involvement of leadership can help sustain change long-term (Hopwood, 2024). While involving headteachers could have been great, it could have changed the climate of the discussion, and teachers might have found it difficult to be vulnerable and share their frustrations and difficulties with their leaders present. While it might have helped, the way I engineered it also created an important safe space for teachers to share those vulnerable aspects of their practice. The approach created a space where teachers felt comfortable expressing their concerns without fear of judgement or reprisal. It facilitated an open and honest dialogue, which was essential for meaningful professional learning.

While contradictions occur at systemic levels, what this study has shown is that it is possible to address some of these contradictions and the associated conflict of motives encountered by teachers in a particular setting. These contradictions within the system, such as the lack of resources and the emphasis on curriculum coverage at the expense of student active learning and engagement, remain prevalent in the broader Ghanaian education system. The main concern is how insights from the Change Laboratory could be scaled out to the wider Ghanaian context. I think this will require multiple interconnected Change Laboratories from local to district, regional and national levels with longitudinal follow-up, which is the focus of the fourth generation of activity theory (Engeström & Sannino, 2021). According to Engeström &

Sannino (2021), “such fourth-generation Change Laboratories face methodological and practical challenges that are different from those of earlier CLs and require concerted research efforts in their own right” (p.21). That notwithstanding, the ideas generated from this Change Laboratory can start a national conversation about how effective teacher-professional learning can be initiated. This may involve collaboration between researchers, policymakers, educational leaders, teachers, students, and other stakeholders to co-design and implement interventions that address systemic contradictions in the education system. It will also require a shift towards more participatory and collaborative decision-making and policy implementation approaches.

Collecting the data in a single term presents some limitations as it was not enough to follow the teachers to see how they would sustain the change in their practice. There were practical and logistical reasons why I could not follow up with teachers to see whether they would sustain the change in their practice period time, as my study duration was limited. However, the evidence is strong in showing that teachers could implement changes and had plans to continue in the future. It would have been better to be able to have a longer trail, to understand those changes over a longer term, but that does not mean anything less about the fact that teachers were able to address those contradictions and conflicts of motives and learn expansively, taken on *what matters* to students to make relevant, impactful changes in their practice.

8.6 Implications of the study

This study has shown that science teachers professional learning and practice can be enhanced when teachers are offered effective professional development. Using the Change Laboratory as the platform, the teachers could analyse the tension in their activity system and design their own solutions to overcome the contradictions in their activity system. I have shown that it is possible for research to support teachers to transform their practice even when they think it is not possible or believe that conditions are not favourable. Although the results of this study are of particular interest to Ghana, they can be applied to similar contexts, especially in Africa, where teachers are faced with challenges implementing a new curriculum. Therefore, the findings are relevant as thinking tools that others can use to adapt to their context.

Based on my study's findings, I suggest a need to think about student-centred teaching and learning differently. This should start at the policy level as policies play a critical role in an activity system, constituting both a part in the 'tools' and the 'rules' – and would be linked to the systemic and historical barriers to change. The key policy document for this study was the new science curriculum as the cornerstone for science teaching and learning. This document was critically analysed and implemented in the Change Laboratory, although other policies could affect changes to teachers' practices. It is therefore recommended that curriculum policies, especially ones that focus on student-centred teaching and learning, consider *what matters* to students to bring change in teaching practice.

In practice, by developing student-centred pedagogy, teachers could take into consideration *what matters* to students**.** Exploring student perceptions, interests and attitudes towards science is crucial for informing pedagogical practices and promoting student-centred approaches in science education. Teachers must understand *what matters* to students and what influences their engagement with science and then tailor their instructional strategies to better meet students' needs and interests.

While Change Laboratory may not be universally applicable in every school or context, because it needs resources such as time, willing participants, etc., there are valuable principles and lessons that can be adapted and applied to enhance teacher professional development more broadly. Creating collaboration and idea development opportunities among teachers is crucial for fostering a culture of continuous learning and improvement. This can involve establishing regular meetings, workshops, or professional learning communities where teachers can share experiences, exchange ideas, and learn from each other's practices. Facilitating reflective practices among teachers is also essential. Providing time and space for teachers to critically examine their own teaching methods, student outcomes, and areas for growth can lead to meaningful insights and improvements in practice. This could involve structured reflection activities, peer observation and feedback, or mentorship programs. Moreover, integrating student perspectives and interests into professional development can be a powerful stimulus for reflection and innovation. By understanding *what matters* to students and incorporating their voices into discussions about teaching and learning, teachers can tailor their approaches to better meet the needs and interests of their students, which will also have a positive impact on the work of teachers.

In contexts like Ghana, there is often an assumption that successful curriculum implementation requires smaller class sizes and well-equipped laboratories for engaging and active science teaching. However, this study challenges that notion by demonstrating that providing teachers with dedicated time for critical reflection and collaborative work, can lead to meaningful changes in practice within existing resource constraints. Therefore, rather than solely focusing on resource-intensive solutions, educational stakeholders should prioritise strategies that empower teachers to critically reflect on and adapt their practice within their current contexts. This approach not only maximises the utilisation of existing resources but also fosters a culture of continuous improvement and innovation within the education system. Ultimately, by investing in professional development initiatives that promote collaborative inquiry and reflective practice, schools can enhance the quality of teaching and learning without necessarily requiring significant infrastructure or resource allocation changes.

The study has implications for research as well. I agree with Botha (2017) when he argues that "if serious changes are to be made in our schools and to our education systems, then perhaps they should start with our traditions of research" (p. 91). This is because for over some decades now research on science education in Africa has continued to illuminate the challenges.

Future research in science education could adopt a more solution-oriented approach like the one used in this study. This might involve conducting studies that identify challenges and investigate effective strategies, interventions, or best practices that can address these challenges in science education in Africa. Furthermore, collaborative efforts between researchers, educators, policymakers, and other stakeholders could be beneficial in co-designing and implementing professional development programs tailored to African science teachers' specific needs and contexts. By adopting a more proactive and collaborative approach to research such as the use of Change Laboratory, the field can move closer to addressing the persistent challenges in science teacher professional learning and fostering positive change in science education across the continent.

The study has led to significant insights and pedagogical changes among the research participants, demonstrating how the Change Laboratory helped a small group of teachers align their practice with the intended curriculum. It marks an important first step in showcasing the potential for such changes at the local level. However, key questions remain: what is needed to maintain and support these teachers' continued learning and practice? and what kind of policy support is necessary for scaling this type of professional learning more broadly? These are critical issues not addressed by the current study, and future research could focus on exploring them further to ensure the sustainability and wider implementation of such professional learning initiatives.

8.7 Final reflections

As a researcher interventionist, I had varying roles compared to the participants (Virkkunen & Newnham, 2012). I served as the organiser and supervisor of the Change Laboratory sessions. This involved planning the entire session, preparing the agenda for each meeting, securing venues, and managing logistics during the sessions. Additionally, I acted as the chair of the discussions, facilitating the dialogue and ensuring that all participants had the opportunity to express their views.

Building mutual trust among the participants was a crucial aspect of my role. I created a conducive environment where open communication was encouraged and respected to achieve this. I also played a key role in ensuring that ideas expressed during the sessions were clearly understood. This involved seeking clarifications, challenging assumptions, summarising discussions, and highlighting key ideas. By fulfilling these roles, I helped foster a collaborative and productive atmosphere where participants felt comfortable sharing their perspectives and engaging in meaningful dialogue.

As the conductor of the process, I also had to compel the participants to analyse and question their activity with the help of the mirror data. It enabled the participants to identify the root cause of the problems in their activity system. In this role I needed to be "sensitive to various manifestations of inner contradictions in the activity system in the participants' speech such as expressions of impossibility, double-blind, conflict and dilemmas, and bring the opposition of the divergent needs, motives and pressures expressed in them to a head" (Virkkunen & Newnham, 2013, p.107). Moreover, as a researcher interventionist, I was the one to record the whole process and analyse it for the next session. These diverse roles within the Change Laboratory provided invaluable learning experiences throughout my PhD journey, deepening my understanding of research methodologies and intervention strategies. But this is just the beginning of my learning.

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APPENDICES

APPENDIX 1: Sessional planning templates

Workshop number:

To do list:		
Main purpose:		
Time	Activity	Tools and stimuli for mirroring
	Introduction Issues to be discussed Conclusion	

Participants' task for the next session:

APPENIX 2: Ideas that matter to students used for the interview

- Performing well in science
- Getting understanding
- Connecting to my personal experience
- Applying the knowledge
- Being active in teaching and learning
- Getting support from mates
- Getting teachers attention

APPENDIX 3: Good Interview guides followed

- I followed the rules of polite conversation
- I interviewed participants in a comfortable place
- I planned well before the interview began
- I learned to listen well to participants
- I explored participants’ understanding

APPENDIX 4: Sample synoptic unit developed during analysis

	S1	S2	S3	S4	S5	S6
Resources and improvisation	Teachers believed that without resources, especially science labs understanding science for student become difficulty, and teaching become difficult as well as they have to teach in abstract. This is because they cannot demonstrate certain ideas. Teachers were of the opinion that without resources the only option was to use teacher centred methods like lecture. Inability to engage students actively in class was also attributed the lack of resources. This is because engaging students actively was equated with practical lessons	Here teachers changed their position and improvisation was given a positive image as option to cater for the lack of resource and therefore should be tried out as it will make their lesson practical. Teachers questioned why certain resources are not part of the new curriculum. Teachers believe they needed resources to be able to deliver the curriculum. This because teachers believe that without resources they cannot act as facilitators as expected of them under the new curriculum.	In discussing the *what matters* to students, the idea of teaching science beyond classroom was taken up by teachers as it was realized that they can take their students outside of the classroom to use resources outside of the classroom like nature to let students have experiential learning. The suggestion of student bringing materials was criticized by the teachers as some saw it as not a feasible option because student will not bring. However suggestions were	Teachers begun to put to actions some of the suggestion made like taking students outside of the class to teach science and reported on their outcome which was successful as students enjoyed the lesson. Improvisation was also into practice by some of the teachers. Teacher took time to explicate on some of the ideas like improvisation by looking the benefits, challenges, feasibilities, alternatives etc Teacher came to realized that there are a lot of	The idea of improvisation was further discussed. Teacher expanded on how they will apply some of these discussed in previous sessions in their lessons in the ensuing week. Ideas like student bring materials and taking students outside of classroom were emphasized in teachers planned lessons. There was shift in teachers ideas that resources were the key ingredient for making the curriculum work to active involvement of	Teachers reported on how the students having experiential learning within their environment helped in their teaching as student could actually see and touch thing which made them to understand. Some teacher indicated the need for them to use these ideas (like taking students within the community where resources exist) in their future lessons.

	which they believe erase students misconceptions. Teachers were aware that without these resources, improvisation can be done but criticized it saying that authorities hide behind that idea and fail to provide the needed resource. They expressed the challenges in having access to technology in teaching science as well	Teachers begun to realized that resources can exist outside of their classroom so one way to addressing the lack of resource is to embark on field trip. Teachers made a turning point in their thinking about resources when they came to realized that they do not need resources to be able to actively involve students in their class as not all activities involve practical work. To address the issue of lack of resource, suggestions such as students materials from home and students watching videos were made.	made as to how to make the idea feasible	options to fall on in the absence of science labs for the schools. Some of these resources can be brought by the students, some can be within the school immediate environment or outside which field trips can be used to access. It was also realized that student understanding of science does not necessary depend on having science lab but teachers being resourceful and relating things to student environment	student as seen as key.	

APPENDIX 5: UTS ETHICS APPROVAL

HREC Approval Granted - ETH21-6684

Isaac.S.Coffie/Inbox

RE

research.ethics@uts.edu.au

To:Research.Ethics@uts.edu.au,MunYee.Lai@uts.edu.au,Isaac.S.Coffie@student.uts.edu.au

Thu, Apr 7, 2022 at 4:10 PM

Dear Applicant

Re: ETH21-6684 - "Teacher learning from students: a relational turn in Junior High School science curriculum implementation in Ghana"

Thank you for your response to the Committee's comments for your project. The Committee agreed that this application now meets the requirements of the National Statement on Ethical Conduct in Human Research (2007) and has been approved on that basis. You are therefore authorised to commence activities as outlined in your application.
You are reminded that this letter constitutes ethics approval only. This research project must also be undertaken in accordance with all UTS policies and guidelines including the Research Management Policy.

Your approval number is UTS HREC REF NO. ETH21-6684.

Approval will be for a period of five (5) years from the date of this correspondence subject to the submission of annual progress reports.

The following standard conditions apply to your approval:

- Your approval number must be included in all participant material and advertisements. Any advertisements on Staff Connect without an approval number will be removed.
- The Principal Investigator will immediately report anything that might warrant review of ethical approval of the project to the Ethics Secretariat.
- The Principal Investigator will notify the Committee of any event that requires a modification to the protocol or other project documents, and submit any required amendments prior to implementation. Instructions on how to submit an amendment application can be found here.
- The Principal Investigator will promptly report adverse events to the Ethics Secretariat. An adverse event is any event (anticipated or otherwise) that has a negative impact on participants, researchers or the reputation of the University. Adverse events can also include privacy breaches, loss of data and damage to property.
- The Principal Investigator will report to the UTS HREC or UTS MREC annually and notify the Committee when the project is completed at all sites. The Principal Investigator will notify the Committee of any plan to extend the duration of the project past the approval period listed above.
- The Principal Investigator will obtain any additional approvals or authorisations as required (e.g. from other ethics committees, collaborating institutions, supporting organisations).

- The Principal Investigator will notify the Committee of his or her inability to continue as Principal Investigator including the name of and contact information for a replacement.

This research must be undertaken in compliance with the Australian Code for the Responsible Conduct of Research and National Statement on Ethical Conduct in Human Research.

You should consider this your official letter of approval. If you require a hardcopy please contact the Ethics Secretariat.

If you have any queries about your ethics approval, or require any amendments to your research in the future, please don't hesitate to contact the Ethics Secretariat and quote the ethics application number (e.g. ETH20-xxxx) in all correspondence.

Yours sincerely,
The Research Ethics Secretariat

On behalf of the UTS Human Research Ethics Committees
C/- Research Office
University of Technology Sydney
E: Research.Ethics@uts.edu.au

Ref: E38

APPENDIX 6: Permission letter from Ghana Education service

GHANA EDUCATION SERVICE

(WESTERN NORTH REGION)

In case of reply the number and date of the letter should be quoted

Tel: 0312094221
E-mail: [redacted]
My Ref. No.: [redacted]
Your Ref No.: ……………………

REPUBLIC OF GHANA

Municipal Education Office
P.O. Box 75
Sefwi Wiawso

2nd February, 2022.

RE: PERMISSION TO CONDUCT RESEARCH IN YOUR MUNICIPALITY

In reference to your letter dated 19th January, 2022 on the above subject matter, I am happy to inform you that permission has been granted for you to conduct your research in the Sefwi Wiawso Municipality.

The engagement with teachers in the research work should not be at the expense of the students normal contact hours.

There should be strict adherence to Government protocols on COVID-19

Thank you.

[redacted]

MUNICIPAL DIRECTOR
GHANA EDUCATION SERVICE
SEFWI - WIAWSO

……………………………………………
(ABRAHAM FLETCHER)
MUNICIPAL DIRECTOR OF EDUCATION
SEFWI WIAWSO

PROF. NICK HOPWOOD
PROFESSOR OF PROFESSIONAL LEARNING
SCHOOL OF INTERNATIONAL STUDIES & EDUCATION
UTS
15 BROADWAY, ULTIMO NSW 2007

CC:
THE REGIONAL DIRECTOR
GHANA EDUCATION SERVICE
BIBIANI

THE HEADTEACHERS
SELECTED SCHOOLS
SEFWI WIAWSO MUNICIPAL

APPENDIX 7: INTEVIEW GUIDES

INTERVIEW GUIDE FOR FOCUS GROUP MODIFIED AFTER PILOT TESTING

1. What words would you use to describe your ideal science lesson?
    - Do you like science?
        - ✓ Why or Why not?
    - When do you enjoy science lesson?
    - So, in your opinion, how should teachers teach Science?
2. Think of a time that you thought something you learned in science was really important or beneficial for you. Tell me about that.
    i. Why was it important? / What made it important to you?
    ii. What were you doing in the lesson? / Did you contribute in that lesson? & how?
3. What do you think doing well in science means?
    i. Do you do well/not so well in science?
    ii. How do you know that you are doing well in science?
    iii. How is doing well in science the same or different from doing well in other subjects? / Do you do better in science than the other subjects? & Why?
4. If you could change something about your science lessons, particularly how it is taught (rather than the room or environment), what would you change?
    i. Why?
    ii. What difference would that make to you?
5. I'm interested in *what matters* to you when you learn science. I mean the things you find important. What makes science worth learning. What makes lessons valuable for you. If I walked into a science lesson that focused on things that matter to you, what would I see? What would you be doing? What would the teacher be doing?
    i. What do you want your science teacher to do to make science lesson more exciting?
    ii. Will that make you happier and more interested in science?
    iii. If you are given the opportunity to teacher science how will you teach it.

INTERVIEW GUIDE FOR FOCUS GROUP FOR PILOT TESTING

1. What words would you use to describe your ideal science lesson?
2. Think of a time that you thought something you learned in science was really important or beneficial for you. Tell me about that.
    i. Why was it important?
    ii. What were you doing in the lesson?
3. What do you think doing well in science means?
    iii. How is doing well in science the same or different from doing well in other subjects?
4. If you could change something about your science lessons, particularly how it is taught (rather than the room or environment), what would you change?
    iv. Why?
    v. What difference would that make to you?
5. I'm interested in *what matters* to you when you learn science. I mean the things you find important. What makes science worth learning. What makes lessons valuable for you. If I walked into a science lesson that focused on things that matter to you, what would I see? What would you be doing? What would the teacher be doing?

INTERVIEW GUIDE FOR TEACHERS: 1ST INTERVIEW

1. *What matters* to you as a science teacher?
   a. When you are teaching a class, what is important to you?
   b. What do you feel your key responsibilities are as a science teacher?
   c. When you think of what science education offers students, what do you value most?
   d. What are some of the challenges of teaching science?
2. Can you tell me about a time when you felt the science teaching really mattered to the students?
   a. What were you teaching?
   b. How were you teaching it?
   c. What were the students doing?
   d. What made you think it really mattered to the students?
3. Thinking about the new curriculum, what are the most important changes that you see in terms of your practice?
   a. What opportunities do you think this will present?
   b. What might be challenging about this?
4. The new curriculum mentions student-centred approaches to teaching. What does this mean to you?
   a. If I were to observe a science lesson that was really student-centred, what would I see?
   b. How might that be different from a typical lesson that we might see in Ghana?

INTERVIEW GUIDE FOR TEACHERS: 2ND SECOND INTERVIEW

1. What has changed with regard to your understanding of *what matters* to students compared to the start of the workshops? How did it change? How has the change impacted your understanding of the new curriculum?
2. What has changed or is different from now compared to the start of the workshops in your understanding of the new curriculum.
3. What advise will you give to a colleague with regards to the benefits you have derived from the workshops. What has been the most important issue, discussion idea or theme for you in the workshop and why?
4. Think about a recent lesson that you considered *what matters* to you students
    a. What were you teaching?
    b. How were you teaching it?
    c. What were the students doing?
    d. Why do you think it was or not successful?

5. Tell me, what have you done differently in your practice in the light of all the discussions we have had during the workshops?
   How did you do it?
   Why did you do it?
6. Think about your future
   What are some of the things you want to keep on doing?
   Why do you want to keep on doing them?
   What are some new things you want to try out in your teaching?

APPENDIX 8: PARTICIPANT INFORMATION SHEET AND INFORMED CONSENT

PARTICIPANT INFORMATION SHEET FOR TEACHERS: (OBSERVATION AND INTERVIEW)

[ETH21-6684] TITLE OF RESEARCH: TEACHER LEARNING FROM STUDENTS: A RELATIONAL TURN IN JUNIOR HIGH SCHOOL SCIENCE CURRICULUM IMPLEMENTATION IN GHANA

WHO IS CONDUCTING THIS RESEARCH?

My name is Isaac Sonful Coffie and I am a student at UTS. My supervisor is Prof. Nick Hopwood of the Faculty of Arts and Social science, with email address: Nick.hopwood@uts.edu.au and tel:+61295144658

WHAT IS THE RESEARCH ABOUT?

The purpose of this research is to help science teachers to change their practice under the new curriculum by coming to learn *what matters* to their students and align their pedagogies to that.

WHY HAVE I BEEN INVITED?

You have been invited to participate because you are science teachers implementing the new science curriculum in Junior High School.

Before you decide to participate in this research study, please check the criteria, you must be teaching JHS1 science in the Wiawso municipality.

Your contact details were obtained from your school administrator.

WHAT DOES MY PARTICIPATION INVOLVE?

If you decide to participate, I will invite you to

- be involved in 2 semi- structure interviews with each lasting for 45-60 minutes on how you can know *what matters* to your students in science learning and align your practices to that. The interviews will be face -to-face and will be audio-recorded. All the audio recorded interviews will be transcribed and use for analysis in a non-identifiable manner. The interview will take place in a venue acceptable to you like an office space in your school. The purpose of the recording is to always have access to the raw data for purpose of analysis.
- be observed as you teach for 1 hour on 3 different occasions. No audio or video recording will be made only; handwritten notes will be taken in non-identifiable form.

- be involved in 6 workshops (every second with five other colleagues where I, the researcher, will be the facilitator to discuss ways you can implement the new science curriculum by taking *what matters* to students into consideration. Each workshop will last for 1hour. The venue for the workshop will be a negotiated place agreed by all participants, eg it can be in one of your school where you teach or will move to each participant school or the campus of Wiawso College of Education. The workshops will be audio recorded and transcribed for the purpose of research analysis in a non-identifiable manner

ARE THERE ANY RISKS/INCONVENIENCE?

Yes, there are some risks/inconvenience.

They are;

1. you may feel embarrassed during the observation that they are being judged or evaluated.

2. you may be burdened for the time involved in being interviewed, reading and signing forms, workshopping.

3. issues discussed in workshops, may raise uncomfortable memories, or create anxiety relating to classroom interactions.

4. you may feel embarrassed or awkward during interview for sharing certain information and the process itself may cause you to be anxious.

5. you may be worried that aspects of your performance might be shared with people who could negatively judge you.

6. you may be embarrassed if an idea to practice does not go well in the classroom.

7. you may be asked to travel to the workshop venue which will not be 5-10minutes from your workplace in which you will be reimbursed to and fro.

The following strategies will be put in place to minimize the risks.

1. To reduce risk of inconvenience for you, workshop and interviews times and venues will be negotiated at your convenience. Moreover, the venue of the worship will be negotiated and if possible rotated to each participant school to reduce the level of inconvenience associated with the travelling

2. To reduce and/or manage risk associated with discomfort in the workshop. proper code of conduct will be developed in collaboration with your other colleagues from the start of the workshops so that there will proper ways of working together where no one is embarrassed and intimidated.

3. I will be guided by my research objectives which will be to support you in the implementation of the new science curriculum and not to judge or evaluate you. Also, I will not impose any ideas during workshop for you to try but facilitate a collegial and collaborative discussion among you to identify the challenges and find ways of making the implementation of the science curriculum better. This reduces the risk of you having to do things on own without any support.

DO I HAVE TO TAKE PART IN THIS RESEARCH PROJECT?

Participation in this study is voluntary. It is completely up to you whether or not you decide to take part.

If you decide not to participate, or to withdraw from the study, it will not affect your relationship with the researchers or the University of Technology Sydney or your school.

WHAT IF I WITHDRAW FROM THIS RESEARCH PROJECT?

If you wish to withdraw from the study once it has started, you can do so at any time without having to give a reason, by contacting your school administrator. If you withdraw from the study, your audio records will be erased and notes relating to your observation will be destroyed.

However, it may not be possible to withdraw your data from the study results if these have already had your identifying details removed.

WHAT WILL HAPPEN TO INFORMATION ABOUT ME?

By signing the consent form you consent to the research team collecting and using personal information about you for the research project. All this information will be treated confidentially.

Your data will be stored in the following format: handwritten notes, audio recordings and transcripts. Audio data will be stored on Cloudstor and on a password protected hard drive. Anonymised data will be saved on UTS OneDrive, a backup copy will be saved and password protected in Cloudstor, the university cloud storage system. Data in storage will not contain your' personal details such as your school and your name will be anonymised by using pseudo name. Hard copies of the researcher's notes will be stored in a locked UTS researcher filing cabinet locker. Only my academic supervisor and I will have access to this data.

We would like to store your information for future use in research projects that are an extension of this research project. In all instances, your information will be treated as confidential and stored securely.

It is anticipated that the results of this research project will be published and/or presented in a variety of forums. In any publication and/or presentation, information will be provided in such a way that you cannot be identified, except with your permission. This will done by using pseudo names

In accordance with relevant Australian and/or NSW Privacy laws, you have the right to request access to the information about you that is collected and stored by the research team. You also have the right to request that any information with which you disagree be corrected. Please inform the research team member named at the end of this document if you would like to access your information.

The results of this research may also be shared through open access (public) scientific databases, including internet databases. This will enable other researchers to use the data to investigate other important research questions. Results shared in this way will always be de-identified by removing all personal information (e.g. name, address, date of birth etc.).

WHAT IF I HAVE ANY QUERIES OR CONCERNS?

If you have queries or concerns about the research that you think I or my supervisor can help you with, please feel free to contact my supervisor, Prof Nick Hopwood on tel:+61295144658 email: nick.hopwood@uts.edu.au. You can also contact your school administrator.

You will be given a copy of this form to keep.

NOTE:

This study has been approved in line with the University of Technology Sydney Human Research Ethics Committee [UTS HREC] guidelines. If you have any concerns or complaints about any aspect of the conduct of this research that you wish to raise independently of the research team, please contact the Ethics Secretariat on ph.: +61 2 9514 2478 or email: Research.Ethics@uts.edu.au], and quote the UTS HREC reference number. Any matter raised will be treated confidentially, investigated and you will be informed of the outcome.

CONSENT FORM FOR TEACHERS (OBSERVATION AND INTERVIEW)

TITLE OF RESEARCH: TEACHER LEARNING FROM STUDENTS: A RELATIONAL TURN IN JUNIOR HIGH SCHOOL SCIENCE CURRICULUM IMPLEMENTATION IN GHANA

I ____________________ agree to participate in the research project being conducted by Isaac Sonful Coffie of University of Technology Sydney.

I have read the Participant Information Sheet or someone has read it to me in a language that I understand.

I understand the purposes, procedures and risks of the research as described in the Participant Information Sheet.

I have had an opportunity to ask questions and I am satisfied with the answers I have received.

I freely agree to participate in this research project as described and understand that I am free to withdraw at any time without affecting my relationship with the researchers or the University of Technology Sydney or my school.

I understand that I will be given a signed copy of this document to keep.

I am aware that I can contact his supervisor, Prof Nick Hopwood on tel:+61295144658 email: nick.hopwood@uts.edu.au or my school administrator if I have any concerns about the research.

____ ____/____/____

Name and Signature [participant] Date

____ ____/____/____

Name and Signature [researcher or delegate] Date

PARTICIPANT INFORMATION SHEET FOR STUDENT: INTERVIEW

TITLE OF RESEARCH: TEACHER LEARNING FROM STUDENTS: A RELATIONAL TURN IN JUNIOR HIGH SCHOOL SCIENCE CURRICULUM IMPLEMENTATION IN GHANA

Dear student,

My name is Isaac Sonful Coffie. I am a tutor at Wiawso College of Education and I am currently doing a study at University of Sydney in Australia with my two supervisors Dr. Mun Yee Lai and Prof. Nick Hopwood.

There is a new curriculum in use in Ghana. Your teachers and others are involved in working with me about how to make implement this curriculum in a way that really listens to students and *what matters* to them. You are therefore being asked to participate in this research because your teacher is involved.

If you are willing, I will have a group discussion with you and your two peers together about *what matters* to you in learning science. The group discussion will take place in your school in place where you all comfortable and secure and will last for 30 minutes which will be audio recorded. Your name will not be mentioned anywhere in public about this discussion and your participation will not affect your marks in school.

Please note that you may feel embarrassed or awkward for sharing certain information and the process itself may cause you to be anxious.

You can stop the discussion at any time if you are not comfortable without given any reason.

If you have issues or questions about this information or do not want to be part of this project you can contact your school administrator.

If you are happy to be part of this project, please complete the consent sheet.

Thank you.

CONSENT FORM FOR STUDENTS (INTERVIEW)

TITLE OF RESEARCH: TEACHER LEARNING FROM STUDENTS: A RELATIONAL TURN IN JUNIOR HIGH SCHOOL SCIENCE CURRICULUM IMPLEMENTATION IN GHANA

I ____________________ agree to participate in the research project being conducted by Isaac Sonful Coffie, Faculty of Arts and Social Sciences, Email: Isaac.s.coffie@student.uts.edu.au Tel: [redacted] or [redacted]

I have read the Participant Information Sheet or someone has read it to me in a language that I understand.

I understand the purposes, procedures and risks of the research as described in the Participant Information Sheet.

I have had an opportunity to ask questions and I am satisfied with the answers I have received.

I freely agree to participate in this research project as described and understand that I am free to withdraw at any time without affecting my relationship with the researchers or the University of Technology Sydney and my school.

I understand that I will be given a signed copy of this document to keep.

I am aware that I can contact Isaac Sonful Coffie, or my school administrator if I have any concerns about the research.

____ ____/____/____

Name and Signature [participant] Date

____ ____/____/____

Name and Signature [researcher or delegate] Date

PARTICIPANT INFORMATION SHEET FOR PARENT: INTERVIEW

TITLE OF RESEARCH: TEACHER LEARNING FROM STUDENTS: A RELATIONAL TURN IN JUNIOR HIGH SCHOOL SCIENCE CURRICULUM IMPLEMENTATION IN GHANA

WHO IS CONDUCTING THIS RESEARCH?

My name is Isaac Sonful Coffie and I am a student at UTS. My supervisor is Prof. Nick Hopwood of the Faculty of Arts and Social science, with email address: Nick.hopwood@uts.edu.au and tel:+61295144658

WHY HAS MY CHILD BEEN INVITED?

Your child has been invited to participate because they and their science teacher are involved in the implementation of the new science curriculum which is the focus of this study

Your contact details were obtained from child school administrator

WHAT DOES MY CHILD'S PARTICIPATION INVOLVE?

If you decide to allow your child to participate, they will be invited to have a group discussion with me and their two peers together about *what matters* to them in learning science. The group discussion will take place in their school in place where they all comfortable and secure and will last for 30 minutes which will be audio recorded. The purpose of the recording is to always have access to the raw data for purpose of analysis

ARE THERE ANY RISKS/INCONVENIENCE?

Yes, there are some risks/inconvenience. They are

1. your child may be burdened for the time involved in being interviewed, reading and signing forms

2. Issues discussed in interviews may raise uncomfortable memories, or create anxiety relating to classroom interactions

3. your child may feel embarrassed or awkward for sharing certain information and the process itself may cause them to be anxious.

The following strategies will be put in place to minimise the risks/ inconvenience.

To reduce and/or manage risk associated with discomfort; I will conduct the interviews in group with the presence of their peers to reduce risk of researcher being alone with your child. A group discussion will be in a location approved by the school principal and teacher, and could be in a shaded spot on the school grounds, or in a classroom not being used at the time. If indoors, the door will be left open, and people will be able to see in through windows, creating a private space where students can talk without being overheard, but not sealed off from others

DOES MY CHILD HAVE TO TAKE PART IN THIS RESEARCH PROJECT?

Participation in this study is voluntary. It is completely up to you whether or not you agree to allow your child to take part. If you decide not to allow your child to participate, it will not affect your relationship with the researchers and your child's school.

WHAT IF I WITHDRAW MY CHILD FROM THIS RESEARCH PROJECT?

If you wish to withdraw your child from the study once it has started, you can do so at any time without having to give a reason, by contacting Isaac Sonful Coffie Tel:

Email: Isaac.s.coffie@student.uts.edu.au. If you withdraw your child from the study, their audio will be erased.

However, it may not be possible to withdraw your child's data from the study results if these have already had their identifying details removed.

WHAT WILL HAPPEN TO INFORMATION ABOUT MY CHILD?

By signing the consent form, you consent to the research team collecting and using personal information about your child for the research project. All this information will be treated confidentially. The data will be stored in the following format: handwritten notes, audio recordings and transcripts. Audio data will be stored on Cloudstor and on a password protected hard drive. Anonymised data will be saved on UTS OneDrive, a backup copy will be saved and password protected in Cloudstor, the university cloud storage system. Data in storage will not contain your' child's personal details such as their school and name. They will be anonymised by using pseudo name. Hard copies of the researcher's notes will be stored in a locked UTS researcher filing cabinet locker. Only my academic supervisor and I will have access to this data.

We would like to store your child's information for future use in research projects that are an extension of this research project. In all instances, your child's information will be treated as confidential and stored securely.

It is anticipated that the results of this research project will be published and/or presented in a variety of forums. In any publication and/or presentation, information will be provided in such a way that your child cannot be identified, except with your permission. This will be done by using pseudo names for your child and their school.

In accordance with relevant Australian and/or NSW Privacy laws, you have the right to request access to the information about you that is collected and stored by the research team. You also have the right to request that any information with which you disagree be corrected. Please inform the research team member named at the end of this document if you would like to access your information.

The results of this research may also be shared through open access (public) scientific databases, including internet databases. This will enable other researchers to use the data to investigate other important research questions. Results shared in this way will always be de-identified by removing all personal information (e.g. name, address, date of birth etc.).

WHAT IF I HAVE ANY QUERIES OR CONCERNS?

If you have concerns about the research that you think I or my supervisor can help you with, please feel free to contact Isaac Sonful Coffie Tel:

Email: Isaac.s.coffie@student.uts.edu.au. You can also contact me if you want the information to be explained to you in Twi. You can also speak your child's school administrator.

You will be given a copy of this form to keep.

NOTE:

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CONSENT FORM FOR PARENT (INTERVIEW)

TITLE OF RESEARCH: TEACHER LEARNING FROM STUDENTS: A RELATIONAL TURN IN JUNIOR HIGH SCHOOL SCIENCE CURRICULUM IMPLEMENTATION IN GHANA

I ____________________ give permission for my child ________________ to participate in the research project being conducted by Isaac Sonful Coffie, Faculty of Arts and Social Sciences, Email: Isaac.s.coffie@student.uts.edu.au tel: or +

I have read the Participant Information Sheet or someone has read it to me in a language that I understand.

I understand the purposes, procedures and risks of the research as described in the Participant Information Sheet.

I have had an opportunity to ask questions and I am satisfied with the answers I have received.

I freely agree to allow my child to participate in this research project as described and understand that I am free to withdraw my child at any time without affecting my relationship with the researchers or the University of Technology Sydney or my child's school.

I understand that I will be given a signed copy of this document to keep.

I am aware that I can contact Isaac Sonful Coffie, or my child's school administrator if I have any concerns about the research.

____

Name of child [please print]

____ ____/____/____

Signature or mark of child [optional remove if not required] Date

____

Name Parent/Guardian [please print]

____ ____/____/____

Signature of Parent/Guardian Date

______________________________________ ____/____/____

Name and Signature [witness*] Date

PARTICIPANT INFORMATION SHEET FOR STUDENT: OBSERVATION

TITLE OF RESEARCH: TEACHER LEARNING FROM STUDENTS: A RELATIONAL TURN IN JUNIOR HIGH SCHOOL SCIENCE CURRICULUM IMPLEMENTATION IN GHANA

Dear student,

My name is Isaac Sonful Coffie. I am a tutor at Wiawso College of Education and I am currently doing a study at University of Sydney in Australia with my two supervisors Dr. Mun Yee Lai and Prof. Nick Hopwood.

There is a new curriculum in use in Ghana. Your teachers and others are involved in working with me about how to make implement this curriculum in a way that really listens to students and *what matters* to them. You are therefore being asked to participate in this research because your teacher is involved.

If you are willing, I will sit in 3 of your science lessons making notes only without any recording. Your name will not be written or mentioned anywhere in public about observation and your participation will not affect your marks in school.

If you do not want to be observed, you will be made to sit at place in your class where I cannot see you. In that case, no information about your participation in the class will be written and it will not affect your marks.

If you have issues or questions about this information or you do not want to be part of this project, please contact your school administrator.

If you are happy to be part of this project, please complete the consent sheet.

CONSENT FOR STUDENTS(OBSERVATION)

TITLE OF RESEARCH: TEACHER LEARNING FROM STUDENTS: A RELATIONAL TURN IN JUNIOR HIGH SCHOOL SCIENCE CURRICULUM IMPLEMENTATION IN GHANA

I ____________________ agree to participate in the research project being conducted by Isaac Sonful Coffie, Faculty of Arts and Social Sciences, Email: Isaac.s.coffie@student.uts.edu.au tel: [redacted] or [redacted]

I have read the Participant Information Sheet or someone has read it to me in a language that I understand.

I understand the purposes, procedures and risks of the research as described in the Participant Information Sheet.

I have had an opportunity to ask questions and I am satisfied with the answers I have received.

I freely agree to participate in this research project as described and understand that I am free to withdraw at any time without affecting my relationship with the researchers or the University of Technology Sydney and my school.

I understand that I will be given a signed copy of this document to keep.

I am aware that I can contact Isaac Sonful Coffie, or my school administrator if I have any concerns about the research.

____ ____/____/____

Name and Signature [participant] Date

____ ____/____/____

Name and Signature [researcher or delegate] Date

PARTICIPANT INFORMATION SHEET FOR PARENT: OBSERVATION

WHO IS CONDUCTING THIS RESEARCH?

My name is Isaac Sonful Coffie and I am a student at UTS. My supervisor is Prof. Nick Hopwood of the Faculty of Arts and Social science, with email address: Nick.hopwood@uts.edu.au and tel:

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WHY HAS MY CHILD BEEN INVITED?

Your child has been invited to participate because they and their science teacher are involved in the implementation of the new science curriculum which is the focus of this study

Your contact details were obtained from child school administrator

WHAT DOES MY CHILD'S PARTICIPATION INVOLVE?

If you decide to allow your child to participate, I will sit in 3 of your ward's science lessons making notes only without any recording. The notes will focus on how their teacher align their lesson to *what matters* to students. Your wards' name will not be written or mentioned anywhere in public about this observation and their participation will not affect their marks or grades in school.

ARE THERE ANY RISKS/INCONVENIENCE?

Yes, there are some risks/inconvenience. Participants may feel embarrassed during the observation that they are being judged or evaluated. To reduce discomfort in observation, I will be visible but discreet, quietly writing notes; I will introduce myself, and remind students my main focus is on the teacher's practices, and I will not write down any of their name.

DOES MY CHILD HAVE TO TAKE PART IN THIS RESEARCH PROJECT?

Participation in this study is voluntary. It is completely up to you whether or not you agree to allow your child to take part. If you decide not to allow your child to participate, it will not affect your relationship with the researchers and your child's school.

WHAT IF I WITHDRAW MY CHILD FROM THIS RESEARCH PROJECT?

If you wish to withdraw your child from the study once it has started, you can do so at any time without having to give a reason, by contacting Isaac Sonful Coffie Tel:

Email: Isaac.s.coffie@student.uts.edu.au. If you withdraw your child from the study, any written notes in relation to them will be destroyed.

However, it may not be possible to withdraw your child's data from the study results if these have already had their identifying details removed.

WHAT WILL HAPPEN TO INFORMATION ABOUT MY CHILD?

By signing the consent form you consent to the research team collecting and using personal information about your child for the research project. All this information will be treated confidentially. The data will be stored in the following format: handwritten notes. Anonymised data will be saved on UTS OneDrive, a backup copy will be saved and password protected in Cloudstor, the university cloud storage system. Data in storage will not contain your' child's personal details such as their school and name. They will be anonymised by using pseudo name. Hard copies of the researcher's notes will be stored in a locked UTS researcher filing cabinet locker. Only my academic supervisor and I will have access to this data.

We would like to store your child's information for future use in research projects that are an extension of this research project. In all instances, your child's information will be treated as confidential and stored securely.

It is anticipated that the results of this research project will be published and/or presented in a variety of forums. In any publication and/or presentation, information will be provided in such a way that your child cannot be identified, except with your permission. This will be done by using pseudo names for your child and their school.

In accordance with relevant Australian and/or NSW Privacy laws, you have the right to request access to the information about you that is collected and stored by the research team. You also have the right to request that any information with which you disagree be corrected. Please inform the research team member named at the end of this document if you would like to access your information.

The results of this research may also be shared through open access (public) scientific databases, including internet databases. This will enable other researchers to use the data to investigate other important research questions. Results shared in this way will always be de-identified by removing all personal information (e.g. name, address, date of birth etc.).

WHAT IF I HAVE ANY QUERIES OR CONCERNS?

If you have concerns about the research that you think or my supervisor can help you with, please feel free to contact Isaac Sonful Coffie Tel: [redacted]

Email: Isaac.s.coffie@student.uts.edu.au. You can also contact the researcher, if you want the information to be explained to you in Twi. You can also speak your child's school administrator

You will be given a copy of this form to keep.

NOTE:

This study has been approved in line with the University of Technology Sydney Human Research Ethics Committee [UTS HREC] guidelines. If you have any concerns or complaints about any aspect of the conduct of this research that you wish to raise independently of the research team, please contact the Ethics Secretariat on ph.: +61 2 9514 2478 or email: Research.Ethics@uts.edu.au], and quote the UTS HREC reference number. Any matter raised will be treated confidentially, investigated and you will be informed of the outcome.

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____

Name of child [please print]

____ ____/____/____

Signature or mark of child [optional remove if not required] Date

____

Name Parent/Guardian [please print]

____ ____/____/____

Signature of Parent/Guardian Date

____ ____/____/____

Name and Signature [witness*] Date

____ ____/____/____

Name and Signature [witness*] Date