Connected Learning for STEM (CL4STEM)

Strengthening Secondary School Teacher Capacities for Higher Order Thinking with Inclusion and Equity

CL4STEM Tanzania Endline Report

TANZANIA | BHUTAN | NIGERIA | INDIA

The Connected Learning for STEM (CL4STEM) project aimed to pilot an innovation and to research its effectiveness and potential scaling for capacity building of secondary school teachers in science and mathematics to foster higher order thinking with inclusion and equity. The CL4STEM pilot engaged teachers in curated OERs-based modules in science and maths and facilitated their participation in online communities of practice. It is a South-South collaboration among higher education institutions to adapt and pilot the Connected Learning Initiative (CLIx, https://clix.tiss.edu) in Tanzania, Nigeria, and Bhutan. CLIx has been successfully implemented at scale in India.

The associated research studies focused on two broad areas. First, the Impact Study analysed the impact of innovation on teachers' knowledge, attitudes, and practise for higher-order teaching and learning of science and maths inclusively and equitably. Second, the Innovation Diffusion Study generated knowledge on the processes of innovation and adoption for specific local contexts and the conditions that will support scaling.

Knowledge generated from this project would be disseminated to stakeholders in the ministries responsible for education and relevant regulatory and professional bodies to seed it into the country's policy agenda. Further, key insights from this project would be shared with other researchers and opinion leaders in the spirit of creating global public goods.

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The report is available for download at https://www.connectedlearningforstem.org. Any questions, suggestions or queries may be sent to the contact details indicated on the website.

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Abbreviations

BL	Baseline
CAST	Centre for Applied Special Technology
CBA	Competency Based Assessment
CBAM	Concerns Based Adoption Model
CBE	Competency Based Education
CL4STEM	Connected Learning for STEM
CLIx	Connected Learning Initiative
CoP	Community of Practice
CPD	Continuous Professional Development
EL	Endline
GB	Gigabyte
GPK	General Pedagogical Knowledge
HOTIE	Higher Order Thinking with Inclusion and Equity
IBBUL	Ibrahim Badamasi Babangida University, Lapai
ICT	Information and Communication Technology
IDRC	International Research Development Centre
IRB	Institutional Review Board
KAP	Knowledge, Attitudes and Practice
LoU	Levels of Use
MBA	Master of Business Administration
ML	Midline
OER	Open Educational Resources
OUT	Open University of Tanzania
PCK	Pedagogical Content Knowledge
PG	Post Graduation
RTICT	Reflective Teaching with ICT
SCE	Samtse College of Education
SMK	Subject Matter Knowledge
SNA	Social Network Analysis
SoC	Stages of Concern
STEM	Science, Technology, Engineering, & Mathematics
TE	Teacher Educator
TISS	Tata Institute of Social Sciences
TPACK	Technological, Pedagogical And Content Knowledge
TPD	Teacher Professional Development
TV	Television
TZ	Tanzania
UDL	Universal Design for Learning

1.0 Introduction

Tanzania provides free education up to the secondary school level. It identifies STEM education (that includes science and mathematics) as one of the focus areas with the objective of encouraging innovation and contribution to the country's socio-economic development. It does so by implementing various policies, frameworks, and projects, that include developing supportive curricula, learning materials, and infrastructure and providing Continuous Professional Development (CPD) opportunities for teachers that enable them to focus on quality, inclusive and equitable education. In line with the government's focus on STEM education, the Open University of Tanzania (OUT) collaborated with the Ibrahim Badamasi Babangida University, Lapai (IBBUL), Nigeria, the Samtse College of Education (SCE), Bhutan and the Tata Institute of Social Sciences (TISS), India, on a project funded by the International Development Research Centre (IDRC), Canada to implement a research-based project on Connected Learning for Secondary School Teachers Capacity Building in STEM (CL4STEM). The project aimed to pilot an innovation and to research its effectiveness and potential scaling for capacity building of science and mathematics teachers in secondary schools to foster Higher-Order Teaching with Inclusion and Equity (HOTIE). It is a South-South collaboration among institutions of higher education to adapt and pilot the Connected Learning Initiative[1] developed and scaled in India to new contexts in Bhutan, Nigeria, and Tanzania.

Scaling innovation must factor in macro and micro perspectives to synergise organisational efforts and individual roles (Panirsilvam, 2017). Hence, the project proposed involving teacher education institutions and educators and engaging with policymakers. Johnson et al. (2010) draw attention to the need for TPD change-directed innovations to be sensitive to local efforts, synergise local agents, actors, and sites, and to set targets based on indigenous conditions. Cooley and Linn (2014) point out that scalability benefits from the possibility of allowing local variations and/or segments to be selected for adoption and tested innovations to be taken to relevant new constituencies.

The pilot involved a knowledge transfer of CLIx to teacher educators in partner institutions in order to build their capability to design and curate OERs.This would also help them use and manage the *Learning Management System and online communities of practice. It also involved building professional capacities of teachers through their engagement with curated modules based on Open Education Resources (OER) packaged as a certificate course, suitable to local contexts and accessible over a Learning Management System (Moodle) with the support of vibrant online communities of practice (Telegram) to enhance participation, sharing, and learning.

Teacher Educators (TEs)/faculty of teacher education were the key agents responsible for adapting the innovation and implementing it in Bhutan, Nigeria and Tanzania. They employed the CLIx approach to Teacher Professional Development (TPD) which utilizes specially designed Open Educational Resources (OERs) to enhance the teachers' Pedagogical Content Knowledge (PCK) and the mobile-based Community of Practice (CoP) to promote peer group professional learning. In the context of each country, this involved:

1. Offering a course that comprises a set of 13 CL4STEM modules to enhance the teachers' PCK using OERs and blended learning.

[1] https://clix.tiss.edu

2. Supporting the teachers in their capacity-building exercise and translating the learning experience into practice by enrolling them into a mobile-based CoP to promote peer group professional learning.

The implementation of the innovation took place in 3 stages:

- Stage 1: Knowledge transfer of the CLIx approach to TPD
- Stage 2: Adaptation and development of contextually relevant design of innovation
- Stage 3: Development of a contextually relevant implementation strategy and plan for roll-out

Knowledge Transfer

The process of knowledge transfer under Stage 1 was led by the faculty of TISS. Teacher educators from the three collaborating universities participated in virtual workshops and created 13 modules for TPD, based on the programme's theory of change (See Figure 2.1). The workshops focused on the following elements:

1. Mathematics and science PCK
2. Beliefs regarding inclusion, active and hands-on learning
3. Skills to integrate hands-on learning into the classroom; to integrate ICT (where available) into the classroom; to use resources to enhance student talk and the quality of questions asked to develop higher-order thinking and to adopt inclusive practices
4. The management of a subject-based online CoP to share experiences and build contextual pedagogical content knowledge collaboratively
5. The use of ICT in education and its role in peer-learning and the professional development of teacher educators

The knowledge transfer was executed in five phases (Figure 1.1).

Figure 1.1: Timeline of Knowledge Transfer

Phase 1 was designed for TEs to experience an online practice-based reflective teaching course for teachers along with CLIx and other exemplar OERs for high school students. The experience was designed for TEs to explore the pedagogical ideas adopted to design the OERs and to enhance their PCK. Synchronous sessions were conducted weekly while the TEs were carrying out the course. During the length of the course, TEs also participated in subject-based mobile CoPs.

Phase 2 focused on Universal Design for Learning as the underlying principle of the project. It was designed to enhance teachers' PCK to ensure an equitable and inclusive teaching-learning process. The sessions were facilitated by the faculty from the Shreemati Nathibai Damodar Thackersey Women's University, Mumbai.

Phase 3 consisted of a synchronous workshop to introduce the process of design thinking and explore its potential to create meaningful and pedagogically valid teaching-learning resources and modules for teachers. The strategy to employ design thinking was envisaged to help TEs while they develop STEM modules.

Phase 4 of the knowledge transfer involved TEs from all the three countries along with the subject teams from TISS, who together developed 13 contextually relevant modules for teachers of their respective countries.

Phase 5 was meant to consolidate the experience of being a part of CoP during the earlier phases and to equip TEs to manage a mobile-based CoP for teachers which enables the development of a social learning environment[2].

In total, thirteen modules were collaboratively developed, contextualised and implemented in all the three participating countries. Every teacher was enrolled in four modules on the Moodle platform: a Common Pedagogy Module and three modules in any one of the following subjects– mathematics, biology, chemistry and physics. They were required to respond to the assignments specifically designed and embedded in the modules. The assignments were practice-based reflective assignments. The teachers were also asked to submit lesson plans on the topic, implement them with the students and then write a reflective report based on the teaching experience.

This was followed by Stage 2 that comprised the adaptation and development of contextually relevant materials. The situational analysis study of the current status of Tanzania's basic education system, specifically STEM, established the grounds for population and sample data collection in secondary schools. The results of situational analysis presented a better understanding of STEM education in Tanzania and specifically in these schools.[3] In response to the findings of the situational analysis, STEM teacher educators along with the consortium partner universities co-developed three modules based on higher-order thinking and subject-specific OERs. Further, the modules were designed in adherence to the national curriculum framework to support teachers' professional development in PCK, content enhancement, technology use, and inclusive and competency-based pedagogies.

In this manner, 12 modules were collaboratively developed and contextualised for Tanzania context along with a common pedagogical module, thus making a total of 13 modules that were implemented in CL4STEM intervention (Figure 1.2). The participating teachers were given orientation on how to engage with Moodle platform, mobile-based CoPs, and the main approach to Teacher Professional Development (TPD) intervention using the common module and its application in the subject-based modules.

[2] Thirumalai, B. R., & Sarangapani, P. M. (2023). Designing a Mobile-Messaging App-Based Teachers' Community of Practice in India. *Bulletin of Science, Technology & Society*, 02704676231165652.
[3] The situational analysis report is available here: https://www.connectedlearningforstem.org/wp-content/uploads/2022/02/Tanzania-Situation-Analysis.pdf

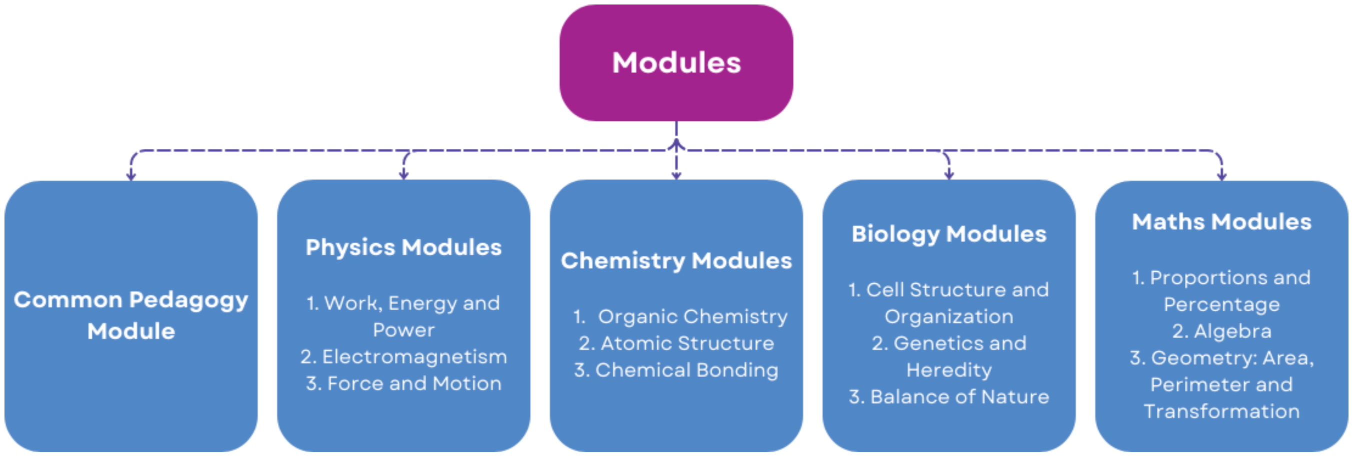

Figure 1.2: The 13 modules that were Developed

From June to December 2022, teacher educators used these modules to empower 68 secondary school in-service STEM teachers on Subject Matter Knowledge (SMK), Pedagogical Content Knowledge (PCK), and General Pedagogical Knowledge (GPK) to foster inclusion and equity in STEM classes. Baseline- Endline surveys, classroom observations, lesson plans & reflection reports, learning activities and assignments on Moodle-based modules, and subject-specific Telegram based CoPs were used to facilitate this process. This enabled them to learn, do assignments, interact, and provide feedback in CoPs, implement the modules in classes, post lesson plans and associated reflections, get evaluated by TEs and during the entire phase, equipped them to participate in interviews, surveys, observations, and related activities aimed at research knowledge generation.

The result of this exercise will provide the grounds for the dissemination of the same among stakeholders for seeding it into the policy agenda and scaling up opportunities in Tanzania. The report details the methodology adopted, the descriptions of participants, the results in terms of the extent to which STEM teacher Knowledge, Attitudes and Practice (KAP) has been enhanced or gained, the perceptions on CL4STEM intervention and social learning, and ends with the conclusion.

2.0 Methodology

This chapter discusses the approach adopted for the implementation of CL4STEM. It describes the theory of change, data collection strategies and the analyses involved. It concludes with the discussion of the participants' demographic profiles. Research shows that the application of teacher professional knowledge is contextual and value-based, where teacher learning is social and situated in nature (Cochran-Smith & Lytle, 1999; Winch, 2004; Sarangapani, 2011). Hence, the CL4STEM design focuses on supporting the teachers' professional development through online modules to gain new professional knowledge, attitude and practice and through mobile-based communities of practice to engage in social learning.

2.1 The Theory of Change & Conceptual Framework (Knowledge, Attitude and Practices)

The project pilot and research design were informed by the conceptual framework of PCK, which focuses on the importance of core subject knowledge and related pedagogy as the core of teaching quality (Shulman, 1986), the integration of technology in TPACK and the relevance of and approach to developing PCK in developing contexts (Ramchand, 2017). These concepts further pointed to the significance of 'contextualisation and evolution' , 'social learning in communities' and the use of mobile technologies to engender the adoption and scaling of innovation in TPD in the Global South (CLIx TPD research and Johnson et al., 2010). The impact of PCK development interventions has shown mixed results (Evens, Elep & Depaepe, 2015). Yet, there has also been strong evidence which suggests that teachers "develop a vision for their professional learning as a consequence of learning how to teach particular content in a particular way for a particular reason with a group of students" (Loughran & Hamilton, 2016, also seen in CLIx research, Ramchand, 2017).

Figure 2.1 presents the CL4STEM theory of change that grounded the implementation and all research activities. It's salient features are as follows:

a. Teacher educators' knowledge, attitudes, and practices with regard to higher-order teaching with equity and inclusion will improve when they meaningfully engage with the online practice-based, reflective professional development course through Knowledge Transfer (described earlier) and online communities of practice and participate in the designing, implementation and monitoring of the online teacher professional development modules.

b. Teachers' knowledge, attitudes, and practices with regard to higher-order teaching with equity and inclusion will improve when they meaningfully engage with the online professional development modules (designed by their teacher educators), implement the lesson plans, reflect on their practice, and participate in online communities of practice to support their professional development.

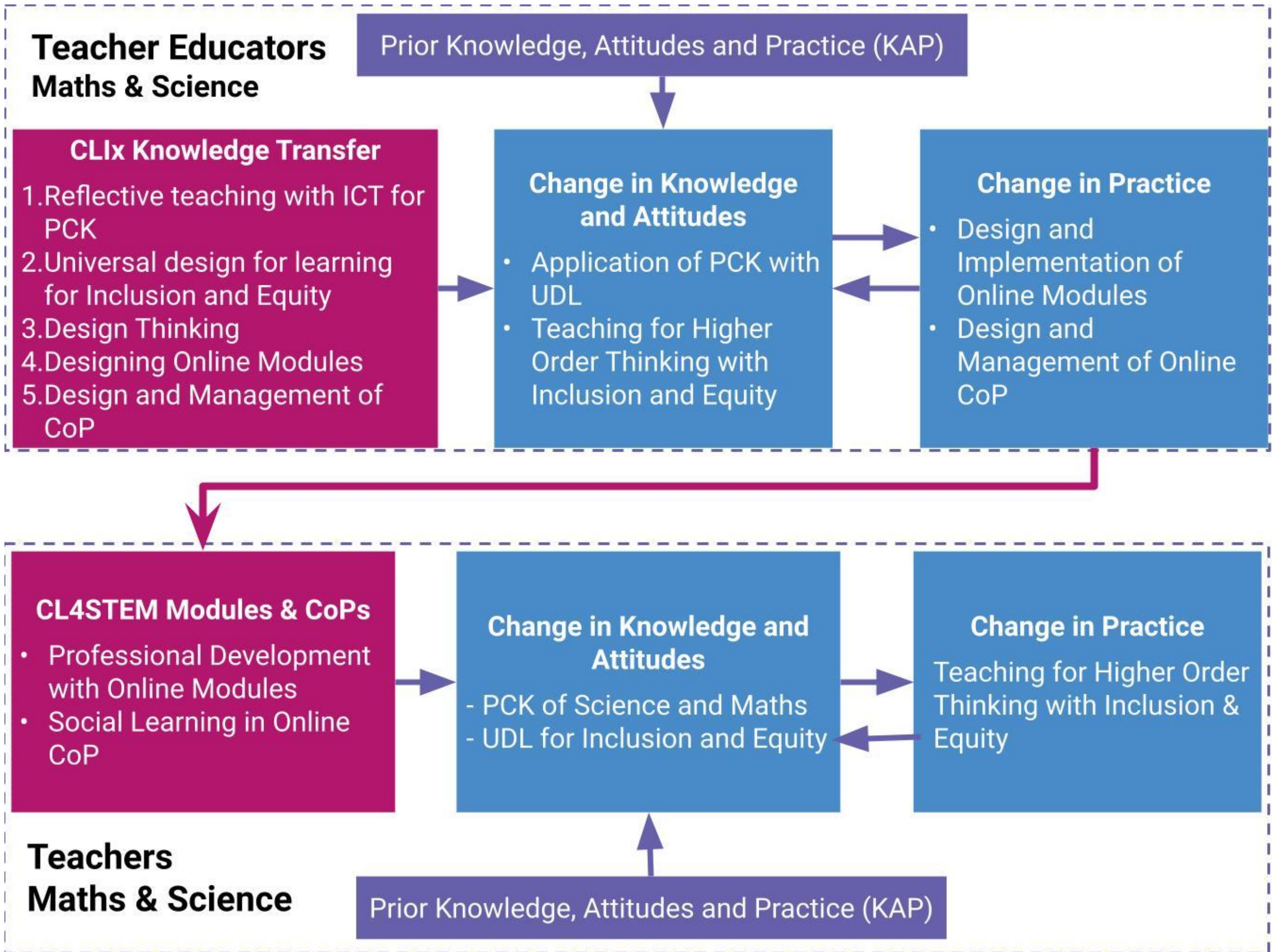

Figure 2.1: CL4STEM Theory of Change

A conceptual framework was developed to support this theory of change and to assess teachers' knowledge, attitudes, and practices with respect to the development of pedagogical content knowledge with inclusion and equity. The conceptual framework aims to enhance science and maths teacher knowledge for promoting Higher Order Thinking among learners with Inclusion and Equity – HOTIE (Figure 2.2) and is based on the conceptual principles of Pedagogical Content Knowledge - PCK (Ball, Hill & Bass, 2005; Grossman, 1990; Kind, 2009; Ramchand, 2022, and Shulman, 1986), Universal Design for Learning - UDL (CAST, 2018) and Competency-Based Education (CBE) (Shawer, 2022). The conceptual framework includes subject matter knowledge, pedagogical content knowledge and general pedagogical knowledge categories. Each of the three categories guided analyses of the impact of CL4STEM on secondary school teachers (Table 2.1).

Table 2.1. Conceptual Framework for Higher Order Thinking with Inclusion and Equity (HOTIE)

Higher Order Teaching with Inclusion & Equity (HOTIE) (cc) CETE, 2022	
Subject Matter Knowledge	
1.Knowledge of Science/ Maths Subject Matter	● The knowledge possessed by the teacher in one or more disciplines of science or mathematics - 'Big' ideas, key concepts and theories in the discipline - Knowledge of interconnections between concepts/ topics within the discipline ● Ability to justify what counts as knowledge within the domain of science/maths

2. Nature of Science /Mathematics	● Teachers' knowledge of the nature of science, such as its empiricism; that it is situated in a particular historical, social, economic context; that it requires creativity and imagination; the understanding of modern science as a collaborative enterprise located in institutionalised spaces ● Teachers' knowledge of the nature of mathematics; beliefs about mathematics; processes of mathematics: problem-solving, reasoning, proving and communicating; mathematisation of thinking or ability to represent something mathematically ● Ability to communicate nature and structure of science/maths to students
Pedagogical Content Knowledge	
3. Instructional Strategies	● Knowledge of different instructional strategies and resources - To develop scientific thinking, skills in experimentation, observation, inferring, categorising through data gathering, plotting graphs, problem-solving - To develop mathematical thinking, mathematization, reasoning, and argumentation ● Knowledge of topic-specific pedagogical strategies and resources ● Ability to use different instructional strategies and resources to address diverse needs of learners, that includes addressing students' misconceptions and learning difficulties
4. Students' Misconceptions & Conceptual Difficulties	● Knowledge of students' prior conceptions, errors, misconceptions/alternative conceptions, ways in which students think, and concepts students find difficult to learn ● Knowledge of areas that students find challenging ● Ability to use students' errors to understand their ways of thinking and to design learning experiences to support students' STEM learning
5. Representation of the Content	● Knowledge of multiple forms of representation of content - e.g. analogies, equations, gestures, graphs, diagrams and illustrations, models, tables, texts, videos, simulations, photographs ● Knowledge of the limitations of models and illustrations in representing content ● Ability to use multiple representations of content to meet diverse needs of students
6. Context for Learning	● Knowledge of the larger school/regional infrastructure, and discursive context which shapes their pedagogical choices ● Knowledge of the environmental/ lab/ material resources available in the context which can be utilised to promote science/ maths learning ● Ability to adapt resources/use locally available materials to meet the needs of learners ● Ability to connect different topics in science/maths to everyday experiences/ daily life practices of the students
7. Curriculum Knowledge	● Knowledge of the goals and purposes of teaching science/mathematics ● Knowledge of the hierarchical sequence of foundational concepts for teaching and its inter connection with other concepts/topics in curriculum across grades ● Knowledge of linkages between science and maths and with other school subjects ● Ability to use knowledge of curriculum to design integrated learning experiences for students
General Pedagogical Knowledge	
8. Equity and Inclusion	● Knowledge of Universal Design for Learning ● Ability to provide equal opportunities to all students to participate in classroom interaction ● Ability to use UDL principles to design and implement lesson plans, resources and assessments to meet diverse needs of learners
9. Classroom Management	● Knowledge of multiple modes of classroom interaction eg. organising inquiry learning/project-based learning/problem-solving to promote students' agency, employing a variety of grouping practices to support collaborative learning, using activities to offer multiple ways for students to engage and express ● Knowledge of positive disciplining techniques ● Ability to organise and manage multiple modes of interactions, including group activities

	● Ability to manage time, space and teaching-learning resources effectively ● Ability to manage students' behaviour
10. Assessment	● Knowledge of multiple methods and tools of assessment for students to express in multiple ways ● Ability to use assessment for and of learning ● Ability to design and use a variety of methods and tools of assessment, including task-based assessment

Online Community of Practice (CoP) is the other significant aspect of CL4STEM research design, along with the HOTIE framework. CoP is a well-established mode of social, situated, and professional learning through the regular interaction of community members (Wenger, 1998). It draws on the idea of situated learning (Lave and Wenger, 1991) which states that professional learning happens through participation in social processes that are situated within specific socio-cultural contexts. CoPs provide a social learning platform where participants can interact freely within specific areas of specialisation as a research team at large. In the context of this project, CoPs offered a space for the participating intervention group teachers and the teacher educators to exchange and discuss their experiences with the modules. One common Telegram CoP was created for all subjects (maths, biology, chemistry, and physics), followed by a CoP for each subject. Each teacher educator was assigned as the Course Instructor for respective subject modules and a common module and was responsible for the teachers' participation in that module.

Throughout the implementation, regular cross country meetings were undertaken to understand the research process, including training workshops for field teams, and details of the research work plan were reconfirmed and finalised concerning the proposed work plan. This included the form in which the data were gathered and stored, digitisation, anonymisation and placing in the CLIx-Google Drive for use by all partner teams. IRB clearances were obtained from TISS and other partner institutions. Before commencement, informed consent was obtained from all respondents. Ongoing process data were generated and regularly discussed in the subject-based, cross-country groups tasked with implementing the pilots in their respective countries.

The availability of background information of the respondent groups enabled the analysis of participants' demographic data. Baseline and Endline surveys were used to understand the development and changes in participants' knowledge and attitudes towards PCK, inclusion, and ICT use. Suitable control was identified for each context; however, control group data has not been analysed in this report.

The widely accepted Concerns Based Adoption Model (CBAM) (Hall, 1974) was used to study the diffusion of innovation using the HOTIE rubric, Levels of Use (Hall, Dirksen & George, 2006), and Stages of Concern (George, Hall & Stiegelbauer, 2006)[4] questionnaires and surveys. Stages of Concern (SoC) measures the participants' knowledge of and attitude towards CL4STEM and consists of seven developmental stages with each stage leading to the next one. These stages are described below:

- Stage 0 (Unconcerned): the participant has no concern about the innovation
- Stage 1 (Informational): the participant has limited knowledge about the innovation but has not participated in it

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- Stage 2 (Personal): the participant has concerns about the demands of the innovation, rewards for participating in the same, and its potential conflicts with the existing structures
- Stage 3 (Management): the participant has concerns about efficiency and about organising, managing and scheduling participation in the innovation
- Stage 4 (Consequence): the participant is concerned about the impact of the innovation on student learning
- Stage 5 (Collaboration): the participant is focused on collaborating with others regarding the use of the innovation
- Stage 6 (Refocusing): the participant is concerned about making the innovation more beneficial, or making major changes to it

Levels of Use (LoU) evaluates the behaviour of the participants with respect to CL4STEM. LoU has eight different levels, with each level representing a cumulative behaviour. These levels are described below:

- Level 0 (Nonuse)
- Level 1 (Orientation): the participant has some information about the innovation
- Level 2 (Preparation): the participant is preparing to participate in the intervention
- Level 3 (Mechanical Use): the participant uses the innovation to just master the tasks with little opportunity for reflection
- Level 4a (Routine): the participant is comfortable with using the innovation, but gives little thought to its use or consequences
- Level 4b (Refinement): the participant uses the innovation, while varying the use to improve the impact of the intervention
- Level 5 (Integration): the participant brings the innovation to their colleagues to increase the impact of the innovation
- Level 6 (Renewal): the participant re-evaluates their use of the innovation and seeks modifications to increase the impact and examines new opportunities and new goals for the innovation

Along with CBAM, Moore and Benbasat's innovation diffusion framework (1991) was also used to understand the teachers' perceptions. This framework comprised 7 characteristics:

1. Voluntariness: the perceived degree to which participants voluntarily participate.
2. Relative advantage: the extent to which the teachers perceive the strategies suggested by CL4STEM to be better than the existing ways of teaching
3. Compatibility: the degree to which CL4STEM is compatible with the existing context of the teachers
4. Image: Refers to how the participation of teachers affects their social or professional status
5. Ease of use: the comfort and convenience of teachers to participate in CL4STEM modules and CoPs
6. Results demonstrability: the degree to which the results from participation in CL4STEM could be tangibly demonstrated and communicated to others
7. Visibility: the extent to which the results of participation in CL4STEM would be observable in schools

2.2 Data Collection

Data was collected following a quantitative and qualitative methodology using Baseline-Endline surveys, semi-structured interviews, and classroom observation to assess the teachers KAP and perceptions towards HOTIE. Baseline data collection took place in June and July 2022. Four tools were used in the Baseline: Teacher Profile, Teacher Perceptions Survey, Subject Impact Survey, and Interviews. A brief description of each tool is provided next:

1. Teacher Profile: The teacher profile form was used to collect demographic information about the participating teachers and schools. It also captured information about school principals and the existing infrastructure information for each school.
2. Teacher Perceptions Survey: This survey asked teachers to rate their perceptions of CL4STEM using the Moore and Benbasat's (1991) framework. The baseline tool did not include Levels of Use and Stages of Concern surveys.
3. Subject Impact Survey: The subject impact survey was the primary tool used to capture the teachers' existing knowledge and attitudes towards various categories of HOTIE framework described earlier.
4. Interviews: Semi structured interviews were conducted with selected participants, to get a greater understanding of their knowledge, attitudes towards various categories of HOTIE framework, along with their teaching and learning practices. These interviews were crucial in developing the researchers' understanding of the teachers' context and ground realities.

The total distribution of participants in CL4STEM in Baseline is shown below:

Table 2.2. Overview of Baseline Data

Baseline Tools	Teacher Profile	Teacher Perceptions Survey	Subject Impact Survey	Interviews
Focus Group	23 (Math= 5, Phy= 7, Chem=5, Bio= 6)	24 (Math= 5, Phy= 8, Chem=5, Bio= 6)	21 (Math= 5, Phy= 5, Chem=5, Bio= 6)	20
Others	51 (Math= 13, Phy= 10, Chem= 15, Bio= 13)	55 (Math= 15, Phy= 12, Chem= 15, Bio= 13)	53 (Math= 15, Phy= 12, Chem= 13, Bio= 13)	-
Total per subject	Math= 18, Phy= 17, Chem= 20, Bio= 19	Math= 20, Phy= 20, Chem= 20, Bio= 19	Math= 20, Phy= 17, Chem= 18, Bio= 19	Math= 5, Phy= 6, Chem=4, Bio= 5
Total	**74**	**79***	**74**	**20**

**Due to challenges in data collection, 79 completed teacher perception surveys were obtained, as compared to 74 completed teacher profile and subject impact surveys. During change analysis, data was considered from only those 68 participants, who had consistently participated in all data collection activities.*

Data collection was done through in-depth key informant interviews. Data from school observations, labs, and classroom practice were included. Interviews were conducted electronically as per the planned schedule, and had the following steps:

i) The interview commenced as per the schedule and the audio recording started.
ii) Ice-breaker questions were asked.
iii) The participants were directed to the Levels of Use (LoU) and Stages of Concern (SoC) survey via Chat in Zoom (during the Endline interviews)
iv) The LoU and SoC survey was filled out by the participants (during the Endline interviews).
v) Teachers' justifications for their choices were recorded (during the Endline interviews).
vi) The remaining interview questions were asked.

During instances when internet connectivity was not strong enough to allow using Zoom, ing interviews were conducted via phone calls.

After interviews, the following two steps were taken:

i) The audio files were uploaded to the common folder with the CL4STEM ID.
ii) Verbatim transcripts were generated and uploaded in the same folder.

Midline data collection focused on capturing the qualitative aspects of the implementation. A key component of the Midline data was classroom observations. Research fellows conducted classroom observations for 2 teachers per subject (8 teachers in total), with 3 observations per teacher (24 observations in total), They also interviewed the same teachers. Table 2.3 shows the number of teachers observed and the number of times they were observed.

Table 2.3: Midline Data Collection

Midline Tools	Classroom Observation	Interviews
Total per subject	2 teachers	2 teachers
Total (all subjects)	8 teachers	8 teachers

During classroom observations, the research fellows wrote detailed descriptions of the lesson that they had observed. They also conducted pre-observation and post-observation interviews with the teacher to understand the context of the lesson. Along with classroom observations, qualitative interviews were conducted which focused on teachers' attitudes and practices towards SMK, PCK & GPK, participation in online Telegram CoPs, and their perceptions of CL4STEM. The questions on perception also included those on LoU and SoC from CBAM. Midline data collection went on from September 2022 to November 2022.

Finally, the Endline tools consisted of the following:

1. Subject survey, which was essentially a repetition of the Baseline subject impact survey, measured teachers' knowledge and attitude towards high order teaching and learning with equity and inclusion by assessing their subject matter knowledge, pedagogical content knowledge, and general pedagogical knowledge.
2. Innovation diffusion survey was again, a repetition of the innovation diffusion survey conducted in Baseline. It also included questions on the Stages of Concern and Levels of Use with regards to CL4STEM.
3. Interviews were carried out with the same set of teachers who were interviewed in Baseline and Midline. These interviews focused on innovation diffusion, by capturing teachers' perceptions about the innovation after its implementation. The interviews also focused on documenting the teachers' knowledge, attitudes and practices around higher order teaching and learning for equity and inclusion, to supplement the survey data.

Endline data collection happened between November 2022 and January 2023. An overview of the Endline data collected is shown in the table 2.4 below:

Table 2.4. Overview of Endline Tools

Endline Tools	Innovation Diffusion Survey	Subject Impact Survey	Interviews
Focus Group	19 (Math= 3, Phy= 7, Chem=4, Bio= 5)	19 (Math= 3, Phy= 7, Chem=4, Bio= 5)	17 (Math= 3, Phy= 6, Chem=4, Bio= 4)
Others	49 (Math= 13, Phy= 11, Chem=12, Bio= 13)	49 (Math= 13, Phy= 11, Chem=12, Bio= 13)	-
Total per subject	Math=16, Phy= 18, Chem=16, Bio=18	Math=16, Phy=18, Chem=16, Bio=18	Math=3, Phy=6, Chem=4, Bio=4
Total (all subjects)	**68**	**68**	**17**

During change analysis from Baseline to Endline to study the impact on teachers' KAP as well as perceptions, survey data from 68 teachers and interview data from 17 teachers were considered (as only these teachers had been able to consistently participate in all data collection activities). While the responses in Baseline were greater in number, approximately 6 teachers dropped out from the project and hence were not included in the analysis. Unless otherwise noted, data was analysed for 68 teachers.

2.3 Data Analysis

The survey data was segregated based on gender, the type of school, the type of teacher, and subject for each category of the HOTIE framework. Using such analysis techniques, researchers could identify the commonalities and differences between the findings from quantitative survey data and the qualitative interview and observation data.

All interview data were transcribed and deductively coded using the 1) HOTIE framework for capturing the subject level impact, and 2) Moore and Benbasat's (1991) 7 indicators of innovation diffusion, and CBAM's SoC & LoU for perceptions on the innovation. To capture the holistic picture of the teachers' practice, all classroom observations and pre- and post-observation interviews with teachers were also deductively coded using the CL4STEM HOTIE and perceptions frameworks. The researchers summarised the qualitative data to condense it into significant findings presented in the bulk of this report.

Social network analysis was chosen as the methodology for studying the mobile-based CoPs data, along with qualitative thematic analysis. Social network analysis allows an exploration of the relationships between members in these socio-cultural contexts. Social network research suggests that "informal webs of relationships are often the chief determinants of how quickly change efforts take place, hold, diffuse, and sustain" (Daly, 2010). The social network analysis graphs were created using Gephi software. Each node on the graph shows a participant in that CoP, whereas a line between two nodes shows the interaction between the participants. Three parameters were used to evaluate the nature of the social network: density, average degree and maximum degree. Density refers to the number of interactions that happened between the participants of any group at a given point in time. The maximum possible density is 1, which indicates that every node in the network is connected to every other node directly, or that every participant has interacted with every other participant at least once. The average degree is the average number of interactions each node has participated in and the maximum degree is the maximum number of connections a node has in the concerned social network. The node with maximum degree would correspond to the participant who has interacted the most in the Telegram CoP.

2.4 Demographic Details of Participating Schools

In Tanzania, 18 schools (9 from rural areas and 9 from urban areas) participated in the CL4STEM project. These schools are spread across six diverse regions of the country - Dar es Salaam in the east, Arusha in the north, Mwanza in the northeast, Dodoma in central Tanzania, Iringa in the southern highlands, and Mtwara in the southeast. Of the 18 schools, 10 are day schools, whereas 8 are boarding schools. These schools are broadly categorised as - government special schools (5), community schools (7) and private schools (6). 13 schools are co-educational, 3 are all-girls schools, and 2 are all-boys schools (Table 2.5).

Table 2.5: School Management and Gender Types

School management	% of schools (n)	School gender	% of schools (n)
Government	28 (5)	Co-educational	72(13)
Community	39 (7)	Girls only	17 (3)
Private	33 (6)	Boys only	11 (2)

2.4.1 Head of Schools, teachers, and non-teaching staff

Table 2.6: Distribution of Full-time Teachers in Schools

# of full-time teachers	# of Schools
0 - 19	3
20 - 39	9
40 - 59	3
60 - 79	2
80 - 100	1
Total	18

Out of the 18 heads of schools who participated in this project, 14 are male, and 4 are female. 50% of principals had more than 10 years of experience as school principals. As for professional qualifications, most of them had B.Ed and M.Ed degrees and few had completed an MBA, a diploma, or a Bachelor of Computer Science course. As can be seen from table 2.6, the average participating school had less than 40 teachers (out of which only 6-10 teachers were science and mathematics teachers) and five or fewer non-teaching staff. The distribution of teachers across schools is shown in the table 2.7 below.

Table 2.7: Distribution of Full-time Science & Mathematics Teachers, Full-time Non-teaching Staff Across Schools

# of teachers or staff	0-5	6-10	11-15	16-20	>20	Total
# Schools with full-time science & maths teachers	3	8	5	-	2	18
# Schools with full-time non-teaching staff	11	3	1	1	2	18

2.4.2 Physical infrastructure

All the participating schools except one had a consistent availability of electricity. Ten schools reported that they had internet access most of the time, two schools had erratic internet access, and six schools did not have good access to the internet.

Figure 2.2 : Availability of Physical Infrastructure Across Schools

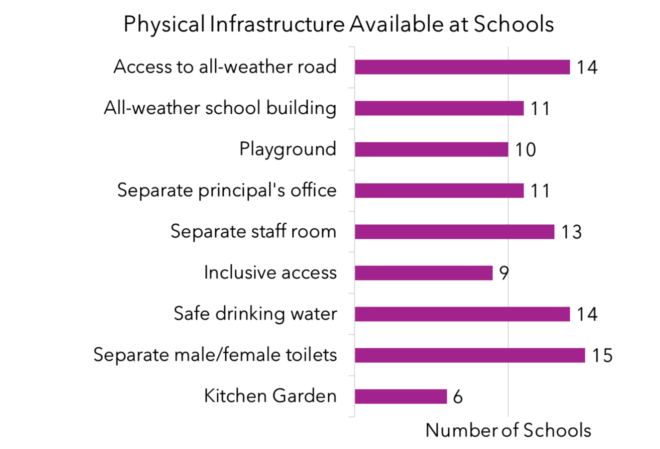


Figure 2.3: Availability of ICT Infrastructure Across Schools

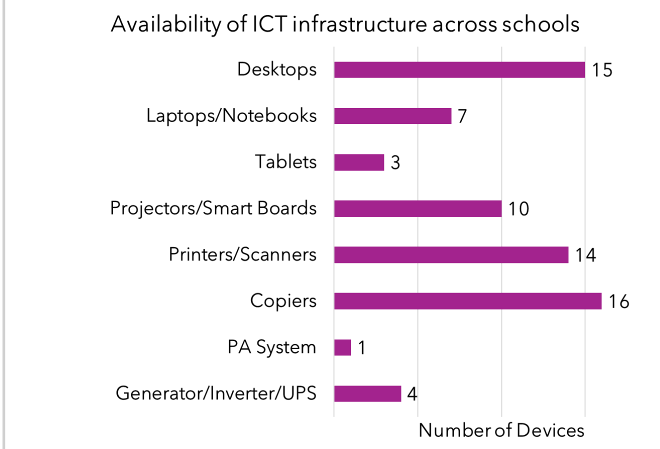


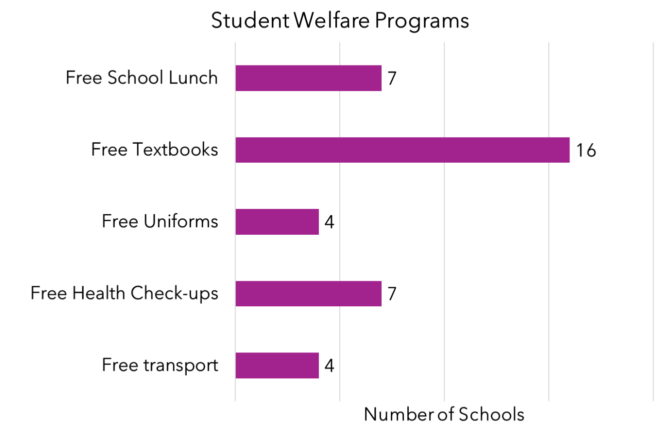
Figure 2.2 above shows the extent of infrastructure available at the participating schools. The first chart shows that almost all schools had access to all-weather roads and safe drinking water, and had separate male and female toilets. Four of 18 schools had access to a majority of physical infrastructure components like all-weather roads and buildings, playground, principal's office and staff room, separate male and female toilets, kitchen garden, safe drinking water and inclusive access to the school. With respect to school laboratories and resource rooms, out of 18 schools, 14 had physics, chemistry and biology laboratories, 12 had computer rooms, 13 had libraries, 3 had mathematics resource rooms, 1 had only chemistry and biology resource rooms, and 1 had only a physics laboratory. One of the schools also had an incomplete library.

Figure 2.3 shows the distribution of ICT infrastructure across schools. 15 schools had desktops, 14 had printers/ scanners, and 16 had copiers. In all but one school, the technology available was used primarily for office work. Nine schools had computer labs for students, and five schools had computers available for the teachers. More than 80% of teachers across 17 schools owned a smartphone. With regard to student access to technology, students from most schools (n=10) did not have access to smartphones at home; 3 urban government schools stated that 40-50% of their students had access to a smartphone; and 2 residential schools stated that most students had access to a smartphone.

2.4.3 Student Welfare Programs

The students benefited from several welfare programs. For example, from Figure 2.4, it is evident that most schools (n=16) had free textbooks programs for students. Almost half the schools offered free lunches and health checkups.

Figure 2.4: Student Welfare Programs



2.5 Demographic Details of participating teachers

In Tanzania, the CL4STEM intervention group consisted of teachers with varied backgrounds who participated in and implemented the innovative modules of CL4STEM in their classrooms. It is therefore essential to understand their background, working conditions and access to various resources. Teacher profile records their professional qualifications, subject specialisation during teacher education training, total number of years of experience as a school-teacher, years of experience as a school teacher in the current school, and the use of ICT devices, the details of which are shared in the following sections.

2.5.1 Professional qualifications

Most participating teachers had completed a professional course in education, and had either a diploma or a degree (B.Ed or M.Ed) in education. This is reflective of the recruitment policy for teachers in Tanzania. Of all the teachers who were part of CL4STEM, the most significant proportion had a Bachelor's degree in education (B.Ed) - 63%, followed by a diploma - 24% (table 2.8).

Table 2.8: Teachers' Professional Qualification Generally and Across Gender

Professional qualification	Total teachers (n=68)	Female teachers (n=15)	Male teachers (n=53)
Diploma	24%	13%	26%
B.Ed	63%	60%	64%
M.Ed	7%	20%	4%
PG Diploma	3%	7%	3%
B.Sc	3%	0	4%

When teachers' professional qualifications were analysed along the axis of gender, it was observed that this trend is consistent among male teachers. However, among female teachers, though the highest proportion had a B.Ed- 60%, there were more postgraduates- either with an M.Ed (20%) or a postgraduate diploma (7%) than among male teachers .

2.5.2 Subject specialisation in teacher education training

68 STEM teachers completed Baseline and End-line surveys on teacher profiles. There were 18 teachers each who had specialised in physics and biology, whereas 16 teachers each had specialised in mathematics and chemistry.

2.5.3 Total number of years of experience as a school-teacher

Most participant teachers in CL4STEM project in Tanzania have =<5 years of teaching experience in schools (46%). Teachers with longer experience, i.e >10 years of teaching are relatively less in proportion (29%) as are teachers who have 6-10 years of teaching experience (25%). Thus, the teaching experience of participant teachers in CL4STEM, Tanzania fall under a wide range.

2.5.4 Years of experience as a school teacher in the current school

Out of the 68 teachers, 67 had stated the number of years of experience in the current school, *i.e.*, the schools which are participating in the CL4STEM programme in Tanzania. Almost 60% of teachers have less than or equal to five years of experience in the current school. 22% of teachers have 6-10 years of experience and 18% have more than ten years of experience in the current school.

2.5.5 ICT Devices and usage

The teachers predominantly use four ICT devices: tablets (15%), desktops (18%), laptops (44%), and smartphones (94%). Across the three criteria of classification, namely the type of school management, gender, and age, the highest proportion of teachers own smartphones as ICT devices - 92% among government special school teachers, 93% among community school teachers, and 100% among private school teachers. However, among the participants in the CL4STEM, the ownership of laptops is highest among the government school teachers (58%) In the case of all other ICT devices (desktops, tablets and smartphones), private school teachers own devices in a higher proportion (Table 2.9).

Table 2.9: ICT Devices Owned by the Teachers on the Basis of the Type of School Management and Gender

ICT devices	Total (n=68)	School management type			Gender	
		Government (n=24)	Community (n=27)	Private (n=17)	Male (n=53)	Female (n=15)
Desktop	18	8	19	29	19	13
Laptop	44	58	33	41	40	60
Tablet	15	13	7	29	17	7
Smart phone	94	92	93	100	94	93

The proportion of female teachers who own laptops (60%) is higher compared to male teachers (40%). However, the proportion of male teachers who own desktops (19%) and tablets (18%) is higher when compared to their female colleagues (13%: desktop, and 7%: tablet). An analysis across teachers' age groups revealed that smartphones are the most commonly owned ICT device (Figure 2.5). Among the teachers enrolled in CL4STEM in Tanzania, there was no discernible difference in computer ownership across age categories, except that the teachers who own a desktop were below 40 years of age. More recently, after this data was captured, the government distributed ICT devices (primarily tablets) to teachers across the schools in Tanzania. Thus, in the immediate future, ICT device penetration could be significantly higher among teachers in Tanzania.

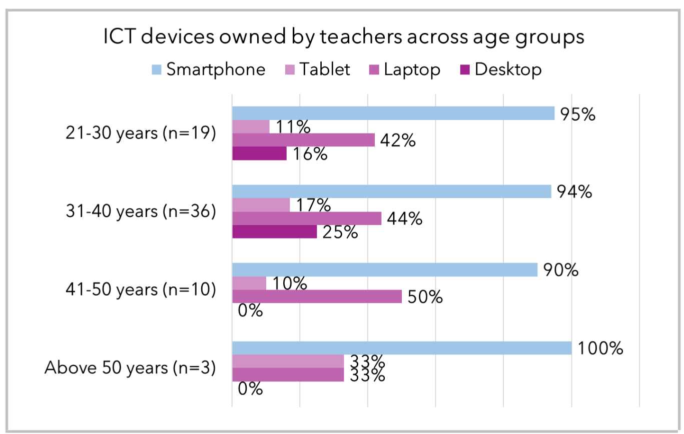


Figure 2.5: ICT Devices by Teachers Across Age Groups

i) ICT device usage among teachers: We further explored which ICT devices teachers used more frequently for their teaching. The survey, captured during the Baseline, allowed us to understand the general prevalence of the devices teachers used before the CL4STEM project. Smartphones remained the most frequently used device in teaching (94%), which is consistent with the patterns of ownership of the device. This is followed by the usage of computers - both laptop (51%) and desktop (16%) (Figure 2.6).

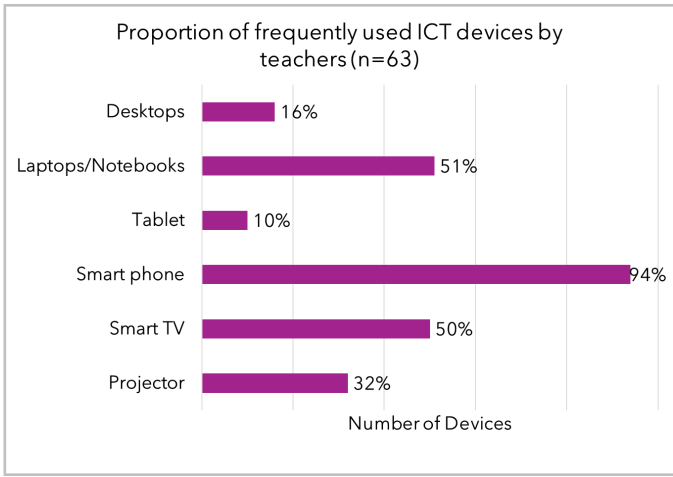


Figure 2.6: Frequently Used ICT Devices by Teachers

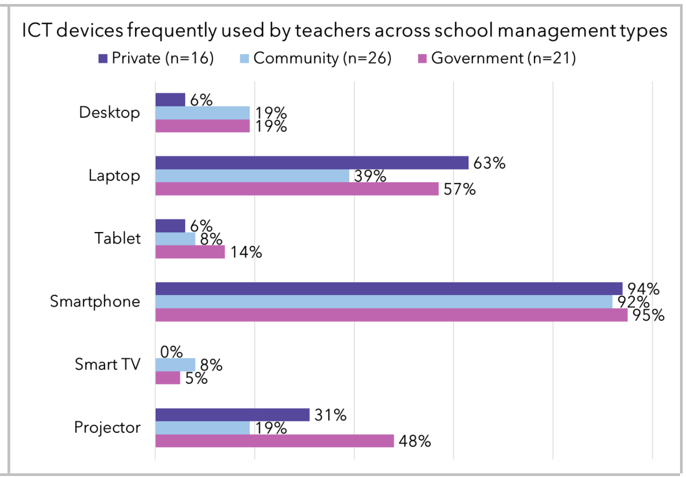


Figure 2.7: ICT Devices Used by Teachers Across Various Types of School Management

The use of ICT devices by teachers was also studied in relation to the type of school management (Figure 2.7). Among male and female teachers, there was no discernible difference between the use of smartphones and laptops. However, a higher proportion of male teachers used desktops (20%) and projectors (35%) while teaching compared to their female colleagues (0% desktops; 21% projectors). While accessing and engaging with CL4STEM modules and participating in the telegram CoP groups, teachers were required to use ICT devices. Hence, at the Endline survey, we asked the enrolled teachers to identify the multiple ICT devices they used to engage with CL4STEM activities.

Smartphones were the most frequently used ICT device (93%), followed by computers (62%), laptop (50%), projectors (31%), and desktop (16%). These overall responses are comparable and consistent with the Baseline survey findings. Across different types of school management, smartphones remained the most used ICT device for CL4STEM implementation in Tanzania, with 88% of government teachers, 93% of community school teachers, and 100% private school teachers using smartphones for module implementation and for participating in Telegram CoP groups. A more significant proportion of teachers in government special schools used laptops (71%) compared to teachers from private (53%) and community (30%) schools. Also, a higher proportion of private school teachers (53%) used projectors for module implementation in classrooms, when compared to government (33%) or community (15%) school-teachers (Table 2.10).

Table 2.10: ICT Devices Owned by the Teachers by School Management Type and Gender

ICT devices	Total (n=68)	School management type			Gender	
		Government (n=24)	Community (n=27)	Private (n=17)	Male (n=53)	Female (n=15)
Desktop	16%	13%	26%	6%	19%	7%
Laptop	50%	71%	30%	53%	49%	53%
Tablet	21%	21%	26%	12%	21%	20%
Smart phone	93%	88%	93%	100%	94%	87%
Smart TV	4%	8%	4%	0	6%	0
Projector	31%	33%	15%	53%	28%	40%

Across all these categories, between Baseline and Endline surveys, more teachers started using tablets. This could be attributed to the government's initiative to distribute tablets among teachers. Conversely, this possibly shows that access to devices is an enabling factor in participation in and teaching of ICT-based education modules, which may be helpful for teachers in low-resource conditions.

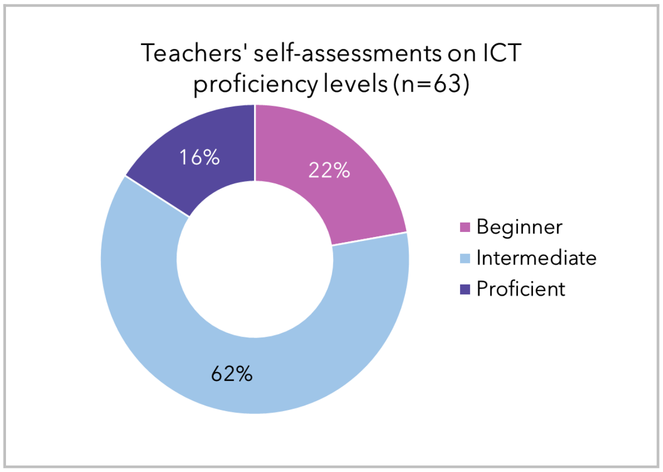


Figure 2.8: Teachers' Self-assessment on ICT Proficiency Levels

ii) ICT proficiency among teachers: Teachers' proficiency in ICT is directly linked to the frequency with which they use ICT and the ways they would use ICT to facilitate their classroom teaching. Hence, in the Baseline survey, we asked the teachers to self-assess their ICT proficiency along the qualitative categories of beginner, intermediate and proficient. Of the total 63 responses, around 78% of teachers identified themselves as intermediate or proficient in ICT (Figure 2.8).

iii) Accessing the internet for CL4STEM modules and Telegram CoPs: We further examined how teachers accessed the internet during CL4STEM implementation. The highest proportion of teachers (57%) used their internet (data) package followed by the proportion of teachers (40%) who used the internet provided by the CL4STEM project to access CL4STEM learning resources.

Table 2.11: Internet Access during CL4STEM Implementation

Mode of internet access for CL4STEM	Total (n=68)	School management type			Gender	
		Government (n=24)	Community (n=27)	Private (n=17)	Male (n=53)	Female (n=15)
Personal internet	57%	67%	41%	71%	60%	47%
Internet through CL4STEM project	40%	33%	52%	29%	40%	40%
Rarely use the internet for teaching	3%	0	7%	0%	0	13%

The above pattern was observed among the government and private school teachers as well. However, in community schools, more teachers used the internet provided by the CL4STEM project (52%) than using their internet (41%) (Table 2.11). A higher proportion of male teachers (60%) used personal internet than their female (47%) colleagues.

iv) Approximate monthly expenses on internet (data) access: Despite government efforts and the growing telecom industry in the country, mobile internet packages in Tanzania are relatively expensive. Given that a significant proportion of teachers use smartphones, examining their monthly internet access expenditures is prudent. For 68% teachers, the average approximate monthly expenditure to access the internet came to more than 10,000 Tanzanian Shilling (Tshs), whereas 30% teachers spent between 5,000-10,000 Tshs to access the internet[5] (Table 2.12).

Table 2.12: Monthly Expenses on Internet Data

Approx. avg. monthly expense (in Tsh)	Total (n=68)	Government (n=24)	Community (n=27)	Private (n=17)	Male (n=53)	Female (n=15)
> 10000 Tsh	68%	75%	56%	77%	64%	80%

[5] 10000Tshs is approximately equivalent to $4 USD.

5000 - 10000 Tsh	28%	17%	41%	24%	30%	20%
< 5000 Tsh	4%	8%	4%	0	6%	0

v) Approximate weekly data usage: Information on weekly data usage allows us to understand the extent to which the internet is used. This is particularly important if teachers rely on the internet to access modules, teach learning material, or participate in peer groups. 57% teachers used between 2-4 GB of data per week; 30% used between 5-10 GB of data per week, whereas around 10% used less than 1 GB per week (Table 2.13). Across different school managements, and genders the same pattern was observed.

Table 2.13: Approximate Weekly Data Usage

Approx. Weekly data usage	Total (n=68)	Government (n=24)	Community (n=27)	Private (n=17)	Male (n=53)	Female (n=15)
<1GB	10%	13%	7%	12%	11%	7%
2-4 GB	57%	58%	59%	53%	59%	53%
5-10 GB	29%	25%	30%	35%	28%	33%
Unlimited	3%	4%	4%	0	2%	7%

Although internet packages are highly priced in Tanzania, most teachers own smartphones compared to other ICT devices. Smartphones are the primary ICT devices for communication and teaching. Capitalising on the use of smartphones could be a good initiative for TPD in Tanzania.

3.0 Teacher Knowledge, Attitudes and Practice

This section focuses on the impact of CL4STEM on teachers' Knowledge, Attitude, and Practices (KAP) by analysing the Baseline-Endline survey data, Midline classroom observations and interviews. The KAP framework mentioned earlier is used for all the analyses in this section. Three major categories covered in this section are subject matter knowledge, pedagogical content knowledge, and general pedagogical knowledge.

3.1 Subject Matter Knowledge

Subject matter knowledge refers to the understanding of content in a particular subject. It requires a deep understanding of the concepts, principles, theories, and methods relevant to the subject. In the CL4STEM project, the category of subject matter knowledge consists of two themes: Knowledge of science and mathematics and the Nature of science and mathematics.

3.1.1 Knowledge of Science and Mathematics

The following box summarises the notion of SMK as per the conceptual framework of this study.

- Knowledge possessed by the teacher in one or more disciplines of science or mathematics.
    - The 'big' ideas, key concepts and theories in the discipline
    - Knowledge of interconnections between concepts/ topics within the discipline
- Ability to justify what counts as knowledge within the domain of science/maths

To examine the impact of CL4STEM on participants' subject matter knowledge, interviews, classroom observations, lesson plans, reflections and surveys were analysed. The results are presented in the subsections.

i) Knowledge of Big Ideas in the Subject: In STEM, the concept of "Big Ideas" refers to overarching, foundational principles or key concepts that provide a framework for understanding and organising knowledge within the disciplines. These Big Ideas serve as fundamental themes that help students make meaningful connections between various topics and promote a deeper understanding of the subjects. Results from endline interviews and classroom observations indicate a positive change in the theme of big ideas in science subjects and mathematics since some participants were able to recognize big ideas in various topics. For example, in physics, participant 2313 was able to guide students to correctly explain the concept of electromotive force (EMF). Participant 2313 demonstrated that a changing magnetic field induces an EMF in a conductor. This concept is fundamental to the operation of various devices and technologies such as generators, transformers, metal detectors, magnetic card readers and wireless charging. In mathematics, participant 2109, while teaching algebra, was able to explain to students that recognizing and understanding 'patterns' is a fundamental concept in mathematics. She gave an example that in linear and quadratic equations, recognising the underlying patterns within equations leads to the discovery of solutions and understanding of relationships between variables.

ii) Interconnections between Topics and Disciplines: The interconnections between topics and disciplines in STEM are vital for fostering a holistic understanding of the interconnected nature of these fields. Results from the interviews underscore the positive influence of the CL4STEM project on the knowledge of the participants. This is justified by the responses of the participants in the Endline surveys, where they demonstrated the ability to relate topics to real-life applications or illustrate connections across different disciplines. These are evidenced in the subsequent quotes:

"I know various mathematics topics such as linear programming, simultaneous equations, etc." -Teacher 2102, Baseline.	*"…learning mathematics is so important in life. The concepts in mathematics are easily integrated into other science subjects such as physics, chemistry and biology; and can be used in other professions like engineering …Science subject concepts and mathematics concepts govern everyday applications and the future."* -Teacher 2102, Endline.

In addition, lesson plans and reflections also demonstrated that the CL4STEM project positively enhanced the knowledge of the participants with regard to interconnections between different topics in the same subject. For example, in Chemistry, participants could connect the key concepts in Organic Chemistry such as the structures of hydrocarbons with concepts from other topics such as Atomic Structure. Classroom observations also demonstrated the positive impact of the CL4STEM project on the participants' knowledge concerning the interconnection between topics within the same discipline. For example, in physics, one participant when teaching the topic 'Forms of Energy' was able to link this topic with another topic called 'Energy Transformation'. In addition, the participant demonstrated the application of this topic to real-life situations by asking students to 'explain forms of energy they know and provide examples of potential energy and kinetic energy in real-life situations'.

Apart from the qualitative analysis mentioned above, baseline and endline surveys were administered to examine teachers' knowledge of SMK (Figure 3.1.1). The results indicated mixed observations. On the one hand, teachers' knowledge improved in a few subtopics, like *Lewis dot structure* in chemistry and *Plant reproduction* and *Cellular Metabolism* in biology and *Fractions* in mathematics; on the other hand, the results of several subtopics like *Inequality, Time and Distance, Area and Perimeter, Force, Gravity and Electromagnetic Force, Chemical and Physical Characteristics of Chemical Reactions, IUPAC name of Molecule and Hydrogen ratios of Organic Molecules, Cellular Structure and Cellular Reproduction* showed negative changes. The content knowledge in each subject, especially concerning these subtopics did not improve after the intervention.

Interestingly, during the Baseline survey, none of the teachers gave the correct answer to the question which tested the knowledge of *Work,* whereas during the Endline survey, 13% gave the correct response, thus indicating a 13% improvement in this subject matter. These results point out that curated physics modules based on OERs and participation in online CoP positively enhanced the subject matter knowledge of physics teachers in the subtopics, namely *Energy* and *Work*. The same trend was observed among mathematics teachers in their knowledge of the subtopic *Fractions*, chemistry teachers in their knowledge of the subtopic *Lewis dot structure*, and biology teachers in their knowledge of the subtopics *Plant reproduction*, *genetic* as well as *cellular metabolism* (Figure 3.1.1).

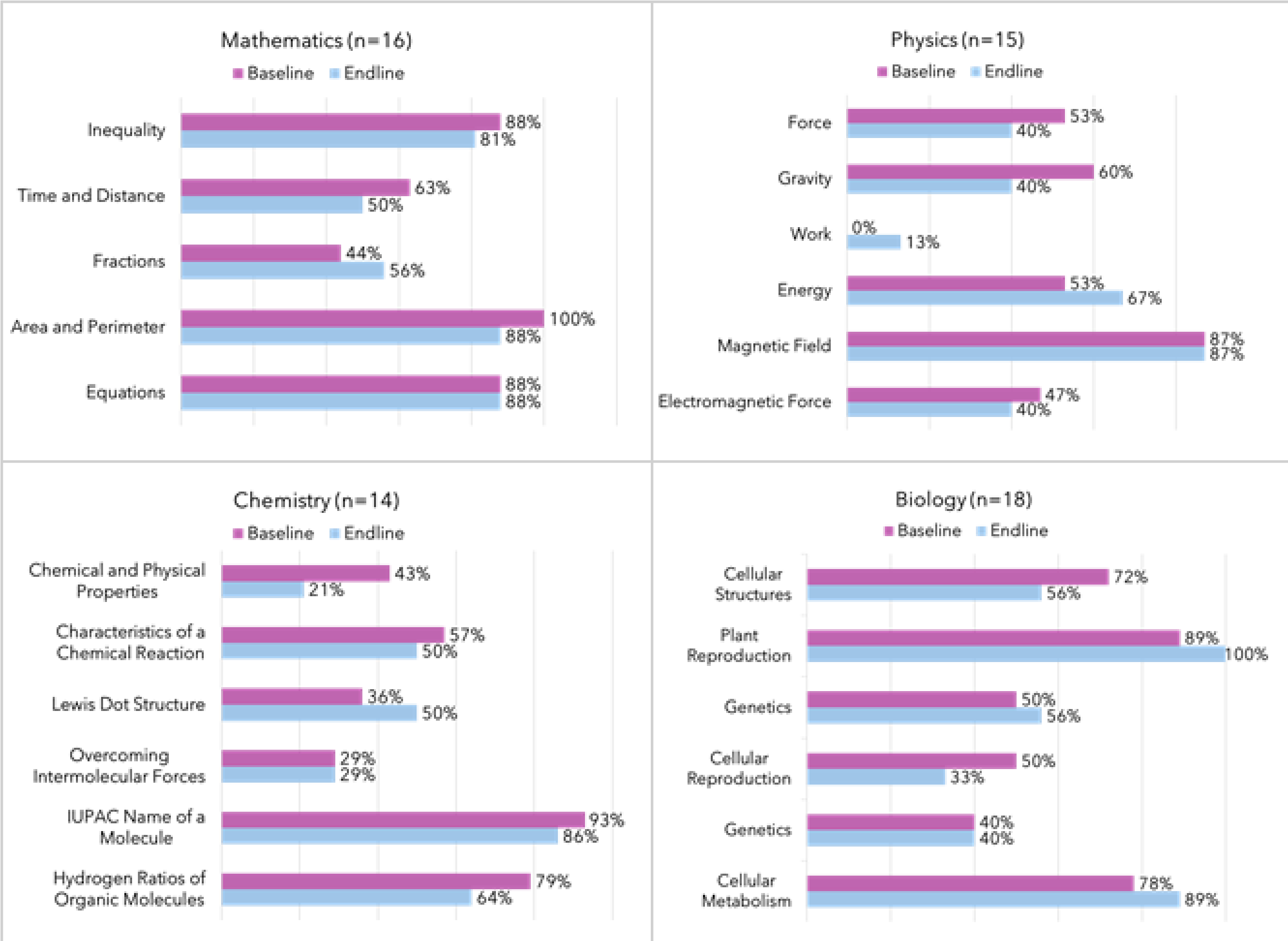


Figure 3.1.1: Responses of Teachers Responding Correctly to Questions on Knowledge of Different Subtopics.

In general, the results from interviews and classroom observations indicated a somewhat positive change in the understanding of key concepts in science/maths, the ability to connect concepts with specific topics, and the application of science/maths to everyday life situations. However, quantitative results show positive changes only in a few subtopics such as *Energy* and *Work* (Physics), *Fraction* (Maths), *Lewis's dot structure* (Chemistry) and *Plant Reproduction*, and *Genetic* and *Cellular Metabolism* (Biology). Therefore, these teachers need more support to better understand the rest of the subject matter knowledge which can be provided during CL4STEM scaling up.

3.1.2 Nature of Science/ Mathematics

The following box encapsulates a basic understanding of the nature of science and maths as conceptualised in this study.

- Teachers' knowledge of the nature of science, such as its empiricism; that it is situated in a particular historical, social, and economic context; that it requires creativity and imagination; and that modern science is a collaborative enterprise located in institutionalised spaces.
- Teachers' knowledge of the nature of mathematics; beliefs about mathematics; processes of mathematics: problem-solving, reasoning, proving and communicating; mathematisation of thinking or ability to represent something mathematically.
- Teachers' ability to communicate the nature and structure of science/maths to students

The nature of science/mathematics knowledge among teachers shapes and affects classroom practices. Results from classroom observations indicate that the implementation of the CL4STEM project slightly improved the knowledge of the participants concerning the nature of science. They could understand the importance of experimentation and observation in science and utilise the same in their classrooms. For example, teacher 2313, while teaching about 'Force and Motion', devised a scenario prompting students to pull each other in opposite directions to experience force and motion.

The interview data was not able to capture the teacher's understanding of the nature of science. However, while talking about the importance of teaching science in high school, some of the teachers could explain that learning science and mathematics is important to developing students' reasoning and thinking processes. This is evident from the quote-

"Learning science makes us innovative, … learning science enables us to innovate something, invent something. We can explain the reason behind a certain phenomenon. We can explain the nature of substance … learning science makes us curious and we know different things and the reasoning behind … science is not about learning theories, it is about doing practical things, meaning that students should learn by doing, by observing what is going on"- Teacher 2023, endline.

They could also explain its importance in terms of its application to solve real-life problems, however, this understanding can not be attributed solely to cl4stem intervention.

"… science subjects such as Biology expose students to their life, help the community to tackle different problems and apply them in normal life, so, science helps to cope with the changing world." - Teacher 2714, Baseline	*"Biology ensures that students learn about the environment and how they interact with it, their hygiene, their body and how it functions so that they can take care of themselves."* - Teacher 2714, Endline

In the survey under the theme of 'Nature of Science/Mathematics' all the participants were asked if they agreed or disagreed with the statements that: "Many things in Science/Mathematics are accepted as true with no explanation". Figure 3.1.2 shows a comparison of the teachers' responses to this survey item in baseline and endline. Generally, the understanding of teachers on the nature of science and maths did not improve after CL4STEM implementation.

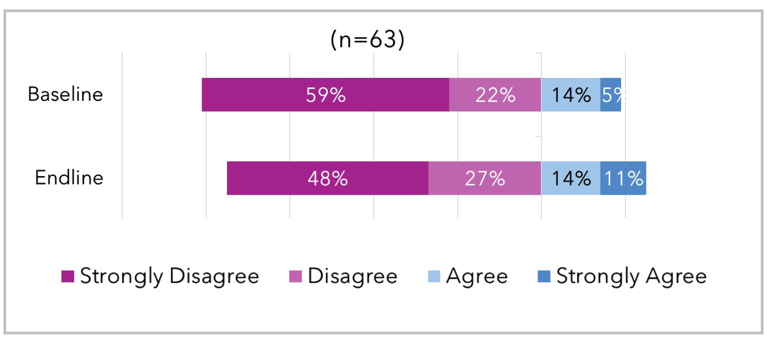


Figure 3.1.2: Responses of Teachers to "Many Things Must be Accepted as True Without Explanations."

However, when the knowledge of teachers on the nature of science and maths was analysed separately for each subject (Figure 3.1.3), the result indicated that the knowledge of biology teachers about the nature of science improved by about 11% after CL4STEM implementation. These results suggest that curated science modules based on OERs and participation in online CoP somewhat positively improved the knowledge of biology teachers concerning the nature of science.

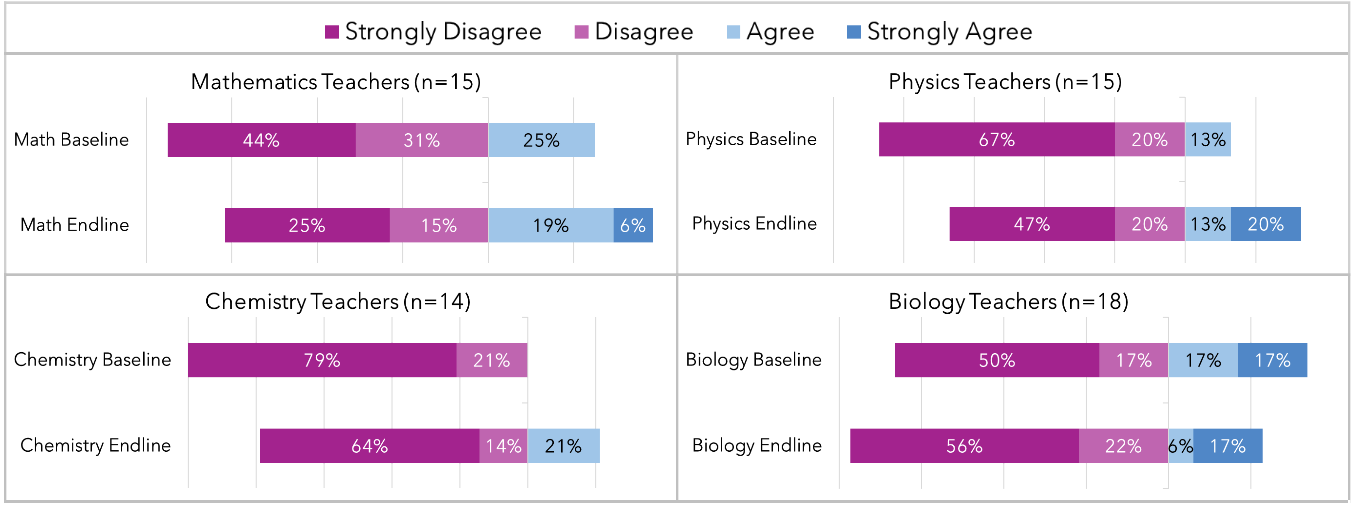


Figure 3.1.3: Responses of Teachers to "Many Things Must be Accepted as True Without Explanations." (Subject Wise)

In general, qualitative findings from interviews indicated some evidence of change in teachers' knowledge about the nature of science and mathematics after the intervention, especially about the notion that knowledge in science is based on experimentation, observation and reasoning. The quantitative results also support this finding, as only the knowledge of biology teachers about the nature of science had improved. As observed in the analysis of the theme of knowledge of subject matter, there is a need for further support for teachers to build their understanding of the nature of the subjects.

3.2 Pedagogical Content Knowledge

Pedagogical Content Knowledge (PCK) refers to the knowledge of the subject specific methodologies that teachers apply in the teaching/learning process in classrooms. In the CL4STEM framework, PCK comprises the following themes: Instructional strategies, Students' misconceptions and conceptual difficulties, Representation of the content, Context for learning and Curriculum knowledge. The results from these themes are discussed hereunder.

3.2.1 Instructional Strategies

The following box gives an overview of the instructional strategies employed throughout the study.

- Knowledge of different instructional strategies and resources
  - to develop scientific thinking, skills in experimentation, observation, inferring, categorising through data gathering, plotting graphs, and problem-solving.
  - to develop mathematical thinking, mathematization, reasoning, and argumentation.
- Knowledge of topic-specific pedagogical strategies and resources
- Ability to use different instructional strategies and resources to address diverse needs of learners, including addressing students' misconceptions and learning difficulties

This section presents and analyses data on instructional strategies for teaching mathematics and science subjects. Coded interview responses through the Baseline to Endline are summarised in Table 3.1. This table indicates that there was an increase in the use of a variety of instructional strategies and an increase in awareness, knowledge and utilisation of resources in teaching.

Table 3.1: Subcategories of Instructional Strategies

Instructional Strategies (Sub-Categories)		Baseline	Endline
i)	Employing various strategies (lecture, discussions, environment) to address different needs of the learners.	5	8
ii)	Developing scientific thinking by observation and problem-solving	1	1
iii)	Knowledge and utilization of resources in teaching	2	5

Towards the Endline interviews, we noted progressive responses to the queries on instructional strategies. The following examples explain the same:

"I employ different teaching methods like role play and use of different teaching aids."- Teacher 2100, Baseline	*"I use different teaching methods to teach and tackle mathematical problems. I can download videos which students see every day to teach mathematical concepts."*- Teacher 2100, Endline

Another teacher gave the following response regarding employing various strategies to address diverse needs of learners:

"I use different teaching methods like group discussions, lecture-based teaching and models."- Teacher 2307, Baseline	*"Use of the surrounding environment as a teaching guide/resource where students can experience how organisms interact with each other."*- Teacher 2307, Endline

During Baseline, the teachers seemed to be strictly guided by what the syllabus prescribes. After the intervention, teachers seemed to go beyond what is specified in the syllabus by employing various instructional strategies and resources to address the needs of the learners, as exemplified by the interviews and the responses given above.

Classroom observations of participating teachers indicated a shift towards learner-centered teaching strategies. Participating teachers seemed to have adopted various instructional strategies ranging from explaining concepts to exploring the ongoing group discussions in the lesson, using questions and answers to engage students in classroom activities and demonstrating concepts using diagrams or teaching materials prepared beforehand.

Teachers encouraged students to engage in classroom activities and mathematical games while learning different mathematical concepts. Using locally available materials (e.g. Teacher 2113 in mathematics; the use of pen, papers to derive mathematical formulas, onions to teach fractions etc.) while engaging with the teaching and learning environment was also observed. Moreover, positive change was observed in how teachers guided their learners to solve classroom problems, the use of setting in learning and how they connected science and mathematics concepts to their real-life situations using simple tools or demonstrations to present the big picture concerning the concepts in science and mathematics disciplines. For example, Teacher 2714 used mixed instructional strategies like question and answers, group discussions, and prepared diagrams and explanations to teach concepts in *Food Webs and Food Chains*.

Similarly, teacher 2713, a male teacher in a community school, while teaching *Cell structure and Organisations*, emphasised definitions to reflect the functional understanding of the primary themes of the lesson with the support of examples of the components and functions of parts within a biological cell. However, the same teacher in another lesson on *Genetics and Heredity,* nudged his students to think about the conceptual definition of science. The teacher used the questioning strategy to build students' understanding of *Genetics*. The nature of the questions prompted the students to engage with the concept beyond the textbook definitions and emphasised exploring their understanding.

Moving to the survey analysis of the questions on instructional strategies, quantitative data indicated a marginal increase in the teacher's role as a facilitator in mathematics, physics and chemistry classes, whereas biology classes showed a decrease in the teacher's role as a facilitator. Individual subject survey results implied improved instructional strategies being used in mathematics and physics classes by the participating teachers. The results for biology and chemistry however show that the intervention failed to make an impact.

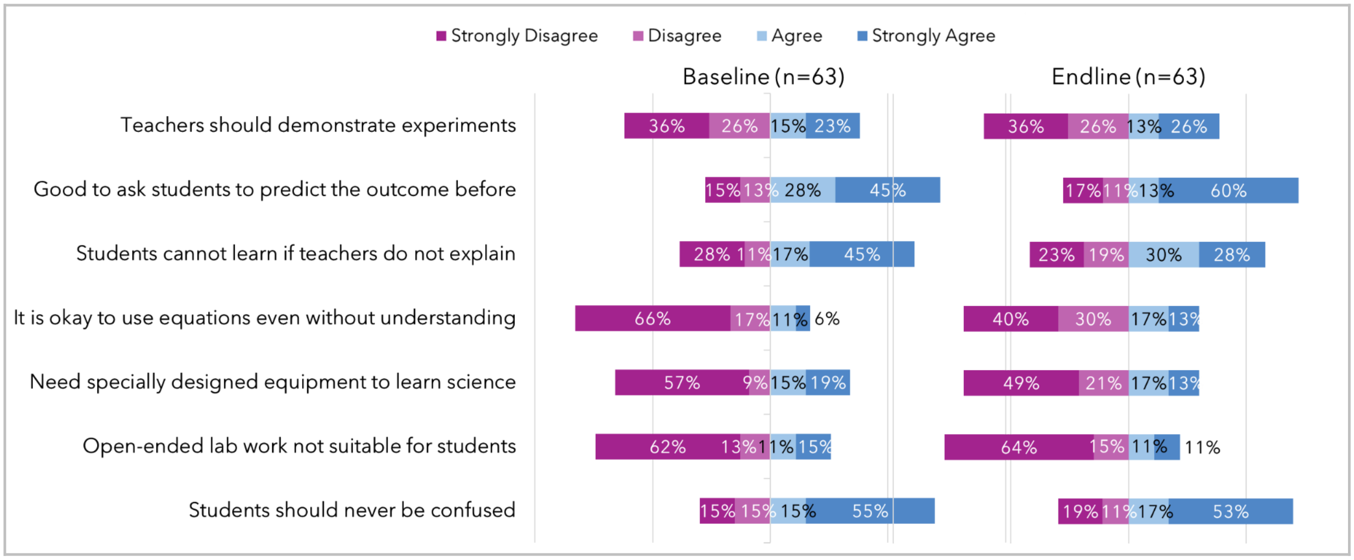


Figure 3.2.1: Instructional Strategies (Science Combined Distribution of Teachers)

The combined survey results on all the science subjects indicated a positive impact on the instructional strategies gained by participating teachers (Figure 3.2.1). Interview, classroom observation, and survey results suggested the positive impact of CL4STEM as the teachers' use of various instructional strategies in science and mathematics improved. The qualitative data from interviews and observations pointed to an increase in the use of various resources as an instructional strategy; however, survey data showed mixed findings, with a positive change in some categories and a negative change in others.

3.2.2 Students' Misconceptions & Conceptual Difficulties

The following box outlines the points on student misconceptions and conceptual difficulties as conceptualised in this study.

- Knowledge of students' prior conceptions, errors, misconceptions/alternative conceptions, ways in which students think, and the concepts students find difficult to learn
- Knowledge of areas that students find difficult to understand
- Ability to use students' errors to understand their ways of thinking and to design learning experiences to support students' STEM learning

The interview data revealed that teachers understood the importance of identifying the misconceptions of the students and dealing with them in the classroom, as is evident from the following quote-

You know before CL4STEM when I planned the Lesson plan, I will not spot the common misconception. I just see and arrange to understand the way I used to arrange it but when I studied in CL4STEM I have realised, I come to realise that it's easy to teach after having anticipation towards a common misconception.- Teacher 2504, Endline

When interviewed during Baseline, science teachers cited a shortage of teaching and learning resources, the use of the English language, students' background in mathematics and science, and classroom overcrowding as some of the difficulties faced by the students. Before the project intervention, the participating teachers didn't articulate students' misconceptions related to specific science or maths concepts and how they could design their teaching to reduce those conceptual difficulties. However, during endline interviews apart from lack of resources and other problems they also stated alternate conceptions of students can hinder their understanding of that concept and hence they shaped their teaching plan to address students' misconceptions.

"Language is not a barrier in learning mathematics" -Teacher 2109, Baseline	*"Lack of textbooks to implement lessons effectively; I can use my smartphone but still it is a problem for my students. I also give my students a five-minute quiz before I start my lessons to help me diagnose their prior knowledge and misconceptions to help in addressing them during the teaching/learning process."* -Teacher 2109, Endline

Similarly, endline interview responses from one of the interviewees (teacher 2516) indicated a positive change as the teacher could now distinguish between difficulties and students' misconceptions. After having understood what misconceptions meant, he started the lesson by finding learners' prior conceptions and misconceptions. Moreover, he seemed to have developed the ability to use students' errors in designing learning experiences to teach STEM subjects, as evidenced by the quotes below.

"The challenge I face when teaching chemistry is lack of resources like books and laboratory chemicals" -Teacher 2516, Baseline	*"I start a lesson by asking questions to check student's prior knowledge and if there is any misconception and clear the doubts as I continue with teaching and learning process"* -Teacher 2516, Endline

In the endline interviews some teachers spoke about designing learning experiences to deal with the misconceptions of the students in the class. One of the maths teachers said that some students have misconceptions related to the relationship between area and perimeter, that is, some students believe that - If the area of a shape increases it necessarily implies that its perimeter will also increase. He elaborated on how a question related to this stirred an interesting conversation in the class.

"And most of the students, also teachers, also I, considered that one to be easy. And that the concept is considered to be easy. But after joining CL4STEM it showed how different questions may be approached ..., which requires critical thinking. That's when it was my best because there were some questions even on my side despite being good at mathematics, but I had to think more. There were some questions which I had put on the board and we were there for every single question finding the perimeter and the areas, and different answers were coming from different students about the same question. So we had a little bit of judgement. So, I showed the students how to approach such a question and they were very amazed, after that, I gave them such a question. This time we had a single answer. It was the question concerning the areas and perimeters, whether it is possible for the area to increase and the perimeter to decrease or vice versa. So different students had different ideas so this time with vivid examples."- Teacher 2100, Endline.

Furthermore, data collected during classroom observation indicated teachers' increasing ability to identify students' misconceptions and address them. For example, a male biology teacher, 2714, in a public school was able to spot and clarify that food webs and food chains are not only found in national parks and game reserves where plants and animals interact but are found everywhere, even in our local environments. In another example, Teacher 2521, while teaching a topic under *Hydrocarbons*, clarified one common misconception that these compounds are made up of Carbon and water, caused by the prefix 'hydro' in hydrocarbons. This indicates that teachers understood the importance of addressing misconceptions. In the endline interview, he said-

"We know that organic compounds are made of carbon atoms. Some inorganic compounds are also made of carbon atoms. So, they might think that if a compound has carbon, they can simply assume that it is an organic compound. But, some are just inorganic compounds."- Teacher 2521, Endline.

Similarly, another teacher (physics teacher 2306) used a sliding bucket and a walking student in front of the class to address students' misconceptions related to the difference between velocity and acceleration (image: 3.2.1).

Image 3.2.1: Teacher demonstrating difference between velocity and acceleration

Survey questions for quantitative data were designed to identify how teachers recognize some of the most prevalent misconceptions in sciences and mathematics. These questions allowed us to examine how teachers perceived these misconceptions and what proportion of teachers were aware of some of the most common misconceptions in the subject. Responses from Baseline and Endline surveys for the subjects mathematics, physics, chemistry, and biology were compared.

The two questions in the mathematics survey were designed to identify misconceptions about *Area and Measurement* (topics from the module). The results indicated no observable difference in the frequency of correct responses between Baseline and Endline (Fig 3.2.2).

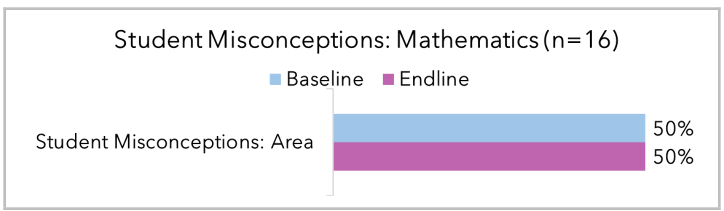


Figure 3.2.2: Proportion of Correct Answers to the Question on Student Misconceptions in mathematics

The multiple selection question was designed to understand what a teacher thinks a student should know for solving a problem based on the concept of area. Three answer options provided with the question were prerequisites for a student to solve the problem (the formula for the area of a rectangle, the technique to count squares (as geometric shapes), and the concept that a right triangle is the half of a rectangle). Thus, when a teacher identified all the three options, it reflected that the teacher recognized the prerequisite concepts a student must be familiar with to solve this problem. If a teacher identified one or two options, it reflected that the teacher had not recognized the exhaustive list of prerequisite concepts a student must have to solve this problem. However, the other options (knowledge of how to use GeoGebra or

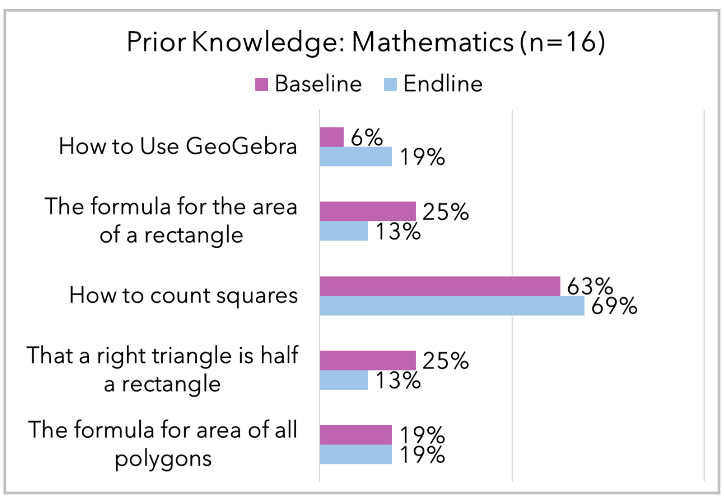


Figure 3.2.3: Proportion of Correct Answers to the Prior Knowledge Question in Mathematics.

the formula for the area of all polygons) were not a necessary prerequisite to solve the specific problem. There was no observable difference between Baseline and Endline frequencies (Figure 3.2.3).
Two questions, one on *Force & Motion* and another on *Energy* were asked to understand misconceptions in physics. In the Baseline survey, many participant teachers identified the common misconceptions (Fig. 3.2.4). However, in the responses given during the Endline survey, there was a variation in how teachers identified the misconceptions. While solving a problem on *Energy*, almost all the teachers could identify where the student might have faced the challenge, but only a fewer number of teachers could correctly identify the misconception in the problem on *Force* in Endline. This suggests that the intervention did not assist participant teachers in identifying students' misconceptions in general from the quantitative point of view.

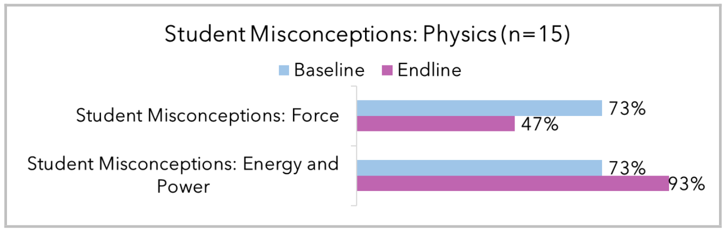


Figure 3.2.4: Proportion of Correct Answers to the Questions on Misconceptions in Physics.

The question in chemistry addressed the conceptual difficulty in understanding matter/material, a fundamental construction in chemical sciences in schools. In both Baseline and Endline surveys, few teachers were able to identify the correct response to this question (Fig. 3.2.5). The lower frequency of the correct responses and the absence of difference between Baseline and Endline surveys suggest no observable change in chemistry teachers' understanding of student misconceptions.

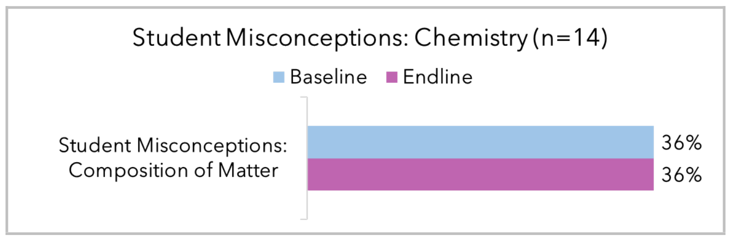


Figure 3.2.5: Proportion of Correct Answers to the Questions on Misconceptions in Chemistry.

There were four questions in the biology survey framed to understand the teachers' recognition of misconceptions among students. These questions, which had a single option as the correct answer, were based on concepts in ecology, genetics and cell biology - spanning the three areas that CL4STEM modules focus on. A higher number of teachers identified the common misconception stated in the question on ecology compared to those who identified the misconceptions stated in the questions on genetics or cell biology (Fig. 3.2.6). The frequency of responses in Endline surveys shows a marginal increase in the correct identification of misconceptions, except about the concept of gene, implying a slightly positive change in teachers' understanding of student misconceptions in biology.

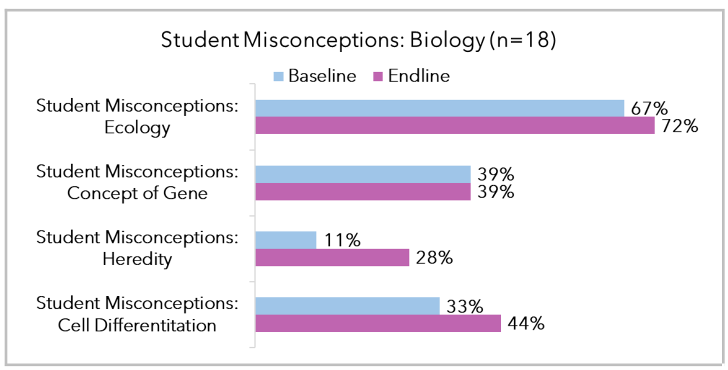


Figure 3.2.6: Frequency of Recognizing Common Misconceptions in Biology.

Overall, the quantitative data imply mixed results with regard to teachers' understanding and their use of student misconceptions and conceptual difficulties to design learning experiences for effective and efficient teaching of mathematics and science. Even though survey results were of mixed implications , the findings obtained through interviews and classroom observation revealed that CL4STEM modules and project practices had somewhat positive impacts. The results suggest that the intervention had a marginally positive effect on teachers' practices in identifying misconceptions and students' learning difficulties, which then helped them design learning experiences to support students' STEM learning. This aspect should receive greater focus while planning for the scaling of the project.

3.2.3 Representation of Content

The following box summarises what the study means by representation of content.

- Knowledge of multiple forms of representation of content E.g. analogies, equations, gestures, graphs, diagrams and illustrations, models, tables, texts, videos, simulations, photographs.
- Knowledge of the limitations of models and illustrations in representing content
- Ability to use multiple representations of content to meet diverse needs of students

This theme explores teachers' understanding of multiple forms of representation of content, which helps them provide learners with various interactive ways to access and engage with course materials and information. It signifies the teachers' ability to present the same concept using more than one representation. This section details the trends in change from Baseline to Endline as observed during surveys, interviews, and classroom observation. The interviews sought to gain insights on how participants represented subject matter content and whether changes in representation could be traced during the duration of the project implementation. Interview data indicates that teachers employed multiple mediums to represent content, such as charts, pictures, models, maps, slides, clips, and real objects. During the interviews teachers revealed that the project created awareness among them regarding the use of ICT as well as locally available teaching-learning resources for representing different concepts.

"I use computers, tablets, and smartphones. But also, I prefer the use of a head projector to teach my students, but in my school, it is not available."- -Teacher 2113, Baseline	*"I was ignoring the use of technology and multimedia in teaching; I was unaware of the different ways of presenting materials using technology, thinking that it is difficult. Now I know that only my smartphone can be useful enough for this purpose."* -Teacher 2113, Endline

The findings from classroom observations showed that teachers employed multiple ways to represent the content in their subject domains. Five teachers out of the eight who participated in classroom observations showed improvements in their ability to use multiple media for representation of content. They could use words to explain concepts, use the local environment, laboratory tools, chemicals and specimens, charts, drawings, illustrations and group discussions to represent the content of the lessons that they had planned to teach. They could switch from one type of representation to another when needed. For example, a mathematics teacher when teaching the concept of fraction to form II students represented the concept using charts as well as concrete materials to ensure internalisation of the concept among students (image 3.2.2).

Image 3.2.2: Teacher representing cell structure and organization (left) and fractions (right) in different ways

Similarly, another teacher used a diagrammatic representation during the teaching of fractions to clarify the concept of proper fractions (image 3.2.3). This visual aid played a pivotal role in making the abstract idea of fractions more tangible and, consequently, enhancing students' grasp of the concept.

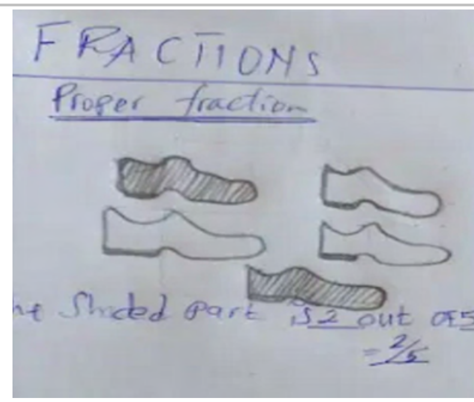


Image 3.2.3: Visual representation of fraction (Student Work)

Teacher 2713 working in a community school carefully prepared his teaching material using charts, diagrams and figures to ensure students' effective learning. Some teachers used locally available materials like different laboratory specimens and drew resources from the environment. 2113 (left) & 2713 right (Image 3.2.4).

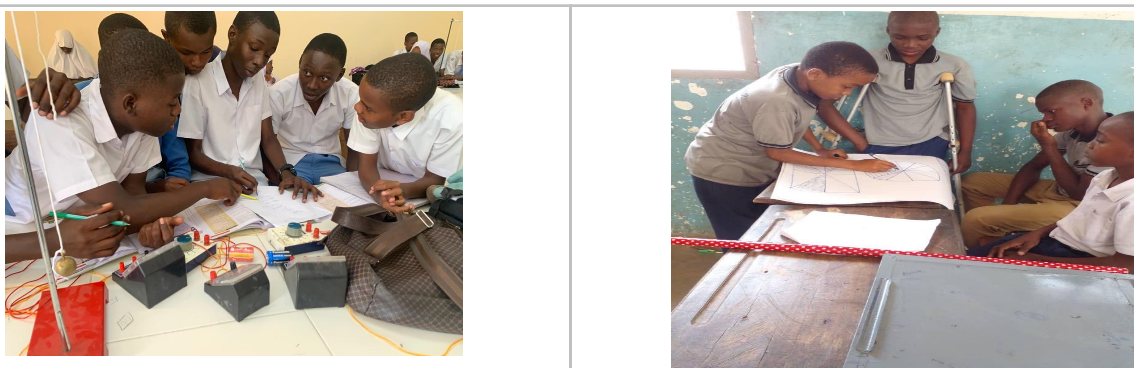


Image 3.2.4: Students using locally available laboratory materials

The survey data provided details about the extent of change in teachers' attitude and knowledge due to their participation in CL4STEM modules. The data from individual subjects showed mixed results, with improved results noted in the responses given by the participants teaching physics and Biology, whereas the participants teaching mathematics and chemistry did not show any improvement, as explained below.

Data from Math teachers indicated a 7% decrease in use for 2 types of resources ('Charts, models, worksheets, and activities prepared by a teacher', and 'Use of the surroundings, contexts and artefacts, real-life experiences'), and no change in the use of 'Digital /ICT-based resources' and 'Popular talks or lectures online /offline'. However, there was also a 7% increase in the use of both– 'own education' and 'textbooks, teaching materials', and a 13% increase in teachers who used 'Other books, magazines and journals' as a major resource across Baseline to Endline. Overall, no observable changes can be implied for Math participants, as the survey showed mixed results.

Similarly, chemistry data indicates no change in the use of teachers' 'Own education in Science'; a 7% decrease in the use of 'Digital/ ICT-based resources', a 15% decrease in the use of 'Popular talks or lectures online/offline', and a 30% decrease in 'Use of the surroundings, contexts and artefacts, real-life experiences'. In contrast, there is a 7% increase in the use of 'Textbooks/ teaching materials', a 15% increase in the use of 'Charts, models, worksheets, and activities prepared by a teacher' and a 21% increase in teachers reporting using 'Other books, magazines, and journals' as a minor resource across the Baseline to Endline. Thus, as there were 3 categories where a decrease was noted and 3 categories where an increased use was noted, no conclusive claims can be made about the impact of CL4STEM on chemistry teachers' Knowledge and Attitudes about using multiple resources to represent content.

In physics, 14% of teachers reported decreased reliance on their education, along with a 7% decrease in the use of 'Charts, models, worksheets, and activities prepared by a teacher'. However, for all other survey options, there was an increase in use reported: a 6% increase in the use of 'textbooks, teaching materials' as a major resource, a 7% increase in 'Use of the surroundings, contexts and artefacts, real-life experiences', 14% increase in 'Popular talks or lectures online /offline', 20% increase in 'Other books, magazines, and journals', and 27 % increase in 'Digital /ICT-based resources'. Thus, it can be concluded that there was a positive impact of CL4STEM engagement on physics teachers' knowledge and attitudes.

The Biology findings indicate a a 17% decrease in the use of 'Other books, magazines and journals', along with a 6% increase in the use of both– 'Own education in Science' and 'Textbook/ teaching materials', a 17% increase in 'Charts, models, worksheets, and activities prepared by a teacher', a 22% increase in both– 'Use of the surroundings, contexts and artefacts, real-life experiences' and 'Digital /ICT-based resources', and a 4% increase in the number of teachers who used 'Popular talks or lectures online/offline' across Baseline to Endline. Hence it can be concluded that overall, for Biology teachers' Knowledge and Attitudes, there was a positive impact on CL4STEM intervention.

An analysis of resource use in terms of gender showed (Table 3.2), a relatively high proportion of positive results- in 4 out of 7 items (57%)- among males than among females- in 3 out of 7 items (43%). Interestingly, after the project implementation, there wasn't much change in the % of male teachers who used popular talks or online lectures as a resource for teaching, but the % of female teachers who used these resources increased by almost 25% (indicating a strong positive change for this resource).

Table 3.2: Use of Resources- Gender-wise Comparison

Resource	Male (n=49)		Female (n=13)	
	BL	EL	BL	EL
Own education in Science/Maths	91%	98%	100%	100%
Textbooks/Teaching materials	98%	96%	92%	100%
Other books, magazines and journals	84%	90%	100%	92%
Charts, models, worksheets, and activities prepared by a teacher	94%	92%	100%	100%
Use of the surroundings, contexts and artefacts, real-life experiences	94%	94%	100%	100%
Digital /ICT-based resources	82%	88%	85%	92%
Popular talks or lectures online /offline	74%	78%	46%	69%

The data across Baseline and Endline reveal that the participants with 5 years of experience or less showed a higher degree (71%) of improvement, while those with 6 and above years of experience showed less improvement (43%). Concerning teachers' knowledge and their ability to use multiple representations of content, the findings showed that the project had a positive impact, particularly on those participating teachers with 5 years of experience or less.

Overall, across Baseline to Endline there was an increase in the teachers' understanding of knowledge and an improvement in their attitude towards the use of local resources (57%) in teaching math, physics and Biology whereas among chemistry teachers only a minor increase was noted. In terms of gender, a relatively higher proportion of positive results was observed among males (57%) than among females (43%). In terms of experience, teachers with less experience demonstrated greater change in knowledge and understanding of the ways to represent content using local resources.

The research findings from surveys, interviews and classroom observations showed that the implementation of the pilot modules somewhat changed teachers' understanding of the representation of content. The intervention initiated awareness among participating teachers. Teachers showed improvement in the use of multiple forms of content representation, especially in the use of ICT to represent content.

3.2.4 Context for Learning

- Knowledge of the larger school/regional infrastructural, discursive context which shapes their pedagogical choices.
- Knowledge of the environmental/ lab/ material resources available in the context which can be utilised to promote science/ maths learning.
- Ability to adapt resources/use locally available materials to meet the needs of learners
- Ability to connect different topics in science/maths to everyday experiences/ daily life practices of the students.

The baseline and endline interviews with teachers revealed that teachers understood different contextual factors that made teaching/learning of science and maths difficult for students like lack of resources and use of foreign language. The under-resourced context in which schools operate with a lack of laboratory equipment, textbooks etc was voiced as the most common learning barrier by most of the teachers in the baseline interviews. However, during the midline and endline interviews, teachers explained how they made use of locally available materials while teaching.

Apart from the lack of resources, another contextual problem identified by the teachers was the usage of English language in the textbook which made comprehension of the subject difficult for students as it was not their native language. Teachers could identify that students grappled with understanding the scientific concepts in that alienated language. The English language was identified as problematic for learners in government and community schools, while in private schools this was not the case. Such differences in response among government, community and private school teachers were expected because, in private schools, there is much emphasis on the use of English as a medium of communication, while in government and community schools, there is less emphasis on the same. This is the reason why teachers in government and community schools identified language as a difficulty.

While analysing the interviews, the subcategories examined and the insights gained during the interviews across Baseline to Endline are given below. Table 3.3 shows the subcategories for context for learning based on the participants' interview responses. Some notable insights include adapting to various resources inside & outside the school environment, using science laboratories and segregating big concepts and ideas in science & mathematics to connect them with individual topics taught in schools as directed in the school curriculum.

Table 3.3: Context for Learning

Sub-Category	Definition	Baseline	Endline
Adapting to different resources in teaching	Identifying and using locally available resources in classroom teaching	9	11
Making use of laboratories and environment in teaching	Exploring science laboratories and making use of them for learning	3	3
Connecting concepts in science and math with topics	Connecting the big ideas in science and math with topics to be covered in classes	4	5

The qualitative data on sub-categories derived from the interviews as shown in Table 3.3 indicates an increase in understanding among participants regarding the aspects of context for learning. The results show that the number of teachers who used locally available resources in the classroom to teach science and mathematics increased from 9 to 11 across Baseline to Endline. The same trend was observed in responses on connecting the big ideas in science and mathematics to topics to be covered in classes. The results in relation to teachers exploring science laboratories and using them for learning showed no change; this also implied desired results because practicals are prescribed in Tanzania's curricula for science and mathematics.

During the interviews, teachers shared that through this intervention they understood how to use locally available materials to teach science and maths concepts in the class, which is evident from quotes like-

"When I found the student to face difficulties in understanding the content particularly that I will say the chemical bonding I use the most likely mostly available resources like he Beans and so I explained to the students on how electrons are arranged initially and how they can share electrons when forming the bond, let's see. So they understood it more… but this is a technique, I found it from CL4STEM. And CL4STEM has worked for me to discover new techniques, new materials and locally available to make a student understanding". - Teacher 2504 Endline.

Teachers also started using digital resources to overcome the barrier of shortage of resources in the class. Teacher 2306 working in a community school had the following to say about the usage of digital resources:

"Some teaching and learning materials can be found in the laboratory... other teaching and learning materials which are not found, the teacher must put personal effort to find it in the surrounding environment. Or may ask to borrow from somewhere"--Teacher 2306, Baseline	*"The resources are available depending on the subject matter we teach. For example, teaching resources can be found anywhere, even in the classroom, if we teach about the matter. I use the smartphone and computer to simplify instruction and also as one of the teaching media in our classroom that facilitates learning. For example, some items that we could not find in school were downloaded from the devices, students can see, and they could learn from those simulations"* --Teacher 2306, Endline

The above responses indicate a positive change across Baseline to Endline concerning understanding and using readily, locally available materials as well as digital resources. Moreover, after participating in CL4STEM, participants identified more advantages of using locally available teaching and learning materials, as revealed by teacher 2714, in the excerpts below:

“Local resources for teaching biology are available around the school surroundings. However, due to the larger number of students, sometimes the resources aren’t enough for all students, but the school has enough textbooks to use.”-Teacher 2714, Baseline	*“When teachers use the resources available in their environment, it is easier for the children to understand, and the lesson is understandable and enjoyable for students. Now I plan to teach [using] locally available aids, very common to my students, and low cost.”*-Teacher 2714, Endline

From interview responses, we could see the improvement in understanding of the context for learning from Baseline to Endline.

During classroom observations, it was noted that the teachers paid attention to the use of the surrounding environment and resources in teaching. They provided examples and gave explanations derived from the student’s everyday life and carefully chose them to direct learning towards the message/concept they were focusing on. For example, Teacher 2713 used the locally available seeds to discuss plant cells; the teacher gave an example of a honeycomb to examine the structural analogy of a cell. Immediately, the teacher asked the students if they knew the English word ‘honeycomb’ . When the students didn’t respond, he asked them in Kiswahili about honeycomb, and they were immediately able to recognise it. In one of the other observed lessons, the teacher used several examples from the local context to elucidate the biotic and abiotic components. The students also responded by quoting examples from the local ecological contexts.

Image 3.2.5 Teacher using locally available material for teaching the concepts of work, energy and force in Physics

An improvement in the teachers’ knowledge of the larger school and context, which shapes their pedagogical choices, the adaptation of the resources and the use of locally available materials to meet the needs of learners were evident during the Endline when compared to the Baseline. Thus, a positive change was observed in participating teachers' knowledge, attitudes and practices regarding the context for learning.

3.2.5 Curriculum Knowledge

- Knowledge of the goals and purposes of teaching science/mathematics
- Knowledge of the hierarchical sequence of foundational concepts for teaching and its interconnection with other concepts/topics in curriculum across grades
- Knowledge of linkages between science and maths and other school subjects
- Ability to use knowledge of curriculum to design integrated learning experiences for students

This section explores participating teachers' knowledge, skills and attitudes concerning their curriculum knowledge. The interviews with teachers revealed their growing understanding of the goals and purpose of teaching science/mathematics. While in the baseline some teachers said learning science increases their knowledge and understanding in general terms, in Endline they could elaborate on the purpose of teaching science, especially for problem-solving. For instance, Teacher 2504 had this to say during Baseline and Endline,

"Learning science at a higher level increases their knowledge, increases their level of understanding." -Teacher 2504, Baseline	*"It gives us a framework, it gives the student a framework as to how they can use different techniques and the processes to get the answer concerning the question which are our problems which are already faced in the society. So, most of the problems are science or mathematical oriented. So teaching science and mathematics is basically, to solve problems or to get the answers to the questions which are always around us. Problems that we have in society including some diseases and Associates and how to tackle those or use locally available materials to create a viable product can increase productivity. How can we offer the planning of how to do so and the actual doing so" -Teacher 2504, Endlin*e

Throughout the interviews, the teachers displayed concern about preparing lessons keeping in mind the goals and objectives of the curriculum. They narrowed it down to the individual topic/subtopic and the lessons taught in the classroom. For instance, Teacher 2306 had this to say during Endline -

"When planning a lesson, I look at the subject matter I will teach, which is which topic and which subtopic. Then the objective of that topic and what my students should learn from that topic. I plan for the activities that will enhance learners' understanding, actually in the introduction, in the development of the lesson, and then I plan for the reflection, the assessment of the students, that is, if what I've taught is understood or not, so I plan for the assessment activities." -Teacher 2306, Endline

Interviews data also reveal that teachers' understanding about the interrelationships between different maths and science concepts and the hierarchical nature of concepts as is evident from this quote-

"Mathematics is build up in terms as you are building the house or building the ladder, it's very important to have the previous concepts because if the student is not good at that, at a number addition, he or she will not be also good at a multiplication if the student is also not good at multiplication, then he or she is not good at will not also be good at division. Now, if the students are good at Division, he or she will not be good at word problems concerning division, we find the basic concepts which the student fails to get this leading to most students not getting this concept. So, we find that to find a student who is not passing in a concept of mathematics, you have to fix those before teaching the next ones. One of these topics which are taught to students, especially in these classes from form one to form three was supposed to be taught in the primary but they were not taught well or they were taught loosely in the topic of integers. We found the students having problems with integers, they began to subtract integers … 90% of the topics which are taught at the secondary school level rely on the concept of integers. So, you may find this student giving a how-to-derive formula showing how to input data after he or she has input the data, we find that he does not know how to proceed with that concept because the previous concepts which he or she is supposed to have to proceed to finish that question, he or she cannot proceed" -Teacher 2100, endline.

They were also able to understand the interconnections of science ideas and communicate the same to students as evidenced by the following quote,

"... I can adequately communicate the properties of carbons and connect these with the lower hydrocarbons like alkanes, alkenes, and alkynes." - Teacher 2508, Endline

The classroom observations demonstrated that the teachers were concerned about curriculum knowledge while preparing lesson plans, teaching, and assessments. Teachers could also align the ideas incorporated in CL4STEM modules to subject-specific contents and classroom activities. We observed how they connected concepts in science and maths across subjects in general and within the subject domain to students' everyday lives.

For example, Teacher 2714 connected the lesson's objectives with the syllabus while planning the lesson and executing activities in a real classroom setting. He demonstrated the importance of the functions of the cell as a fundamental unit of life and how vital it is for organisms to interact for the existence of life on Earth. He connected the big ideas mentioned in the goals and objectives of the biology syllabus to real-life examples familiar to students to help them understand the concepts. For example, he explained prey-predator relationships using real examples from Tanzania's natural environment by bringing into discussion the relationships between wildlife organisms as observed in Serengeti. Another participant, Teacher 2521, showed an understanding of the goals and objectives of lessons, and these were carefully integrated into the lesson plan. Further, the teacher easily connected the uses and importance of organic compounds with other science subjects and the school environment by giving examples from the local setting and the use of different hydrocarbons in daily life. The classroom observation results suggest the intervention's positive impact on the curricular knowledge among science and mathematics teachers.

It is evident that teachers need to have an in-depth understanding of the sequencing of concepts within their subject of specialisation for them to teach effectively. Table 3.4 shows the change in the percentage of teachers' responses across subjects when asked about the hierarchical sequence of foundational concepts across grades. The data indicates that the response denoting agreement was doubled in the case of physics (from 7% to 13%) and chemistry (from 14% to 36%) teachers though the opposite results were observed among biology teachers. For maths teachers, no change was observed across both surveys.

Table 3.4: Teachers' Responses to the Hierarchical Sequence of Foundational Concepts across Grades

Survey	Maths		Physics		Chemistry		Biology	
	Disagree	Agree	Disagree (%)	Agree (%)	Disagree	Agree	Disagree	Agree
Baseline	69%	31%	93%	7%	86%	14%	67%	33%
Endline	69%	31%	87%	13%	64%	36%	84%	17%

The classroom observations and interviews showed a positive impact on teachers' understanding and use of the curricular knowledge. However, the quantitative data showed mixed results.

3.3 General Pedagogical Knowledge

As per the CL4STEM framework, the general pedagogical knowledge comprises three KAP themes: equity and inclusion, classroom management and assessment.

3.3.1 Equity and Inclusion

- Knowledge of Universal Design for Learning (UDL)
- Ability to provide equal opportunities to all students to participate in classroom interaction
- Ability to use UDL principles to design and implement lesson plans, resources and assessments to meet diverse needs of learners

An inclusive classroom is an environment where all students feel supported intellectually and academically with a sense of belonging regardless of identity, learning preferences, or any other identifiers. For example, an inclusive classroom could have a mix of gifted students, auditory learners, visual learners, students with physical and cognitive disabilities, along with students from diverse backgrounds. On the other hand, equity focuses on taking those opportunities presented to students and infusing them with support and resources to turn the education system into a level playing field. Equity creates opportunities for underprivileged and underserved students to overcome disadvantages and succeed. Equity also allows every student to learn in the way that best supports their learning style.

Interviews, classroom observations and surveys were conducted to explore the impact of CL4STEM on teachers' knowledge, attitudes, and practices in relation to inclusion and equity. The interview findings indicated that teacher awareness of equity and inclusion strategies was enhanced in the Endline when compared to the Baseline. There was also an improvement in the awareness of approaches that work to accommodate the needs and abilities of all students in the learning process. In addition, teachers demonstrated skills in using UDL principles to design and implement lesson plans to meet the diverse needs of students. The qualitative findings from interviews also indicated that the CL4STEM project improved the ability of teachers to provide equal opportunities for all students to participate in classroom interaction. The above claims are supported by the evidence shared below:

Teachers' efforts to provide equal opportunities to all students to participate in classroom interaction, and accommodate the needs and abilities of all students are clear from the following responses:

"…. I teach a class with many students, but I can ensure that all students participate in classroom activities by providing group works and individual student assignments whenever necessary."--Teacher 2113, Endline

"… I use simple language to accommodate students from private and government schools with different English language backgrounds."- -Teacher 2714, Baseline	*"… some of my students in the class have problems expressing themselves in English since they studied their Primary education in Government schools where Swahili is the major means of communication. But I always try to ensure that all students, whether they studied in Private schools or Government schools, must understand what I am teaching. …. Thus, I use simple language and clear illustrations to explain various Biology concepts."*--Teacher 2714, Endline
"I provide exercises according to the level of understanding of students."- -Teacher 2100, Baseline	*"I can formulate different groups that combine both slow-learner students and fast-learner students. This inclusion facilitates [a] better understanding of various mathematics concepts and enables sharing of materials."* -Teacher 2100, Endline

For example, Teacher 2516 revealed the following in their interview:

"I am aware of the goals and purpose of teaching science, which is to impart knowledge to learners that are necessary for its application in real life." --Teacher 2516, Baseline	*"My best CL4STEM lesson was the structure of matter. There, I was able to engage my students with significant interactions with their fellow students and me by integrating the principles of universal design of learning for more student participation in the lesson."*-- Teacher 2516, Endline

Generally, the classroom observations indicated that the CL4STEM project improved teachers' knowledge of the need to provide equal opportunities to all students to participate in classroom interaction. For example, Teacher 2113 taught a class with more boys than girls. Of the total 42 - 46 students, only 6-8 were girls. To ensure inclusion in the seating plan, the teacher arranged for the girls to sit among boys so that they could all engage equally in classroom activities. The teacher also asked girls questions to give them a chance to participate in classroom activities. The teacher also asked girls to come in front of the class to solve problems, as he did with boys. However, the number of boys who showed up was higher due to the low numerical strength of girls in the class.

Figure 3.3.1 presents teachers' responses regarding students whom they considered challenging to teach science/mathematics effectively. The results showed that after the intervention, teachers understood the definitions and examples of each challenge category. As a result, during the Endline survey, the percentages of teachers' responses against most categories of challenges increased (with frequency ranging between 30% to 54%), except against the group of difficulties tagged '*students with poor motivation*'. These results implied that modules and participation in online CoP effectively improved teachers' knowledge concerning UDL.

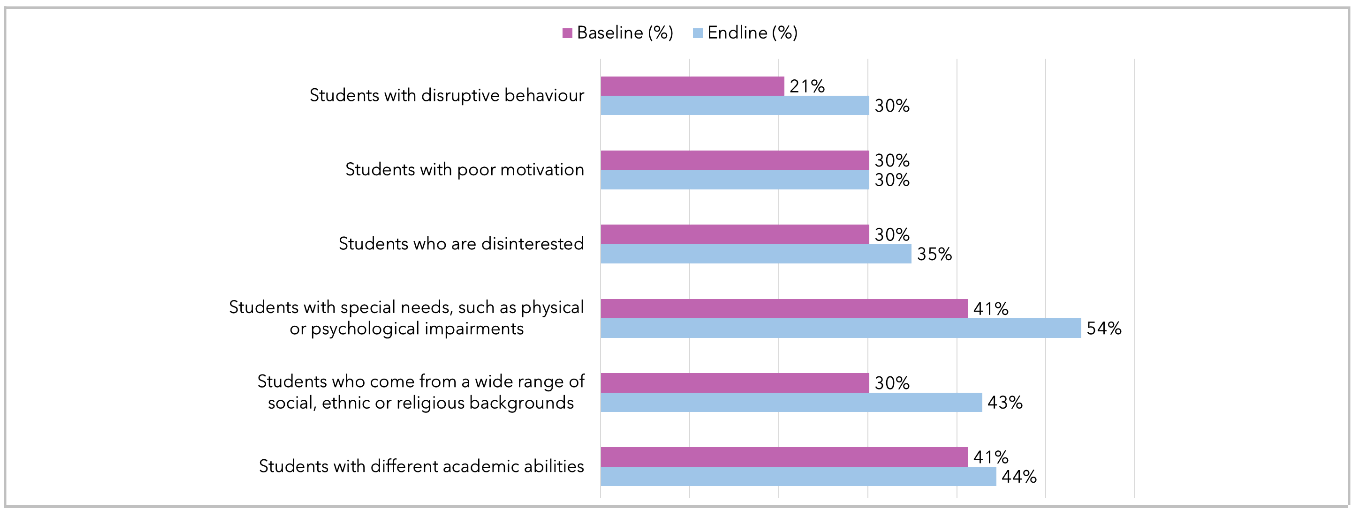


Figure 3.3.1: Responses of Teachers to Which Group of Students Pose a Challenge to Teach Science/Mathematics Effectively?'

To determine the ability of teachers to use UDL principles to design and implement lesson plans that meet the diverse needs of learners, surveys were administered to teachers during Baseline and Endline. Figure 3.3.2 shows teachers' positions on various statements. The findings showed that the total ratio of teachers who disagreed with the statement, '*It was impractical to tailor instructions to different abilities of students'* decreased from 68% to 52%. This indicated a positive change in teachers' attitudes regarding tailoring instruction in accordance with each student's abilities. It should be noted that only the statement *'Using students' home language rather than only English for learning mathematics is better.'* is positively coded, whereas all the other statements are negatively worded.

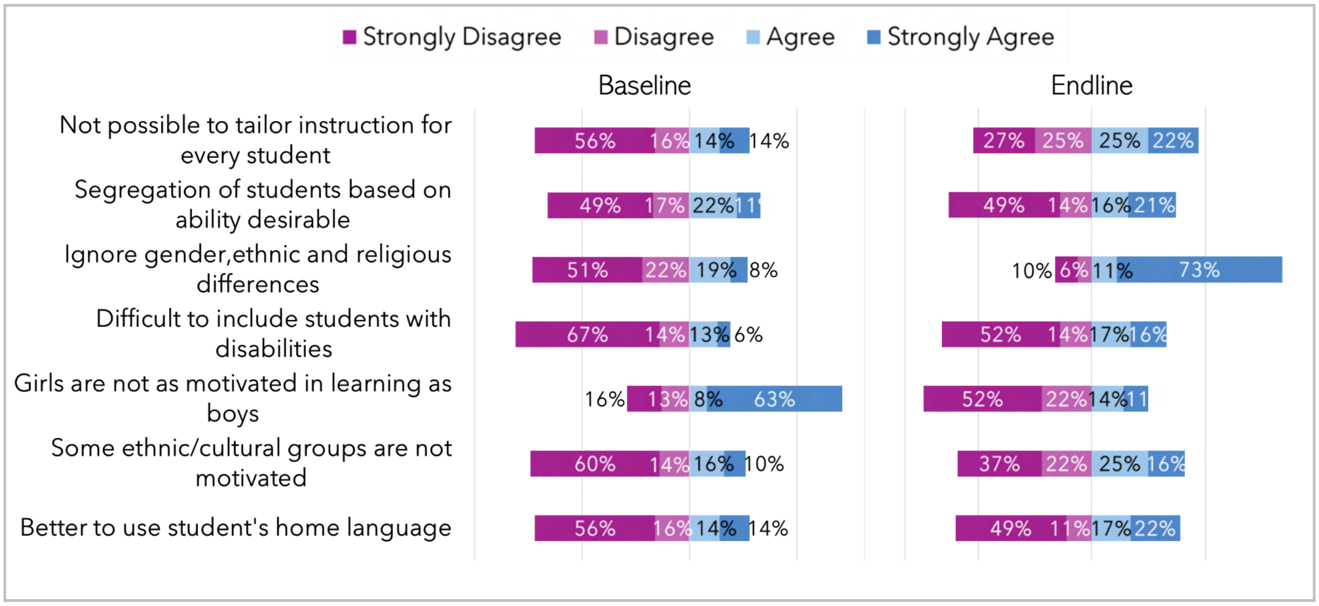


Figure 3.3.2: Teachers' Attitudes to Statements Regarding Inclusion and Equity

The ratio of teachers who disagreed with the statement *'It is better for low-achieving and high-achieving students aged 15-18 to be divided into separate classes.'* decreased from 74% to 63% implying that this intervention did not help most teachers see the importance of mixed student groups as a strategy for inclusion in science and mathematics classes. This is in contrast to teachers using groups as an inclusion strategy as shared in the interviews.

The ratio of teachers in agreement with the statement, '*To teach STEM subjects, I try to ignore gender, ethnic, or religious differences among my students*' increased from 71% to 82% between Baseline and Endline surveys. This suggests that the intervention did not engage teachers on how to foster equity and inclusion in teaching science/mathematics by taking into account the learners' socio-cultural contexts. On the other hand, the ratio of teachers in disagreement with the statement, '*It is always not possible to include students with disabilities in STEM classes*' decreased from 81% to 66% between Baseline and Endline surveys. This shows that in the Endline survey, more teachers acknowledged the possibility of including students with disabilities in their classes.

As shown in Figure 3.3.2, teachers' perceptions regarding the performance of boys and girls in mathematics did not change after the intervention. Regarding the motivation to learn mathematics, the percentage of teachers who disagreed that it is related to specific religious/ethnic/cultural groups decreased from 66% during the Baseline to 59% during the Endline. The negative change is in the desired direction, but as there is some variation in the percentage of teachers who belong to the 'strongly agree' category, no conclusion can be made. The results from questions on teacher attitudes indicated that the response of teachers who disagreed with the view that '*It is better to use students' home language rather than only English for learning mathematics.'* dropped slightly from 72% in Baseline to 69% in Endline. The decrease in disagreement indicated a favourable attitude on the part of teachers to the use of home language for teaching Maths.

Figure 3.3.3 shows male and female teachers' attitudes on various statements regarding inclusion and equity during Baseline and Endline surveys. A slightly positive attitudinal change was observed among female teachers with regard to 1) having students with different ability levels in the same classrooms, and 2) mathematical ability not being related to the student's gender. Similarly, with regard to the use of home language for teaching mathematics, both genders showed a slightly positive attitudinal change in the Endline survey. For all other statements, a minor negative change in teacher attitudes was observed in both genders and it needs to be explored in further research studies.

Figure 3.3.3: Teachers' Attitudes to Statements Regarding Inclusion and Equity (Genderwise)

Figure 3.3.4 shows teachers' perspectives on various statements regarding inclusion and equity in mathematics and science during Baseline and Endline surveys.

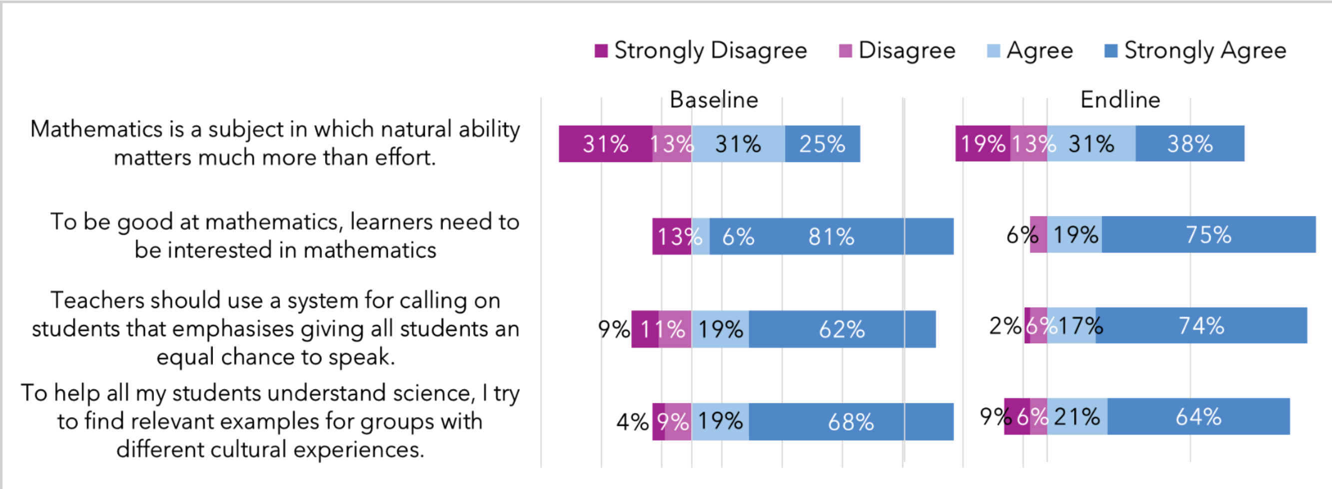


Figure 3.3.4: Comparison of Teachers' Attitudes to Various Statements Regarding Inclusion and Equity

The results showed that most teachers felt students' natural ability mattered more than their effort in learning mathematics. Similarly, there was an increase in the percentage of teachers who believed that students had to be interested in a subject for them to be good at it. The principles of inclusion and equity require that a teacher create interest in students through their pedagogical approaches. In the case of science teachers, a positive change in teachers' attitudes was noted in responses (+10%) on using a system to call on students to encourage everyone's participation. But a slightly negative change (-2%) was seen in the desired responses of teachers finding relevant examples for students with different cultural experiences.

Overall, the qualitative results from interviews and classroom observations demonstrated that teachers improved their understanding and attitudes with respect to equity and inclusion strategies. There was an improvement in the use of strategies such as placing students with different learning abilities in one class, accommodating students with disabilities, providing equal opportunities to students and using UDL principles to design and implement lesson plans to meet the diverse needs of students. The surveys indicated that there was an improvement in the ability of science teachers to provide equal opportunities to all students to participate in classroom interaction. When inclusion and equity were analysed in terms of participants' gender, quantitative results indicated that implementing the CL4STEM project had improved the attitudes on inclusion and equity of female teachers more than male teachers.

3.3.2 Classroom Management

- Knowledge of multiple modes of classroom interaction such as organising inquiry learning/ project-based learning/problem-solving to promote students' agency, a variety of grouping practices to support collaborative learning, use of activities for multiple ways of students to engage and express
- Knowledge of positive disciplining techniques
- Ability to organise and manage multiple modes of interactions, including group activities
- Ability to manage time, space and teaching -learning resources effectively
- Ability to manage students' behaviour

While a traditional interpretation of effective classroom management may focus mainly on 'compliance' — rules and strategies teachers may use to ensure that students sit in their seats, follow directions, listen attentively etc., a progressive view extends to everything that teachers may do to facilitate student learning, which would include elements like *behaviour* (a positive attitude, pleasant facial expressions, encouraging statements, respectful and fair treatment of students, etc.), *environment* (for example, a welcoming, well-lit classroom filled with intellectually stimulating learning materials that are organized to support specific learning activities), *expectations* (the quality of work that teachers expect students to produce, teachers' expectation regarding students' behaviour towards one another, the agreements that teachers make with students), *materials* (the types of texts, equipment, and other learning resources that teachers use), or *activities* (the kinds of learning experiences that teachers design to engage students' interests, passions, and intellectual curiosity).

In general, the qualitative findings indicated that teachers used multiple modes of classroom interaction, specifically, grouping students into different groups to support collaborative learning and using activities to engage students in the learning process. In addition, teachers understood the importance of classroom space management and adequate learning resources as evidenced in the following quote.

The ability to organise and manage group activities/knowledge to engage students in the learning process:

"…sometimes to monitor all the students, especially overcrowded classrooms, is too difficult. Suppose I have 92 students that take physics. It is too difficult to make such a classroom quiet. So sometimes you can try to use punishment for those students who are making noises."-Teacher 2313, Baseline	*"… the project exposed me to different ways of classroom management, even overcrowded classrooms. I can form student groups to create space and provide group work. … I can make all students participate better in classroom activities than ever before. I can navigate slowly to include the slow learners in learning."*-Teacher 2313, Endline

Teachers also showed an increase in awareness about the management of learning resources and the merits of effective grouping. Examples are shared below:

"….I teach overcrowded classrooms but do not face discipline issues during teaching and learning processes."-Teacher 2516, Baseline	*"…I can manage big classes in classroom discussions by grouping them into different groups so that they can discuss while sharing those few available learning resources."*-Teacher 2516, Endline
"…some of our students are excellent in English while others have problems with the medium of instruction, English…students with language problems are not performing well…. overcrowded classrooms make some students indisciplined/ stubborn." -Teacher 2714, Baseline	*"….I have no problem with differences in intellectual abilities because I know my students. During the planning process, I divided my students into groups, so each group has combined students: the students who are slow learners and students who are fast learners. This means the learning process accommodates all kinds of students."*-Teacher 2714, Endline

In general, the qualitative classroom observation results indicated positive changes with respect to teachers' ability to manage extremely overcrowded classrooms, adopt positive disciplining techniques, engage students in collaborative learning and organise and manage group activities—for example, Teacher 2714, who teaches extremely overcrowded classes, cannot move around freely to visit all groups and it takes time to ensure everyone's participation. Despite this, the teacher uses pre-prepared diagrams and while the students name parts/functions, the teacher fills them for students in order to manage student movements and time.

In addition, teachers demonstrated an increased awareness of multiple modes of classroom interaction, especially using groups to support collaborative learning and using activities to engage students. For instance, Teacher 2113 could move freely around his class, checking on each group and evaluating how each student participated in the activities assigned. He emphasized the major concepts they should concentrate on and asked questions to specific groups, random students and the entire class. He also encouraged every student to participate in group activities. When the teacher spotted laziness in individual group members, he gave them an action to accomplish. The groups that accomplished the tasks more quickly than others were motivated and praised. This in turn encouraged other groups to complete their task on time. The teacher also managed students' movements and noise by continuously blocking any interference in learning.

The responses of teachers to the statement '*It is not a good idea to have students work together in solving mathematics problems because brighter students will do all the work*' show that more teachers supported the idea of groups of students with mixed abilities. However, as there was a slightly negative change in teachers' responses in the Endline survey, the result indicates a contradiction with the qualitative data showing an impact on the theme classroom management, especially with regard to the ability of teachers to use group activities.

Though the survey results showed a slightly negative change, the qualitative findings from interviews and classroom observations indicated that teachers have positively improved in various processes related to classroom management. These include organising and managing group activities, using activities to engage students in the learning process, classroom space management, managing learning resources effectively and executing positive disciplining techniques.

3.3.3 Assessment

- Knowledge of multiple methods and tools of assessment for students to express in multiple ways
- Ability to use assessment for and of learning
- Ability to design and use a variety of methods and tools of assessment, including task-based assessment

In the context of secondary school, assessment refers to the wide variety of methods or tools teachers use to evaluate, measure, and document students' academic readiness, learning progress, skill acquisition, or educational needs. Therefore, the purpose of assessments in education is two-fold. It helps the students demonstrate their learning and enables teachers to provide feedback on the errors they make in the process.

In general, the interview findings indicated a change across Baseline to Endline. During the Baseline interview, teachers had stated that they administer traditional assessment methods. However, during the Endline interview, the same teachers stated that they have started to use competency-based assessment methods such as project work, group activities and hands-on activities. Teachers also demonstrated an increased understanding regarding the use of different assessment methods to determine students' learning progress. Some examples are shared below:

The ability to use different types of assessment methods to determine the learning progress of students as described by some teachers:

"…I assess my students using tests and examinations." -Teacher 2504, Baseline	*"… CL4STEM project has empowered me to construct relevant assessment tools. Nowadays, I assess my students using different assessment tools like quizzes, tests and examinations to evaluate the performance of the students. The feedback I use to determine the level of achievement in the set objectives."*-Teacher 2504, Endline
"…I do assessments before classes; I go through the objectives of learning a certain topic/concept. So, I construct questions from specific objectives of a particular matter. Then, I prepare questions after that lesson of 40 minutes."-Teacher 2306, Baseline	*"…I assess student learning in different ways. Normally in the classroom, I use different activities like demonstration if students can demonstrate certain learning or a piece of learning outcome…I can also evaluate the learning outcome of my students by administering the competency-based written test. I also do student assessments by providing hands-on activities. I understand if students have understood something and if they can practise what they have learnt from the topics."* -Teacher 2306, Endline
"I provide weekly test, quizzes (normally 10 minutes) before and after lessons and I also provide students with interactional questions."-Teacher 2109, Baseline	*"I provide short quizzes at the beginning of lessons and I provide exercises at the end of the lessons. From there I can make a conclusion and assessment of my student's learning."*-Teacher 2109, Endline.

During classroom observations it was noted that teachers demonstrated the ability to use competency-based assessment methods. Various forms of assessment were used frequently: Oral & written questions, individual problem-solving on the chalkboard, group work activities, and hands-on activities/practicals. For example, Teacher 2317 primarily used formative assessments by asking questions to students in groups and probing if the students had understood the concept or if they were just recalling the factual answers. The teacher made the exercise interesting by collecting all answers, writing them all on the blackboard, and then arriving at a consensus. At the end of the lesson, he gave a take-home assignment with questions related to real-life situations. A similar strategy was implemented by Teacher 2514, who predominantly used formative assessment, in which the teacher asked questions and prompted students to discuss them. The teacher also gave take-home quizzes at the end of the lesson.

Figure 3.3.5 shows the percentages of teachers' survey responses regarding each type of assessment method they used in teaching. Among the four assessment methods shown in Table 3.5, three (2, 3 and 4) are competency-based-assessment [6](CBA) methods. In the Tanzanian education system, they are the most preferred assessment methods.

Table 3.5: Types of Assessment Methods

S/No	Types of assessment method
1.	Standardized tests/examinations produced outside of school
2.	I give tests with questions that require students to describe or explain their reasoning.
3.	Projects/Practical/ Laboratory activities
4.	Observation and participation of students in the classroom

[6]CBA is an educational system which focuses on the essential knowledge, skills and attitudes that candidates should be able to demonstrate at the end of their learning experiences

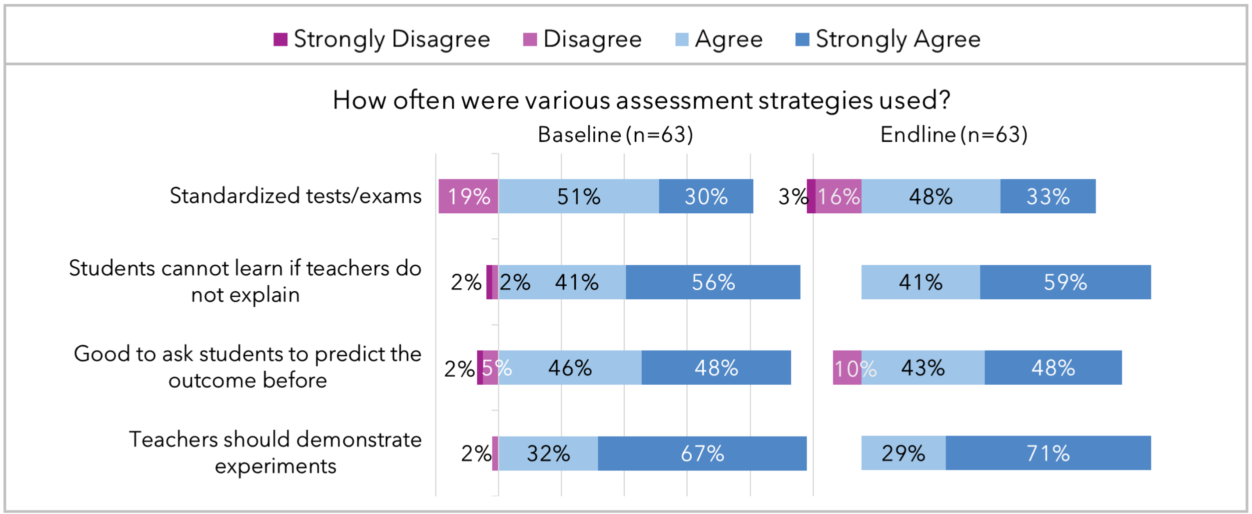
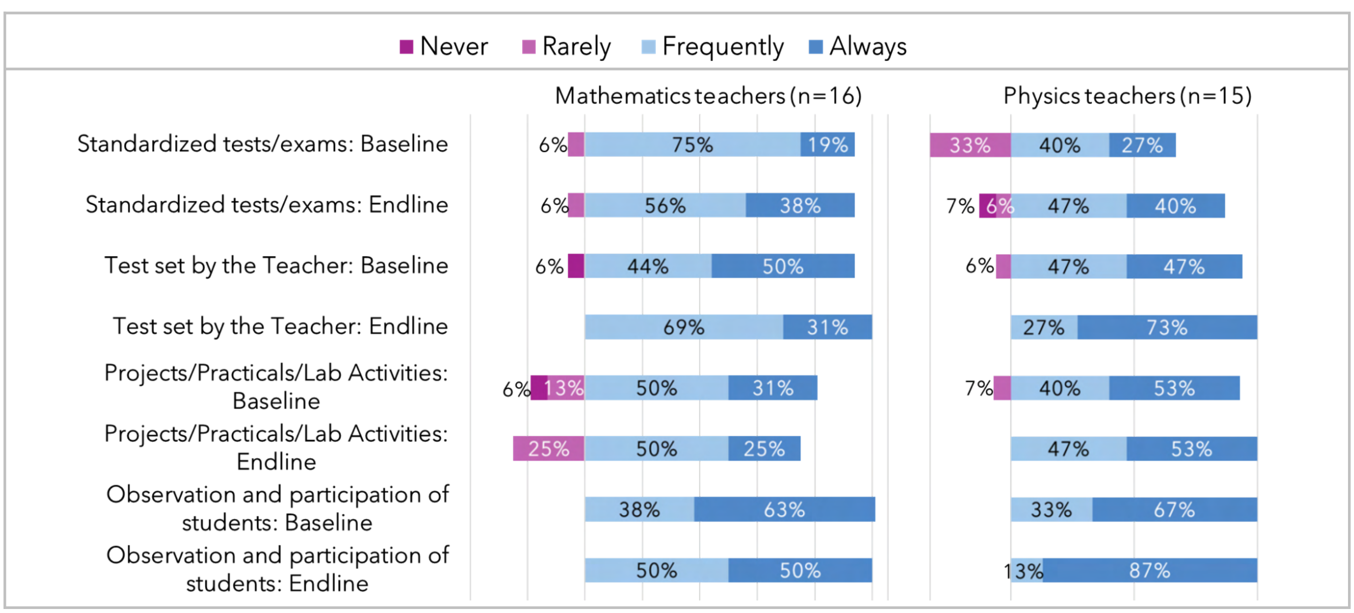


Figure 3.3.5: Responses of Teachers on How Often They have Used Different Assessment Methods

The results showed that during the Baseline assessment itself, most teachers (>90%) used the suitable competency-based assessment methods (tests set by the teacher, projects and student observations). However, there was a slight increase in respondents who 'required students to describe or explain their reasoning' and included 'observation/ participation of students in the classroom' as assessment methods. These results implied that teachers were more inclined to use multiple assessment methods for students aligned to competency-based education. In addition, teachers understood how to design and use a variety of methods and tools of assessment, including task-based assessments oriented towards competency-based learning.

Figure 3.3.6 shows the responses of different subject teachers on how often they had been using assessment methods in their teaching, indicating that during the Baseline survey, mathematics (94%), chemistry (86%), biology (78%), and physics teachers (68%) were using 'standardised tests/exams produced outside school' as mode of assessment. In the Endline survey, mathematics teachers (94%) were still using 'standardised tests/exams produced outside school' as an assessment method in contrast to other subject teachers. Science teachers reported reduced use of standardised tests.



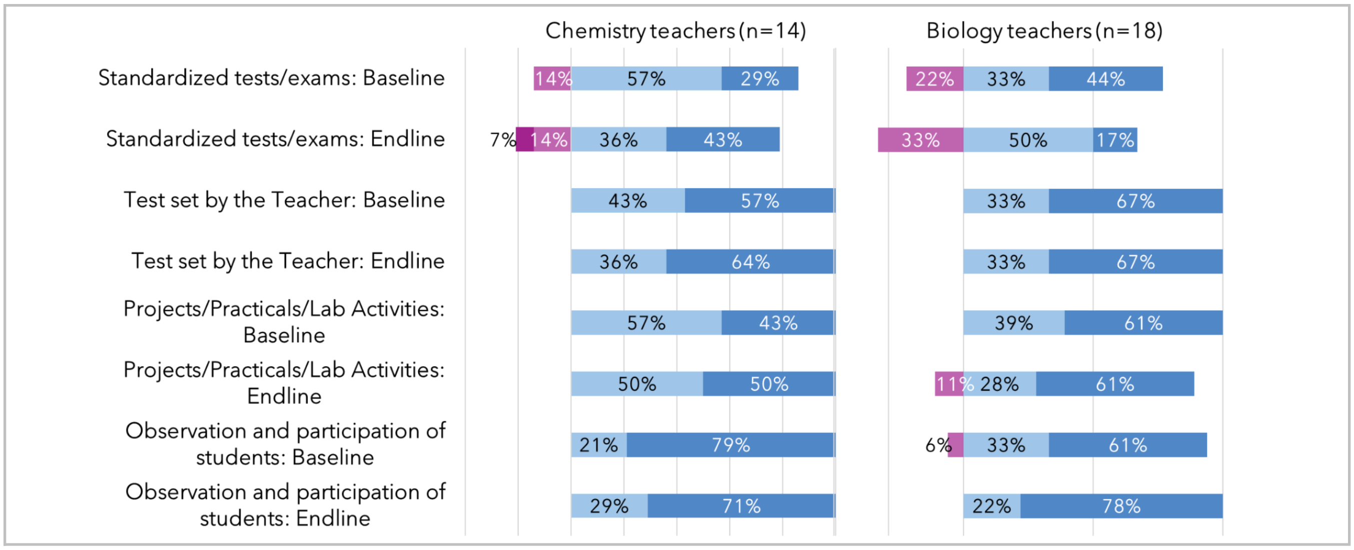


Figure 3.3.6: Responses of Teachers on How Often They had been Using Various Assessment Methods (Subjectwise).

With respect to the use of 'tests set by the teacher requiring students to describe or explain their reasoning' as assessment methods, there was a positive increase among physics and mathematics teachers. Additionally, the frequency of using 'observation and participation of students in the classroom' as an assessment method increased among biology teachers from 95% during the Baseline survey to 100% during the Endline survey.

The qualitative results from interviews and classroom observations indicated that modules and online CoP participation facilitated teachers to better understand the issues regarding multiple assessment methods, their ability to use assessment to enhance the learning process and their ability to design and use a variety of methods for assessment, including task-based assessments. In addition, the quantitative survey results indicated improved understanding of various assessment methods for students. Furthermore, the teachers' knowledge of how to design and use a variety of methods and tools of assessment, including task-based assessments oriented towards competency-based learning was enhanced.

From the analysis discussed so far, it is observed that teachers have progressively advanced their understanding, classroom practices and attitudes in relation to almost all the themes within the KAP framework. We found positive changes from the Baseline through the Midline to the Endline phases.

On the theme of conceptual learning difficulties and misconceptions, we found no change. We observed that the participant teachers did not advance skills required to address the different learning difficulties faced by their students and found it challenging to spot and deal with misconceptions on the part of their learners. This invites further engagement and focus during the future scaling up initiatives.

4.0 Perceptions of CL4STEM

This chapter explores the perception of participant teachers with regard to CL4STEM implementation. As mentioned in the chapter on methodology, the frameworks of the Concerns-Based Adoption Model (CBAM) and the Moore and Benbasat's Perceptions of Innovation adoption were used to study teacher perceptions. This chapter starts with a discussion of the teachers' concerns about the innovation, then presents an overview about their participation in CL4STEM, and concludes with a detailed analysis of the teacher perceptions on innovation adoption.

4.1 Stages of Concern

Stages of Concern (SoC) are among the diagnostics dimensions of the CBAM, which assess participants' attitudes and perceptions towards the innovation. This knowledge helps the programme's leaders take proper action to address specific concerns raised by the participants. Teachers' concerns with the programme and the whole process of implementation influence the adoption of the innovation. Stages of concern assess participants' attitudes and feelings about the innovation. There are seven categories of stages of concern related to innovation. Coded with the numerals 0–6 , the seven categories are *Unconcerned, Informational, Personal, Management, Consequence, Collaboration and Refocusing*. The analysis of teachers' responses to the stages of concern helps to categorise how concerned the participants are about the updates of the project as the innovation proceeds. In the CL4STEM project, the participants were interviewed about the stages of concerns to analyse their progress and awareness throughout the piloting time frame.

Table 4.1: Stages of Concern

Categories of Responses on CL4STEM Stages of Concern in Tanzania		Midline (n=13)	Endline (n=68)
0. Unconcerned	Not interested in participating in CL4STEM	0	0
1. Informational	Know about CL4STEM and would like to use it at some point in time	0	6
2. Personal	Concerned about the demands of CL4STEM vis-a-vis existing workload and how it fits in the existing working conditions	0	3
3. Management	Grappling with how to effectively navigate the online modules and participate in the Telegram groups of CL4STEM	0	4
4. Consequence	Evaluating how CL4STEM teaching strategies impact/help in student learning	8	13
5. Collaboration	Exploring ways of collaboration with other teachers and educators to help impact student learning using CL4STEM teaching strategies	23	44
6. Refocusing	Exploring ways of improving CL4STEM teaching strategies through further refinement of the modules and CoP participation and alternative ways of achieving better results	70	30

As seen in Table 4.1, the majority of responses show that the participants' concerns corresponded to Stage 5 (Collaboration) which involves exploring ways to collaborate with other teachers and educators and Stage 6 (Refocusing) which involves exploring how they could improve CL4STEM teaching strategies through the refinement of modules and alternative ways to achieve better results. For example, Teacher 2706 shared that teachers had to explore new and alternative ways because

"... these are new methods and strategies, so teachers must explore further to customise them and gain more understanding of CL4STEM strategies." Similarly participant 2521 shared that"improvisation techniques that

CL4STEM advocates require us to constantly learn new methods and strategies if we have to be efficient in teaching science subjects and achieving better results."

The survey and interview results showed that teachers' concerns about CL4STEM generally transcend the lower stages of concern. In other words, teachers display knowledge and comprehension about the project, and are concerned about the higher stages which focus on greater adoption and contextualization of the project.

4.2 Levels of Use

The Levels of Use (LoU) tool from the CBAM framework focuses on capturing the use of innovation by the participants using the project. There are eight (8) categories of levels of use, namely, *non-use, orientation, preparation, mechanical use, routine use, refinement, integration and renewal.* In the CL4STEM project, the levels of use were studied using both surveys and interviews. The responses are compared and analysed together to get a clear picture of the project implementation in Tanzania (Table 4.2).

Table 4.2: Levels of Use

	Categories of Responses on CL4STEM Levels of Use	Midline (n=13)	Endline (n=68)
0. Non- Use	Little or no knowledge of CL4STEM, no involvement, and no intention to be involved	0	2
1. Orientation	Trying to know more about CL4STEM	0	0
2. Preparation	Not yet assessed CL4STEM modules and Telegram groups (CoPs) but plan to do so soon	0	2
3. Mechanical use	Still learning how to navigate CL4STEM modules and Telegram groups (CoPs) effectively	0	3
4.a. Routine	Comfortable with CL4STEM online module and Telegram groups (CoPs)/ Able to implement the teaching strategies in my class as per instructions given in the modules and discussions in Telegram groups (CoPs)	39	31
4.b. Refinement	I have adopted CL4STEM teaching strategies to meet the different needs of my students (without diluting the core objectives of CL4STEM-PCK+UDL/Higher order teaching with inclusion and equity)	39	30
5. Integration	Having internalized the CL4STEM teaching strategies, able to collaborate with other teachers around CL4STEM teaching strategies to meet the different needs of students	15	24
6. Renewal	Having internalized the CL4STEM teaching strategies, now in a position to suggest well-thought-out modifications and alternatives to the present innovation	8	10

In both the Midline and Endline interviews, the majority of participating teachers opted middle levels of use, specifically the levels which correspond to the statements, '*Comfortable with CL4STEM online module and Telegram groups (CoPs)...*' and '*Have adopted CL4STEM teaching strategies to meet the different needs of my students…*' During the Endline interview, participant 2703 testified that he was comfortable with CL4STEM by saying: *"I can use CL4STEM teaching methods, comfortable with strategies introduced and I coped easily with some skills in the modules."* Participant 2113 shared that *"I have adopted and coped with some skills and strategies given in the modules which I, therefore, use to teach my students…. I find them useful and healthy for classroom interaction"*.

All participants during the Midline and the majority during the Endline had used the intervention. From the table it is evident that in both Midline (ML) and Endline (EL) surveys, most teachers were comfortable with, and had adopted CL4STEM modules and teaching strategies. However, a few of the participants were using CL4STEM at the two highest levels of use, namely Integration (Having internalized the CL4STEM teaching strategies, able to collaborate with other teachers on CL4STEM teaching strategies to meet the different needs of students: 23.5% at Endline) and Renewal (Having internalized the CL4STEM teaching strategies, now in a position to suggest well-thought-out modifications and alternatives to the present innovation: 10.3% at Endline).

4.3 Teacher perceptions

Moore and Benbasat's characteristics of innovation adoption were used to explore teacher perceptions. They are described below:

4.3.1 Voluntariness

Voluntariness examines the degree to which teachers voluntarily participate in an innovative programme like CL4STEM. There are two items in the questionnaire to explore voluntariness: (1) My school principal does not require me to participate in the CL4STEM (2) Although it might be helpful, participating in the CL4STEM is not compulsory. The two items on voluntariness explore the school administration's role in teacher participation and whether there was any compulsion for their involvement (Figure 4.3.1).

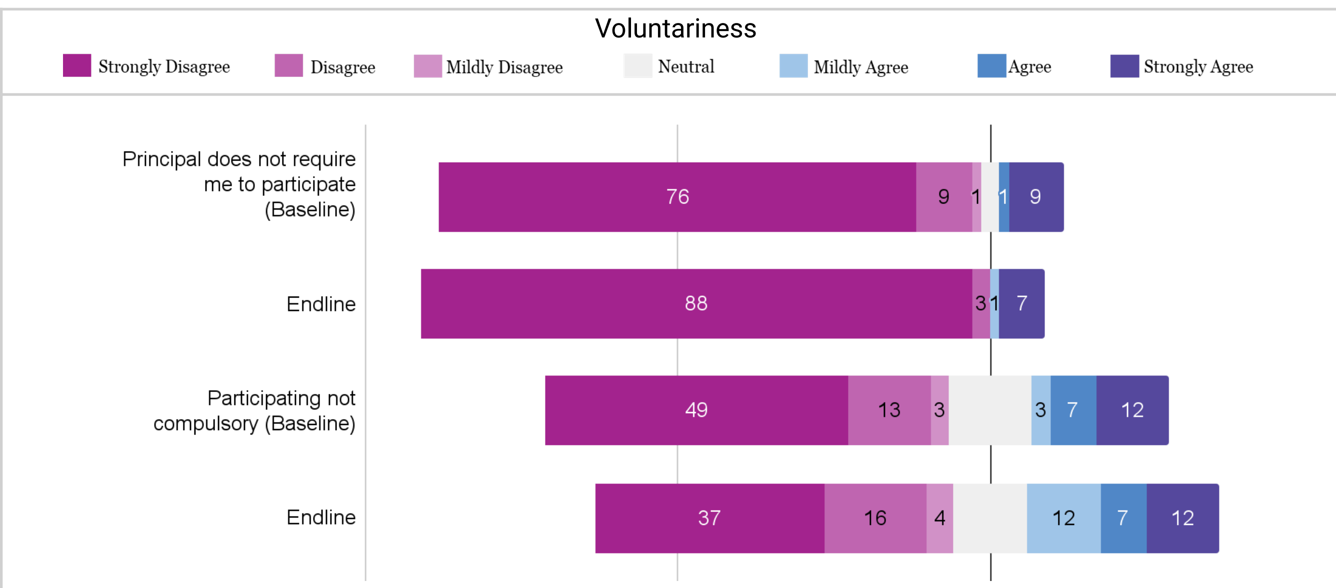


Figure 4.3.1: Percentage of Voluntariness Among Teachers

The results from the survey showed that school administration had played an essential role in facilitating teachers' participation in this innovative programme. During the Baseline survey, the majority (86%) of teachers disagreed- in varying proportions from 'mildly disagree' to 'strongly disagree', in which 'strongly disagree' was the dominant response– that the heads of schools did not require them to participate. Conversely, this means the principals facilitated their participation by identifying and administratively supporting the teachers. This trend remained unchanged in Endline as 91% of teachers identified that the school administration (the principals) made the teachers participate in the CL4STEM programme.

In exploring if there was any compulsion on teachers to participate, the survey results pointed out that most teachers thought that their involvement was compulsory as opposed to being entirely voluntary B65% at Baseline & 57% at Endline). However, it is essential to note that approximately 31% of teachers who responded to the Endline survey participated voluntarily in CL4STEM.

The insights on voluntariness from the survey data were contrasted with the qualitative data from interviews. The interviewers asked questions such as, *"Can you share a little about you and your involvement with the CL4STEM project? What are your reasons for joining CL4STEM?"*. Participants responded that they were nominated by the respective heads of schools to join the programme. However, upon joining the program, some participants voluntarily chose to continue their participation in the project. Participant 2100, testified to this view with the following statement in the Baseline interview: *"'I was nominated by my head of school and later introduced to the project at the launch and from there up now I have been engaged positively with the project."*

The majority of responses attributed the involvement of participants in CL4STEM to the choices of school authorities, except a few who went on to show that they were also willing to join and continue with the programme. One of the participants, Teacher 2304, made the following statement: *"Joined the project first due to appointment from the headmaster among other teachers and then volunteered to go on with the project."*

During the Baseline, a few participants' responses linked their involvement to the requirements for career development.. Participant 2318 stated,

> *"I aim to learn new things for my personal development as a teacher. I do like to learn new things every day. So, when I heard there is this programme, I was thrilled and offered to volunteer to activate or brush my brain to get new content to use as a competent teacher"*

This justifies the small proportion of minority responses obtained in quantitative data, which showed that some participants joined the programme entirely on their own initiative. The interview responses highlighting the role of school authorities in ensuring the participation of teachers in CL4STEM, with concerned teachers showing considerable willingness to participate, became increasingly dominant as the Midline and Endline interviews progressed. The responses from the same participants appeared more pronounced during the Endline than in the Baseline interview, as seen for Participant 2714:

"My head of school nominated me and later introduced me to the project at the launch and decided to continue."-Teacher 2714, Baseline	*"From the beginning, I have been actively involved in this project. I joined for my professional development, to guide my students well in teaching them."*-Teacher 2714, Endline

From these trends observed in responses, it is clear that most participants attributed their involvement to the choices and interests of school authorities. Still, some participants took an active and responsible role as participants over time.

4.3.2 Relative Advantage

Relative advantage examines the degree to which the CL4STEM approach is seen as better than the usual approach to teaching by the participating teachers. The five items in the survey explored teachers' perceptions on whether the innovative modules helped them teach (science and mathematics) faster; whether it contributed to the quality of teaching; whether it made teaching easy; whether it enhanced effectiveness in teaching; and whether it contributed to greater control in teaching. In combination, the questions allowed us to examine if the teachers found the CL4STEM advantageous to their teaching over the methods they adopted hitherto.

The survey result showed that against all the items, most of the teachers identified the modules as advantageous to their teaching (Figure 4.3.2). This high proportion of responses pointing towards a firm agreement among teachers that the CL4STEM innovation is relatively beneficial on all counts is consistent between Baseline and Endline surveys.

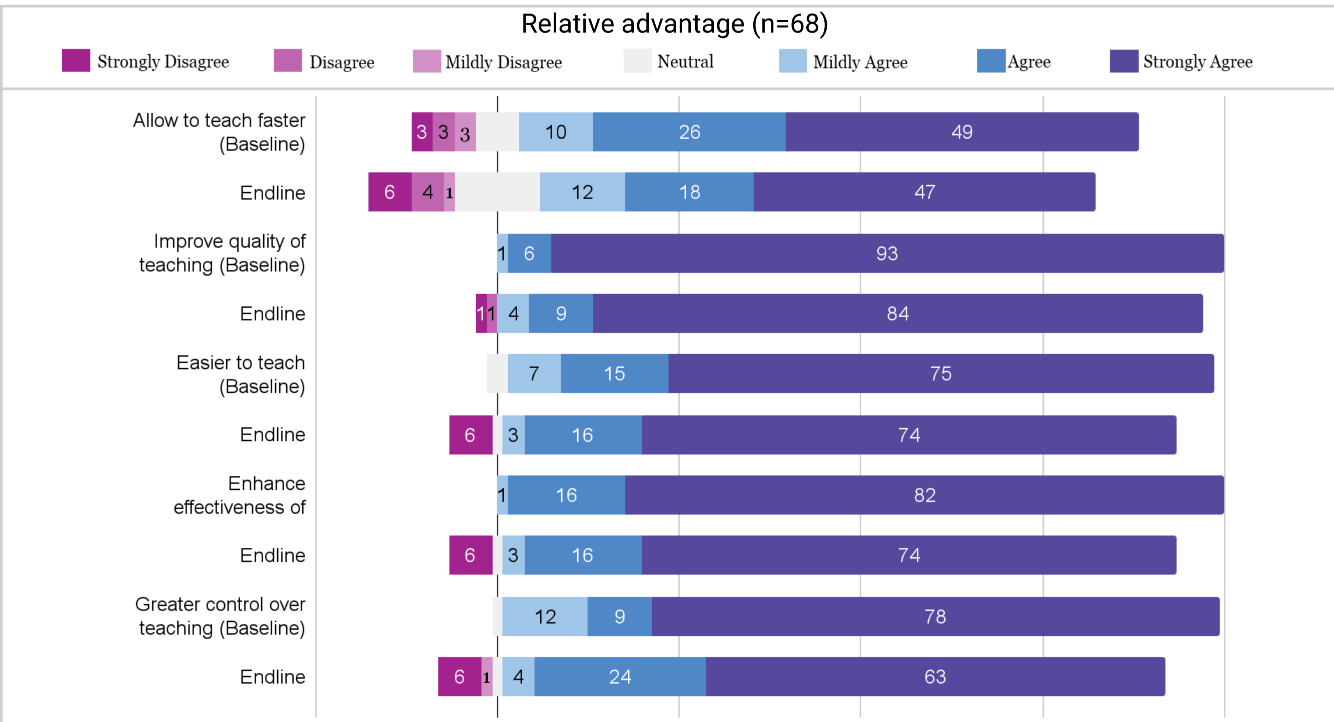


Figure 4.3.2: Relative Advantage for Teachers in the Intervention Group

The result showed a high predisposition of teachers' perceptions towards all aspects of relative advantage of CL4STEM modules. The Baseline survey results indicated that 85% of teachers felt CL4STEM would help them teach science and mathematics faster; 100% of teachers felt that the modules would improve the quality of their teaching; 97% of teachers thought it would make teaching easy; 100% teachers felt it would enhance effectiveness in teaching; and 98% teachers thought it would provide greater control in teaching. Thus, in other words, the teachers expected this innovative programme to be advantageous to their teaching when they joined the programme.

The results from the Endline survey are consistent with the Baseline survey responses, with only a slight departure from the Baseline trend. 76% of teachers agreed that CL4STEM helped them teach science and mathematics faster; 97% of teachers found that the modules improved the quality of their teaching;

93% of teachers thought it made teaching easy; 93% teachers felt it enhanced effectiveness in teaching; and 91% teachers identified CL4STEM to have provided greater control in teaching. The Endline responses, thus, established that in the spectrum of agreement based on teachers' responses, most teachers consistently 'strongly agreed' that CL4STEM was relatively advantageous for them. These findings were compared and contrasted to the interview responses. During the Baseline interviews, participant 2714 stated that,

"*CL4STEM has strengthened my knowledge on how to use resources; the local resources in teaching my students and lesson preparations.*" Similarly, participant 2100 underlined how the project made teaching any subject simpler. "*...I have introduced more in the use of technology, simplified teaching, spotting and removing misconceptions during teaching process.*"

These responses confirmed the survey data on relative advantage corresponding to the items 'improving the quality of teaching' and 'enhancing effectiveness'. These two stood out as advantages, mainly when the data were analysed based on the subjects taught and types of schools. In one of the Endline responses, participant 2521 shared:

"I've learned new strategies concerning teaching and learning, but also, just this kind of social collaboration with others, for example, the way we are talking here now, maybe not like before. I have a big advantage with that. I can share my views with other experts about teaching, including you and others, … it is an advantage".

In general, the responses to interviews through Baseline to Endline and perceptions surveys confirmed teachers' perception that CL4STEM was advantageous to teachers in improving the quality of teaching, enhancing teaching effectiveness and ease of use. However, the responses testifying to the utility of this approach to allow faster teaching and greater control over teaching were not evident in interviews. This discrepancy needs to be studied further.

4.3.3 Compatibility

Compatibility examines the degree to which CL4STEM is seen as compatible with existing values, needs, and past experiences of teachers. The survey items explored if teachers perceived CL4STEM as compatible with different aspects of their teaching practice and if they found it fitting well with how they would like to teach, and their teaching style.

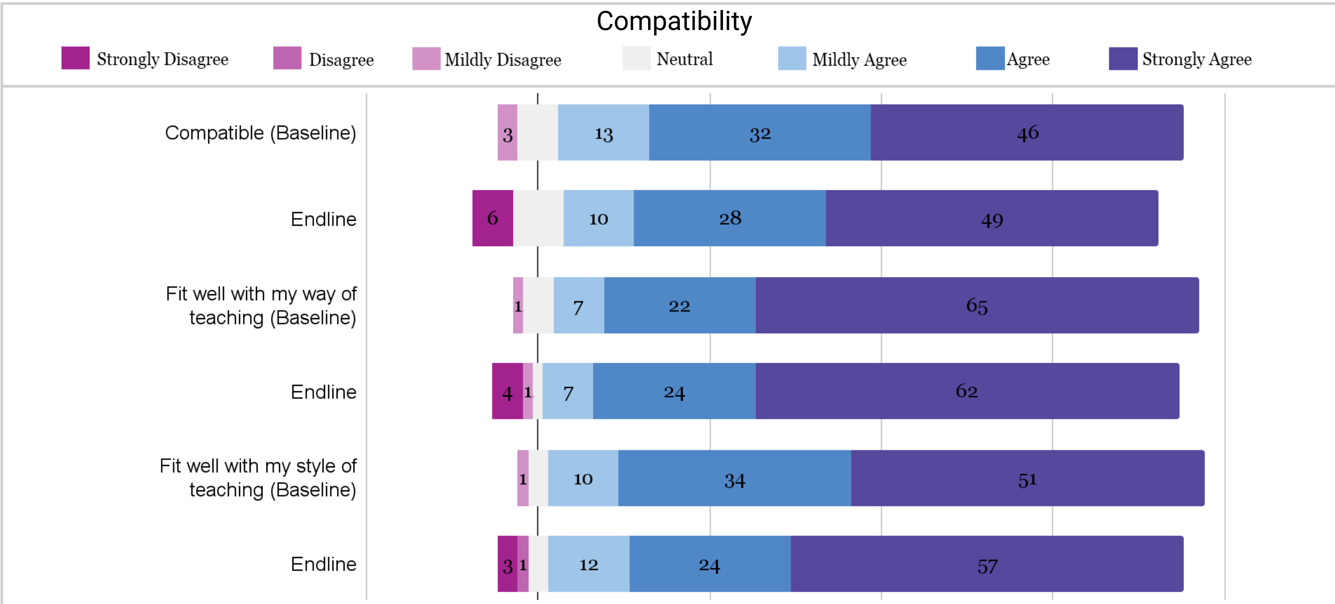


Figure 4.3.3: Compatibility for Teachers in the Intervention Group

The survey result showed that most teachers found CL4STEM compatible with their teaching against all three items (Figure 4.3.3). The Baseline data showed that 91% of teachers perceived CL4STEM to be compatible with every aspect of their teaching, 94% of teachers thought it would fit well with how they would like to teach, and 95% teachers felt CL4STEM would do well with their style of teaching. This expectation is consistent with the Endline responses after they engaged with the modules. 87% of teachers found CL4STEM compatible with all aspects of their teaching; 93% of teachers found it fitting with the way they like to teach, and 93% of teachers found it congruent with their teaching style. Thus, the teachers perceived CL4STEM modules to be compatible with their teaching and consistent with their expectations of an innovative module.

The findings from surveys on the compatibility of CL4STEM were in stark contrast with qualitative data obtained from interviews. Participant 2109 shared during the Baseline interview: "*The CL4STEM modules and design do not always fit well with my everyday teaching; sometimes I use it but not all the time due to time limit. It needs more time to implement CL4STEM modules*."

Similar doubts were expressed by participant 2714 in Baseline, who argued that "*... CL4STEM is compatible though it needs more practicals than our normal teaching. Still, it fits well with the syllabus and my teaching style.*"

However, this attitude towards CL4STEM changed for the better at Endline, at which point none of the interviewees rejected this approach. Participant 2714 shared: "*... fits well with my daily teaching routine and conditions. I can participate in CL4STEM and accomplish my normal teaching routine as well. I can engage my students in some activities, including preparing teaching/learning resources.*"

Another participant in support of this view was Teacher 2313 who said, *"CL4STEM modules are different from our normal text books, but it is compatible with the curriculum."* Thus, while there is some increase in the responses that view CL4STEM intervention as being compatible with the existing curriculum, the huge contrast with the survey responses needs to be studied further.

4.3.4 Image

Image examines the degree to which participation in CL4STEM is seen to enhance a teacher's appearance and status at school. The survey comprises three items that explore prestige, profile, and status symbol perceptions. The results showed that most teachers perceived participating in CL4STEM to have contributed positively to their image as a teacher at school (Figure 4.3.4).

Both the Baseline and Endline surveys showed that 66% of participants felt teachers who participated in CL4STEM had more prestige as teachers at school, whereas a quarter of participants (~22% and 25% respectively) disagreed with the same. Teachers who participated in CL4STEM were perceived to have a higher profile (72% at Baseline & 79% at Endline). 75% of teachers responded that participating in CL4STEM contributed to their status symbol at school. In the Endline survey, 90% of teachers concurred that participating in CL4STEM was a status symbol for the teachers in the participant schools.

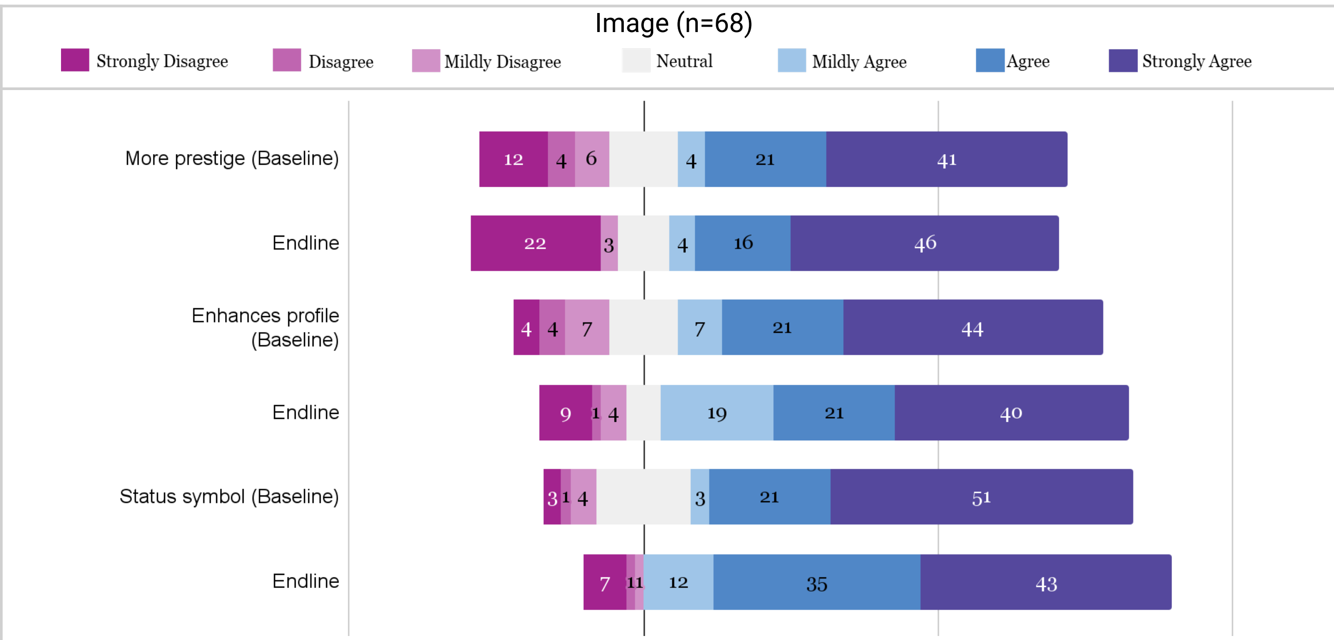


Figure 4.3.4: Image for Teachers in the Intervention Group

The survey responses on the category of image were also contrasted with interview responses. Most participants' responses during the Baseline interviews described what they felt they had gained from CL4STEM, rather than others' views about them. For example, the response from Participant 2504 was, "*... has developed my teaching capacities. The project has elevated me to a high level of understanding and teaching"* Similarly, participant 2704 said, *"I got new knowledge on the use of the local environment in my teaching."* Several other participants gave similar responses, which did not capture their image as viewed by others, in the context of the former's participation in CL4STEM. This is understandable as teachers had not participated in the project when Baseline interviews were conducted.

However, at the Endline, teachers' responses changed drastically. For example, participant 2714 had this to say during the Endline interviews, "*Yes, my image and profile have changed. My fellow teachers' perception of my teaching has changed as they see me as a hard worker, knowledgeable and eager to learn the skill of CL4STEM.*" Participant 2305 also noticed the changes in his image as perceived by others, "*Yes, some teachers see me as a valuable resource ... Many teachers talk about it, especially on the skills of engaging more students in the lesson: student-centred approach!*" The responses, therefore, agreed with the survey findings that teachers' participation in the CL4STEM programme improved their prestige, profiles, and status symbol at school.

4.3.5 Ease of Use

The ease-of-use examined the degree to which teachers believed participating in CL4STEM was not difficult. The items in the survey on ease of use explored if the CL4STEM modules were straightforward for teachers to understand; if they could be easily used to learn new approaches; if they were easy to participate in; and if the teachers felt navigating the CL4STEM modules and CoP was easy for them.

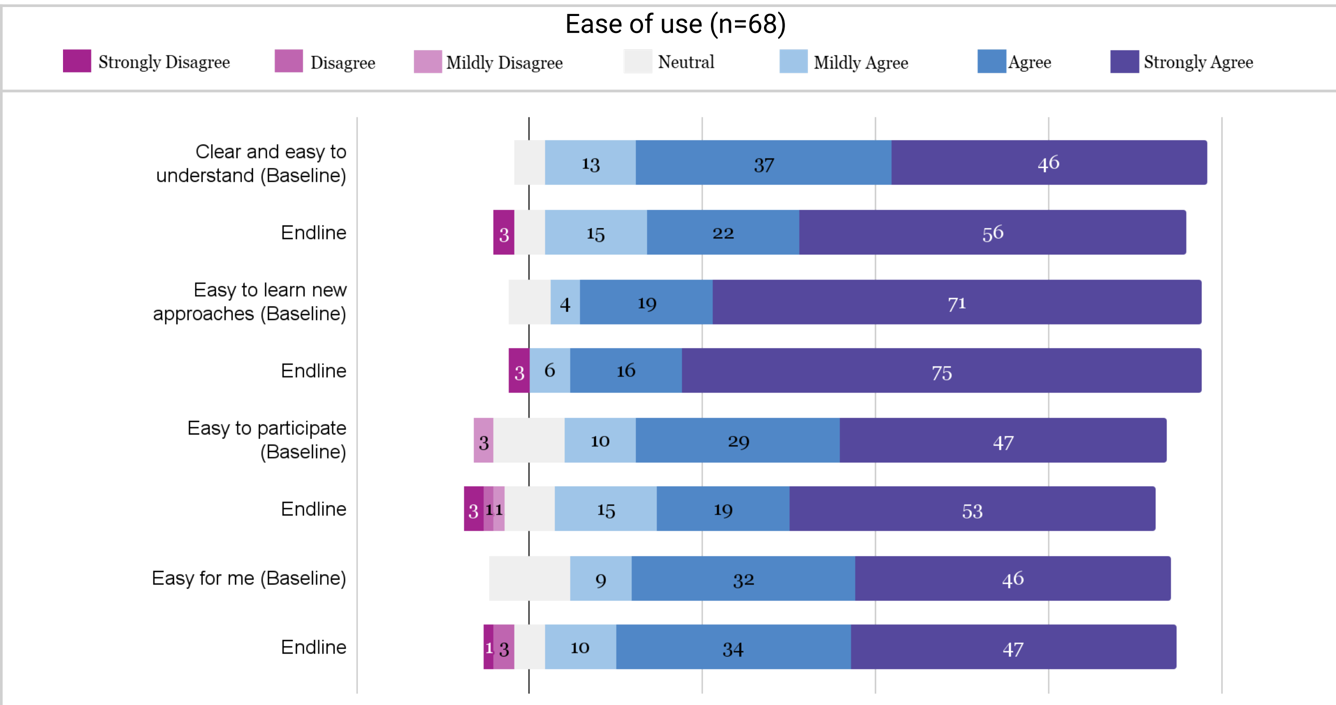


Figure 4.3.5: Ease of Use for Intervention Teachers

The overall results across the Baseline and Endline surveys showed consistently higher ease of use for teachers (Figure 4.3.5). The Baseline data showed that 96% thought that the CL4STEM modules would be straightforward to understand, 94% of teachers perceived they could easily learn new approaches to teaching, 86% of teachers perceived it would be easy to participate in the modules, and 87% of teachers felt it would be easy to navigate the CL4STEM modules and CoP. Thus, a very high proportion of teachers expected CL4STEM to be easy to use.

The Endline results were congruent with the trend observed in Baseline expectations. 93% of teachers found the CL4STEM modules straightforward to understand; 97% of teachers perceived it was easy to learn new approaches to teaching; 87% of teachers found it easy to participate in the modules; and 91% of teachers felt it was easy to navigate the CL4STEM modules and CoP. Thus, the teachers' expectations and experience in CL4STEM were consistent and this positive perception in terms of ease of use built a case for the adoption of the intervention.

The survey results aligned with the interview findings. At the beginning, some participants found it hard to participate in the modules, mostly due to difficulties in managing time and simultaneously carrying on with other school and extracurricular activities. For instance, Participant 2318 stated that *"If a teacher* *is ready in the mind and have resources like smartphones it is easy; but the vice versa of that can also be true".* The majority of respondents testified that the modules were easy to understand and use and that the ease increased as they got more involved in the project, as Participant 2508 observed: *"At the beginning, it was difficult, but with time I found that CL4STEM is an interesting project for my professional development."*

Similarly, Participant 2521 said, *"It was straightforward to participate in the project, and the modules were easy to understand."* This perception about CL4STEM was evident from the responses in the Endline interviews as well. For example, Participant 2305, in the Endline interview, stated, *"At the beginning, it was a little tough, but with time I found it easy to participate in the project; the modules were also easy to understand ".* So, both the survey and interview responses generally showed that CL4STEM was easy to understand and use throughout this study's Baseline, Midline and Endline phases.

4.3.6 Results Demonstrability

Results demonstrability examined the degree to which the results of CL4STEM were observable by others. The survey allowed teachers to reflect on whether the results of participating in CL4STEM were precise and if they could communicate to other teachers or education administrators about these results. The surveys showed a high overall result demonstrability for CL4STEM vis-a-vis participating teachers' perceptions. The Baseline data showed that 93% of teachers felt they would not have any difficulty explaining the results of participation in CL4STEM, whereas, in the Endline survey, 82% of teachers agreed to such a proposition.

On the question of whether teachers could communicate the consequences of their participation in CL4STEM to others,, 88% of teachers who responded in the Baseline survey thought they would be able to communicate the consequences of participating in CL4STEM to others, whereas, in the Endline survey, 82% verified that it would be easy to share the results of participation with others. On whether the results of participation in CL4STEM were clear to the teacher, 91% of teachers who participated in the Baseline survey thought that it would be apparent to them, whereas, in the Endline, 96% of teachers found that it was clear to them.

A question conversely explored if a teacher would find it difficult to explain the benefits of participating in CL4STEM. In the Baseline survey, 60% of teachers disagreed. During the Endline survey, however, 71% of teachers disagreed with the notion that they would find it difficult to explain the benefits of participating in CL4STEM, implying that they would easily explain the same. In general, the findings showed that CL4STEM was clear to participants, and that they would be able to explain its benefits to others who did not participate in this project.

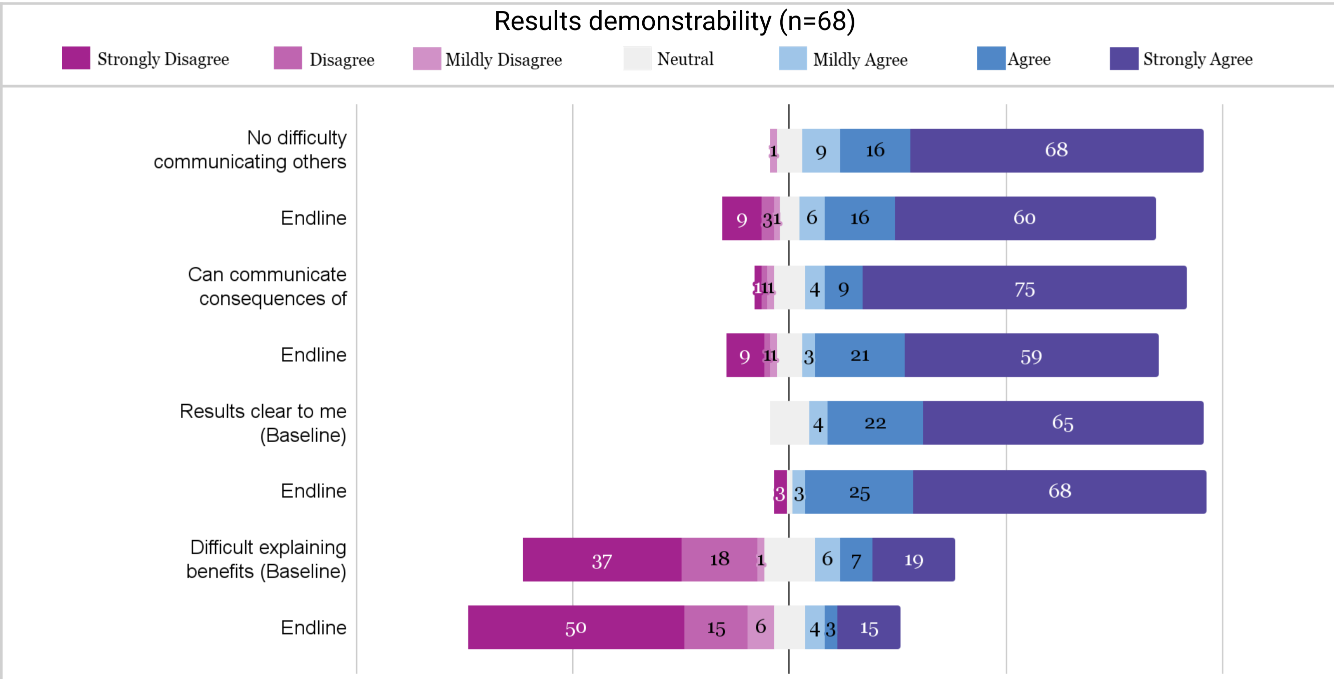


Figure 4.3.6: Results Demonstrability for Teachers

The interview responses testified to the participants' perception that it was not difficult to explain what CL4STEM was about right from the Baseline phase at the beginning. Interview responses were not different from the survey findings, which confirmed that CL4STEM was clear to the participants, and it was not difficult for them to describe it to others who did not participate in this study.

4.3.7 Visibility

Visibility assessed how teachers could observe other teachers using CL4STEM. The two items in the survey explored different aspects of visibility; one examined if one could see many teachers participating in CL4STEM in the school, and another examined the extent of that visibility, i.e., if it was visible to a significant extent.

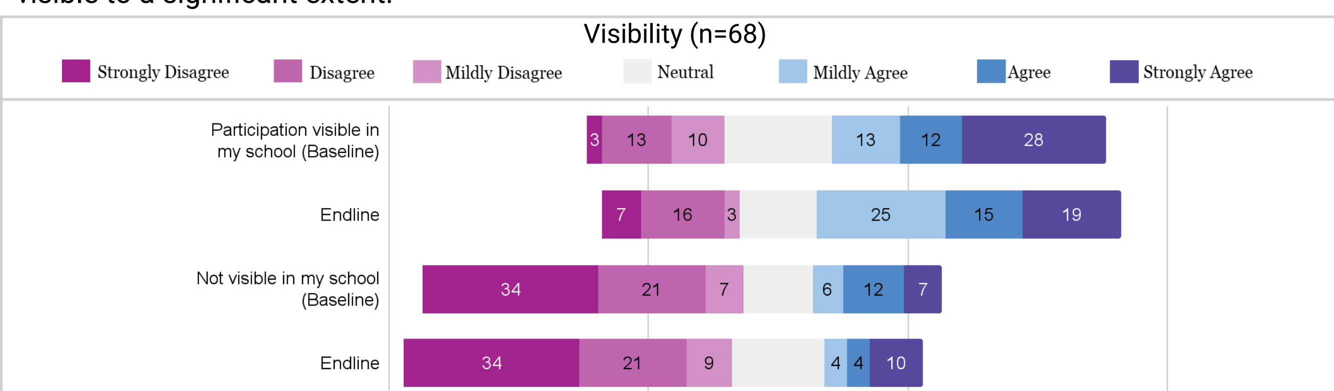


Figure 4.3.7: Visibility Results for Teachers

The results from both the Baseline and Endline surveys showed that CL4STEM was visible in the schools (Figure 4.3.7). It is noted that the responses agreeing with desired answers were higher in number than that of disagreeing answers in both the Baseline (53%) and Endline (59%) surveys. Similarly, the proportion of desired disagreeing answers was higher than that of agreeing answers in both surveys (62% at Baseline, 64% at Endline). Overall, the surveys showed that there is a slightly positive perception in visibility of CL4STEM. At Endline, the desired responses for both questions increased slightly.

The interview responses showed teachers struggling to show the visibility of CL4STEM implementation in their schools. They acknowledged implementing it but could not exactly tell if it was visible to other staff members and students outside the classes involved. For instance, during the Baseline interview, Participant 2100 said, *"Looks like CL4STEM is still new in his school. Can't say exactly if it is visible there."* Participant 2508 acknowledged in the Baseline interview that only participant teachers knew about it. *"We teachers who attended the workshop are implementing the project at our school."*

Such insights prevailed in Midline and Endline surveys too, testifying to other teachers' eagerness to know more about CL4STEM, as Participant 2504 noted during the Midline interview: "*... other teachers are curious about the project, and they are eager to learn from us*." In the Endline interview, most participant teachers acknowledged the usefulness of CL4STEM ideas in their classroom teaching and stated that other teachers are beginning to understand the project but could not exactly ascertain its visibility in their schools. For example, Participant 2102 said, *"I have explained to others about CL4STEM and they love it, talking about it and are also ready to use these strategies in their teaching."* and Participant 2125 had this to say: "*CL4STEM project is important for teachers' professional development and I think teachers will enjoy being part of it when it is scaled up."*

From these responses, we could conclude that although participant teachers implemented CL4STEM, it had little visibility in schools. The fact that other teachers showed interest in it signals bright prospects for scaling up the project to include more teachers and schools.

All categories of stages of concern showed positive change and evidence that participant teachers were very much involved in the project. Their feedback could provide the project leaders with sufficient input for the successful management of the project. The levels of use also showed positive changes except for two categories- routine and refinement- which showed negative change and the category of orientation which showed no change. This necessitates better data management and greater focus with respect to these areas in scaling up initiatives.

The teacher perceptions showed positive changes in all categories except for voluntariness against which teachers responded that they joined the project after being selected by their heads of schools. This suggests that school authorities could play a major role in the future initiatives to scale up the project. Thus, keeping in consideration the present structure of the educational sector in Tanzania, authorities must be involved throughout the project implementation during the scaling up phase of the project.

Table 4.3: Summary of the Teacher Perceptions

Themes	Perceptions	Perceptions
Voluntariness	Negative	The majority of participants perceived that their participation was mandatory.
Relative Advantage	Positive	The majority of participants perceived CL4STEM to be relatively advantageous

Compatibility	Positive	Enhanced teacher understanding of CL4STEM compatibility with their teaching derived from their experience with the pilot.
Image	Positive	There was a positive impact on the perception of teachers' image after participating in CL4STEM. Teachers shared examples of how others' perceptions of their teaching have changed since they participated in CL4STEM.
Ease of Use	Positive	The majority of participants believed CL4STEM strategies to be easy to use.
Results Demonstrability	Positive	There was a positive perception of teachers' abilities to communicate the results of participating in CL4STEM to others.
Visibility	No observable change	Teachers did not perceive observable changes in the visibility of CL4STEM in their schools.

5.0 Social learning

Social Learning in CL4STEM refers to the participants acquiring knowledge and learning from interactions. As mentioned in the chapter on methodology, all teacher educators and teacher participants were members of online Telegram-based groups (one per each subject). This was done to ensure a space for participants to interact with each other as they progressed in the modules. In all these groups, participation ranged from observing to actively initiating conversations, sharing practice, and sharing and receiving feedback. The communities of practice served as a critical part of the design for CL4STEM, as they allowed the teachers to have a safe space to seek support, share progress, and celebrate milestones in the project authentically while also building relationships with their peers and teacher educators who taught the concerned subjects. As participating schools were distributed all across the country, it was essential for these communities to be online. It allowed overcoming the challenge of not being in the same physical space.

Research has demonstrated that there are generally a few different levels of participation in CoPs:

1. Core: Those participants who drive the CoP and are the central actors. This is usually a small group of people.
2. Active participants: Those participants who are involved actively in the CoP but are not the core participants.
3. Occasional: Those participants who interact in the CoP only when there is something special or specific to contribute, but not all the time.
4. Peripheral: Those participants interested in the CoP but do not participate actively in the CoP.

To examine how the nature of participation evolved, Social Network Analysis (SNA) was used. The researchers looked at the interaction among all participants within each subject-specific CoP using SNA and qualitative thematic analysis. In this section, the social network analysis parameters are first described, and then the qualitative analysis is presented.

Table 5.1 shows the development of Telegram-based communities of practice during the implementation of CL4STEM modules in Tanzania. Density refers to the number of interactions that occur between the participants of any group at a particular point. The maximum possible density is 1, which indicates that every node in the network is directly connected to every other node. The average degree is the average number of interactions each node participates in. The maximum degree is the maximum number of connections a node has; in this case, the participant who has interacted with the most number of people has the utmost degree. The visual representation of how the community for each subject changed over time is shown in the graphs later.

Table 5.1: Progression of Telegram CoP during CL4STEM Implementation

	Mathematics			Biology			Chemistry			Physics		
	BL	EL	Δ	BL	EL	Δ	BL	EL	Δ	BL	EL	Δ
Density	0.04	0.26	0.22	0.07	0.38	0.31	0.04	0.13	0.09	0.08	0.43	0.35
Average Degree	1.27	7.6	6.33	1.77	9.53	7.76	1.2	3.73	2.53	2.2	10.77	8.53
Maximum degree	6 (TE)	19 (T)	13	7 (T)	24 (Country Lead)	17	5 (Country lead)	16(T)	11	13 (T)	22 (T)	9

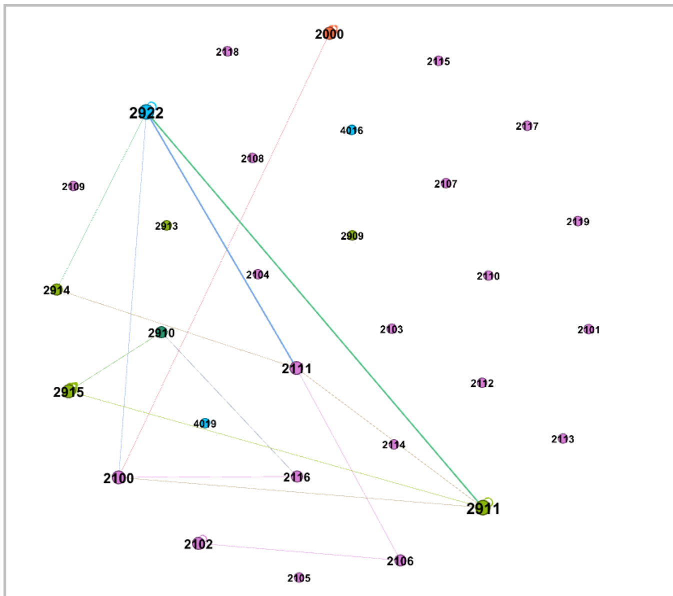
*BL - Baseline, EL - Endline, Δ - Change

At Baseline, all four subject CoPs had a very low density ranging between 0.04 - 0.08. The Baseline time stamp was taken in June 2022 at the end of the common module and the beginning of subject modules, which means that the teachers were oriented to and familiar with CL4STEM but had not started subject-specific professional development. This is understandable, as the participants did not know each other at the beginning of the intervention. The ending time stamp is from December 2022, when all the three modules had been closed, and teacher participation was complete. The density during this period ranged from 0.13 to 0.43. As can be seen from the table above, the density increased somewhat in all four subjects, implying that the number of interactions in each CoP increased over time. This is not surprising, given that the teacher educators were actively using the CoPs to communicate with teachers and also encouraging them to participate in the same. The biggest gain in density was visible in physics CoP, where the teacher educators were actively following up, communicating with, and encouraging teachers to participate in the CoPs and the modules.

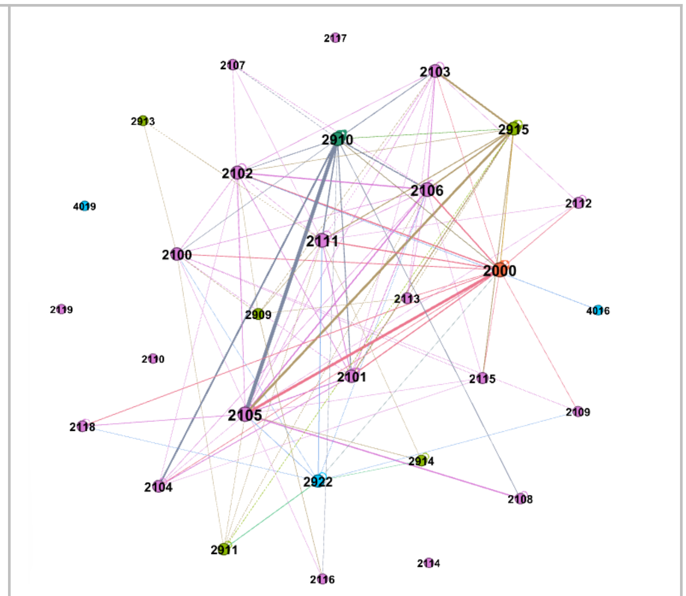
At Baseline, the average degree ranged from 1.2 in chemistry to 2.2 in biology, which means that the participants in chemistry CoP had interacted with, on average, one other person at the start of the subject modules. In contrast, participants in biology CoP interacted with more than two people on average simultaneously. As time progressed, the average number of interactions between the participants increased across all four subjects, as seen in the table above. The maximum growth in moderate degree (8.53) and the highest average degree (10.77) was observed in physics CoP. At Endline, each physics participant interacted with around ten other participants, whereas in chemistry CoP, each participant interacted with three other participants.

Lastly, it is essential to examine the maximum degree, as it represents the participant who has interacted with the highest number of co-participants. It also means that they have the highest number of relationships in the current participant group. It was expected that teacher educators would have high degrees across all four subjects because they were leading the implementation of modules and would have interacted with the maximum number of participants. However, data analysis showed that the full degree was shared between the teachers, teacher educators, and the country lead. Thus, this small group of participants formed the core of the CoP and became the core participants (Lave & Wenger 1991).

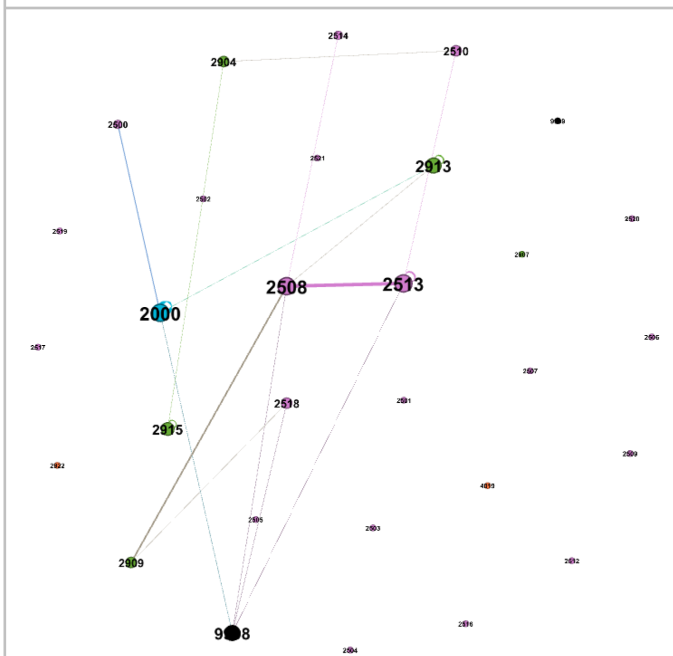
The images of each subject network evolution are shared below (Figure 5.1). These images show how the network evolved and how the nature of participation varied. Some modes are connected to many other modes (which means they have a high degree), but some others are not linked to any other node. These nodes are the participants who did not interact with anyone in the CoP but were present in the community. It is essential to know that the lack of interaction in the CoP did not mean that the participants did not consider the CoP as valuable. These participants would be regarded as peripheral participants, as described by Wenger-Trayner.



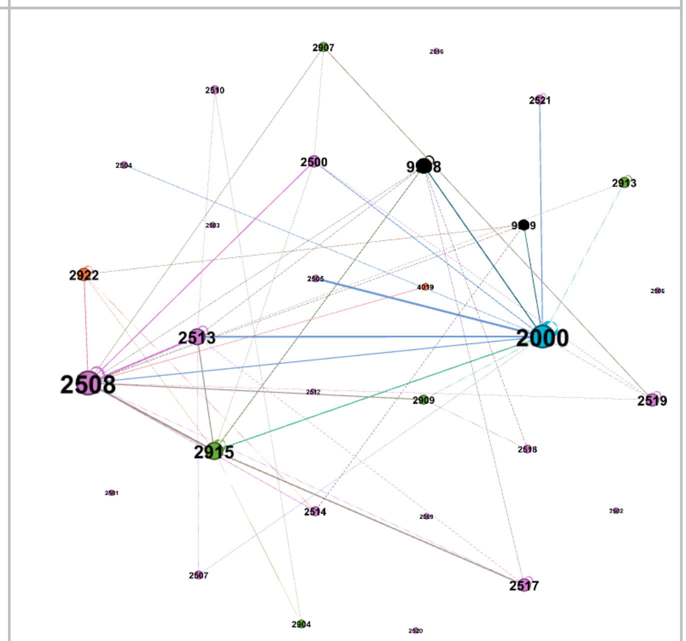
Math: Density= 0.04/ Baseline (June 2022)



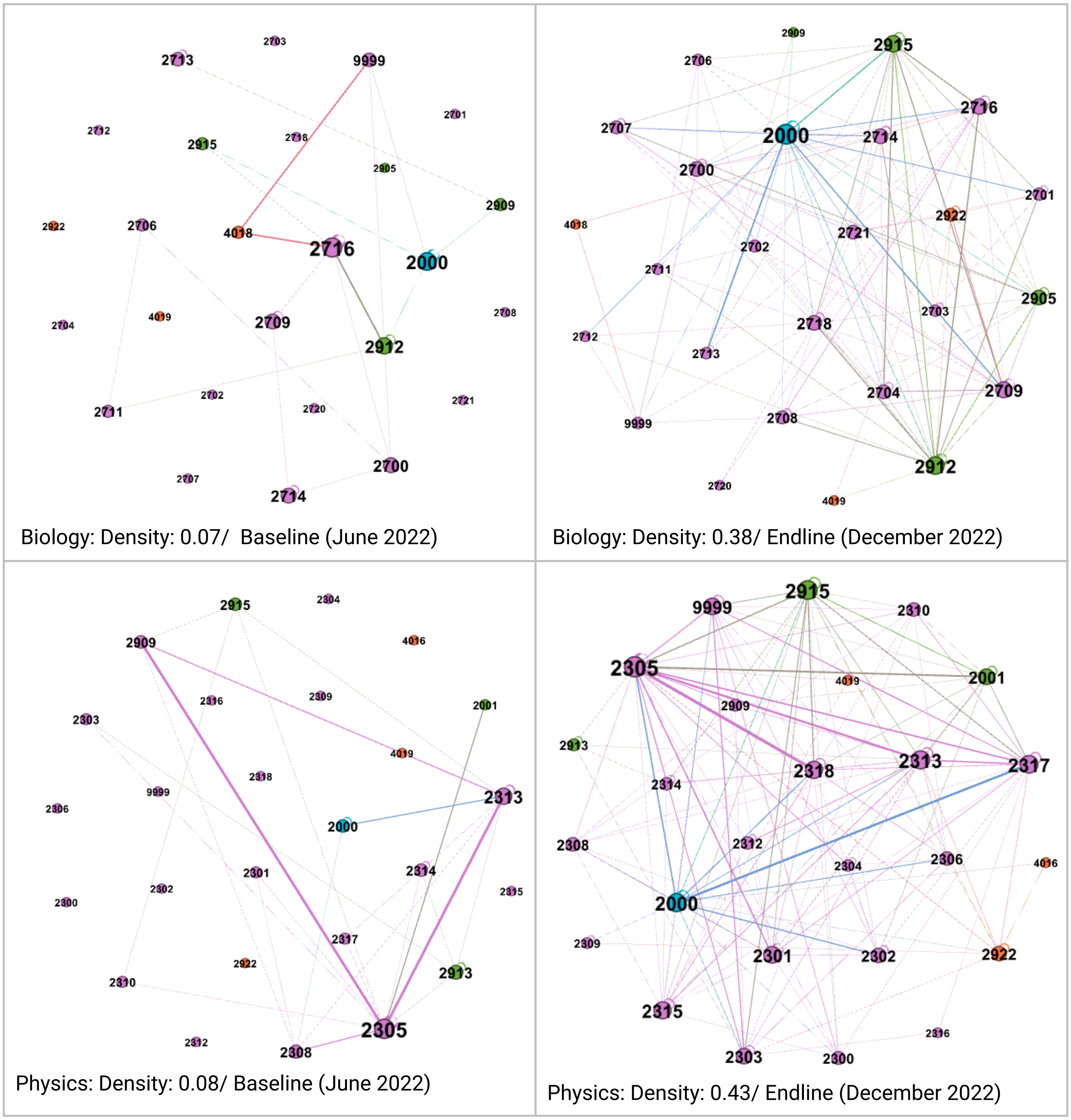
Math: Density= 0.26/ Endline (December 2022)



Chemistry: Density: 0.04/ Baseline (June 2022)



Chemistry: Density= 0.129/ Endline (December 2022)



Biology: Density: 0.07/ Baseline (June 2022)

Biology: Density: 0.38/ Endline (December 2022)

Physics: Density: 0.08/ Baseline (June 2022)

Physics: Density: 0.43/ Endline (December 2022)

Figure 5.1: Evolution of Teacher Online Communities of Practice during CL4STEM Implementation

From the perspective of qualitative analysis, all subject CoPs showed some common types of interactions. These interactions are explained below, and the respective screen grabs of the chats are shared here. Three main types of interactions were seen across all subjects: Teachers sharing practice, reminders and support and feedback.

1. *Teachers sharing practice:* In Tanzania, teachers across subjects shared their practice by sharing photos and details of their school's lesson plan implementation, as seen in the pictures below in

Figure 5.2 (a). This created a platform for the teachers to showcase their lessons and discuss their participation in the project (Figure 5.2 (b)).

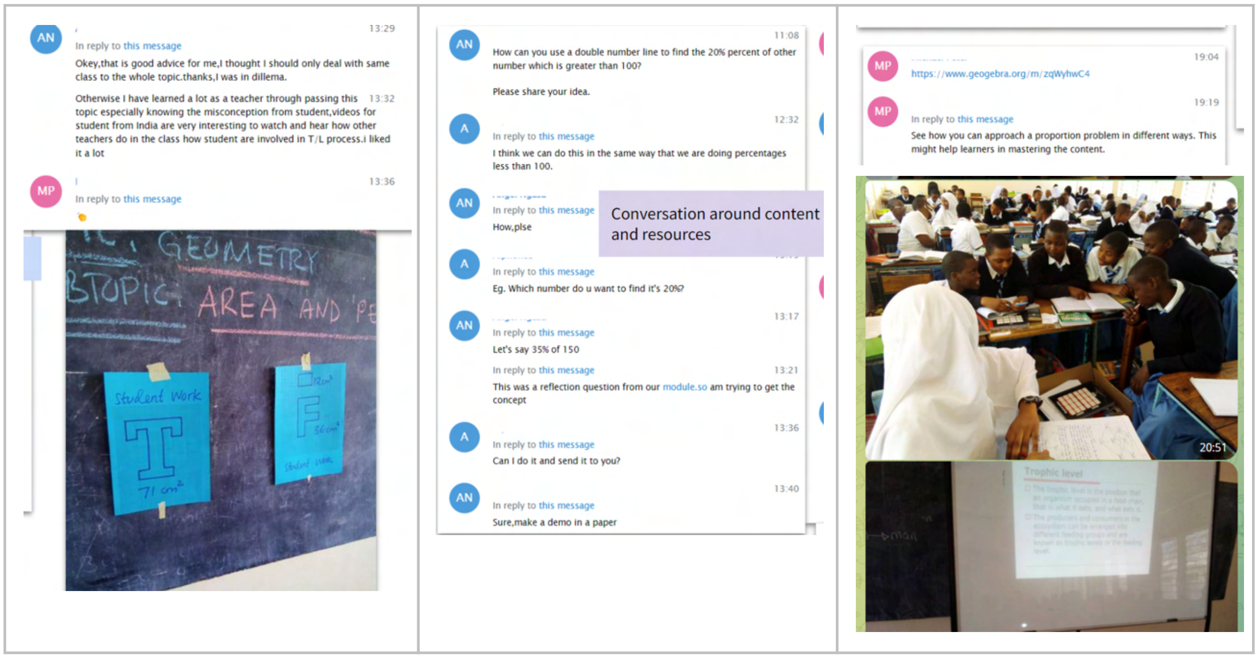


Figure 5.2(a): Examples from CoP on Teachers Discussing Practice.

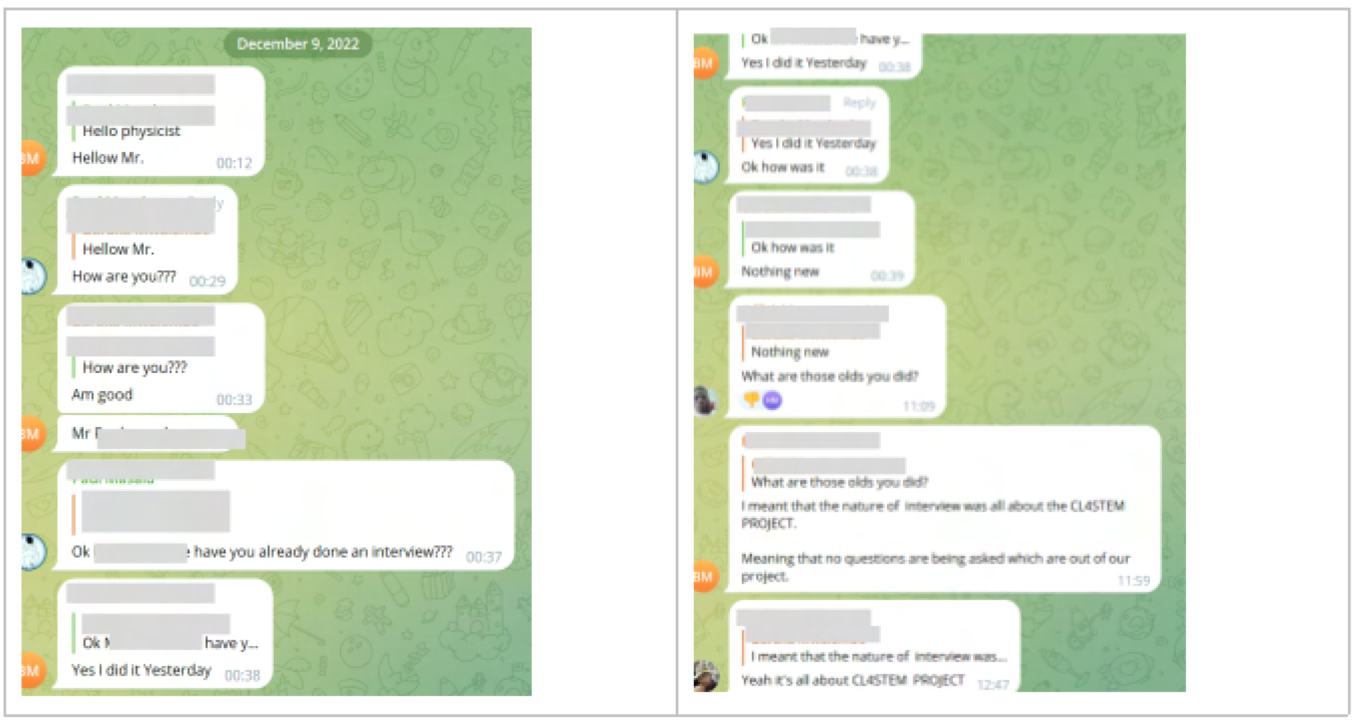


Figure 5.2(b): Examples of Teachers Discussing Participation in the CL4STEM Project.

2. *Reminders:* Teacher educators and subject leaders often shared reminders in the CoPs encouraging teachers to keep making progress in module implementation. Reminders could be general messages to the community or directly tag targeted participants (Figure 5.3). They would also use lists of participants to explicitly call out people to participate.

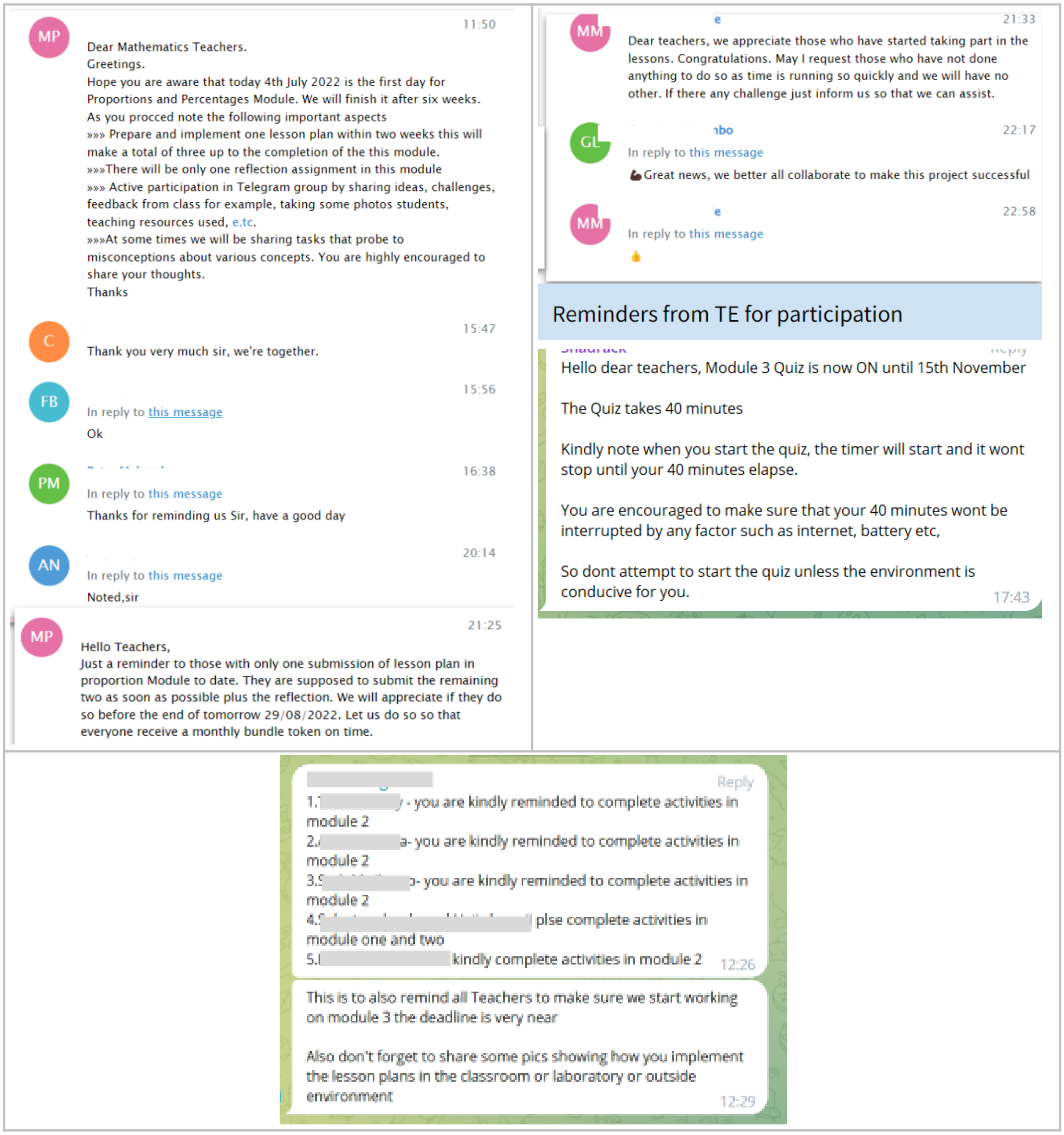
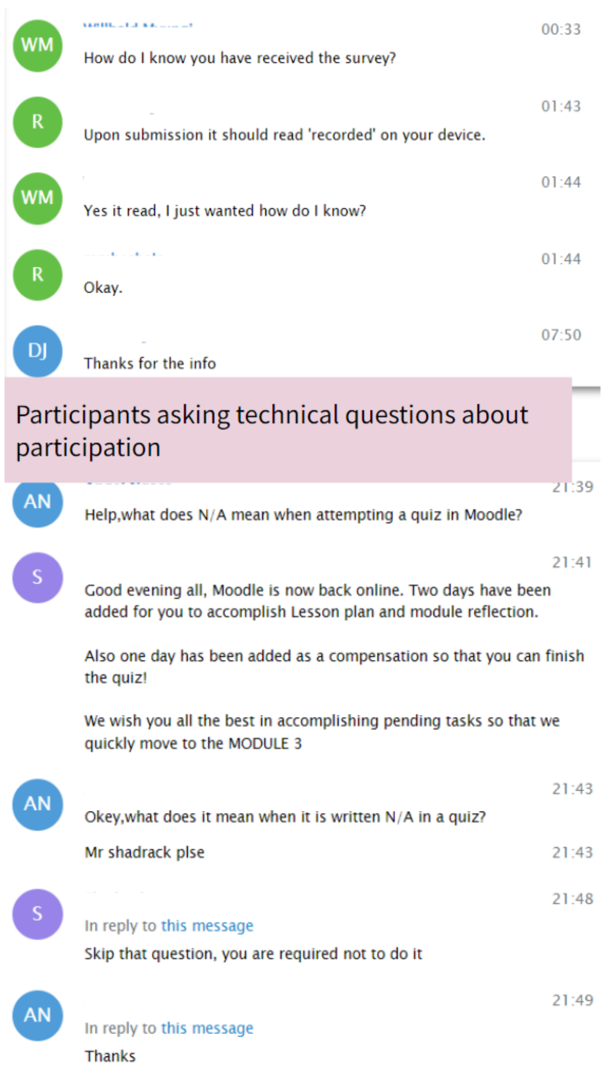


Figure 5.3: Examples of Teacher Educators Using Reminders to Encourage Participation.

3. *Support and feedback:* Teachers and teacher educators both shared messages seeking and offering support. Teachers would seek support to access Moodle-based modules. Figure 5.4 shows a conversation between the research fellow and a teacher on the submission of forms, in which the teacher is wondering if the researchers have received his entry. Similarly, Figure5.6 shares examples of teachers encouraging their peers to participate.

   In Figure 5.5, we can see the math teacher educator engaging with teachers on how to use local resources to teach specific math concepts. Figure 5.7 shows another instance from math CoP where both the teacher and the teacher educator are jointly reflecting on the project and the relevance of its design.



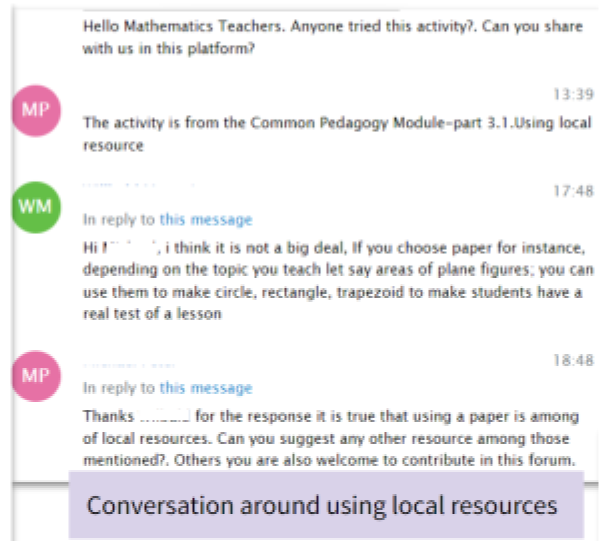


Figure 5.4: Conversation between Research Fellow and Teacher about Accessing Teacher Submission

Figure 5.5: Teacher Educator and Teacher Engaging in Conversation about Using Local Resources

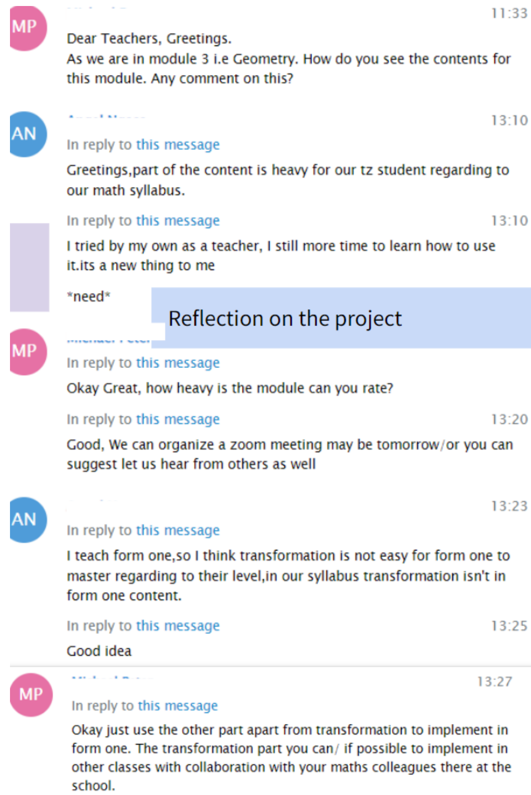


Figure 5.6: Teachers and Teacher Educators Encouraging Others to Participate in the CL4STEM Activities.

Figure 5.7: Teacher and Teacher Educator Jointly Reflecting on the CL4STEM Modules and the Intervention Design.

Thus, these online groups served as communities in which teachers and teacher educators could engage in an authentic community, exchange ideas, tinker with new tools and technologies, discuss their practice, learn from each other, and share their achievements.

6.0 Conclusion

CL4STEM project is a south-south collaboration among higher education institutions to adapt and pilot the Connected Learning Initiative CLIx that has been successfully implemented at scale in India, pioneered by the Tata Institute of Social (TISS) and piloted as innovation transfer by IBBUL in Nigeria, the Open University of Tanzania (OUT) in Tanzania and the Samtse College (SCE) in Bhutan. In Tanzania, this collaboration built capacities of faculties of education and science through knowledge transfer of CLIx to teacher educators which helped them design and curate OERs tailored to the local country context. This laid the groundwork for the main intervention for the secondary school STEM teachers to foster Higher Order Teaching with Inclusion and Equity (HOTIE). The pilot involved building these teachers' professional capacities through their engagement with curated OER-based modules which involved accessing them through a Learning Management System (Moodle) as well as participating in online Communities of Practice (CoP). The project had two associated research foci, the first centered on the analysis of the impact of innovation on teachers' Knowledge, Attitudes, and Practice for higher-order thinking in teaching and learning science and mathematics with inclusion and equity; and the second generated knowledge on the innovation adoption processes for specific local contexts and the conditions that support scaling.

In Tanzania, 18 participating schools were selected from six districts in different regions based on the following characteristics: geographical area, school administration system and ownership of schools. In terms of ownership, these schools were either government schools or community schools or private schools, and comprised single-sex (boys or girls only), co-education, day and boarding schools. The total number of participating teachers was 80 at the beginning of the project, and came down to 68 at the Endline due to dropouts across all participating schools and science domains, i.e., biology, physics, chemistry, and mathematics. While these 68 teachers made up the intervention group, a control group was also formed with 20 teachers from the same districts. The participating teachers were selected based on their subject specialisations and years of experience as school teachers. Thus, there were teachers with less than five years of experience teaching in schools, i.e., the Focus group and others with more than five years of experience.

The change in teachers' Knowledge, Attitudes, and Practice for higher-order thinking in teaching and learning science and mathematics with inclusion and equity was the primary outcome of this intervention. The KAP framework consisted of ten themes categorized under the heads Subject Matter Knowledge, Pedagogical Content Knowledge, and General Pedagogical Knowledge. The findings from the quantitative and qualitative data collected under different themes indicated mixed output and outcome.

Subject Matter Knowledge

The findings related to this KAP category indicated improvement in subject matter knowledge and examined two key dimensions: knowledge of subject matter of science and maths and the nature of science and maths. As a result of participating in the CL4STEM project, teachers could connect specific topic(s) concepts, nature and structure of science and maths as well as their application and convey them to students in a manner they understood quickly. Qualitatively, interviews and classroom observations indicated evidence of transformative change in teachers' awareness of knowledge and the nature of science and maths, especially of the interdisciplinary knowledge and nature of science and maths. However, quantitatively, survey analysis indicated mixed results that showed some positive changes in some areas while not in others, which implies teachers need more support in those areas without significant changes upon scaling up the project.

Pedagogical Content Knowledge

From the Baseline, throughout the intervention period to the Endline, teachers showed improvement in the development of scientific thinking through observation and problem-solving, knowledge of resources and their utilisation and the deployment of a variety of teaching strategies to address specific needs of the students in the classrooms This KAP category consisted of five key dimensions: Instructional Strategies, students' misconceptions and learning difficulties, representation of content, context for learning, and curriculum knowledge. Generally, the qualitative results from interviews and observation showed positive changes in these areas. For example, in the representation of the content and context for learning, we found more teachers applying multiple forms of representation, such as videos and hands-on activities and providing learners with interactive ways to access and engage effectively with the lesson upon project implementation. They were also increasingly updating, identifying, and using the locally available materials and connecting science to real life.

We also found an improvement in the general understanding in areas such as the curriculum knowledge and implementation of the goals and objectives of the specific lesson(s). Further, the teachers showed an enhanced understanding of the interconnectedness of science subjects with other subjects taught at schools which would have a holistic impact on students' behaviour. However, we found minor to no change in the categories corresponding to students' misconceptions and learning difficulties in quantitative and qualitative findings. In this aspect, teachers were still struggling to spot and plan for possible misconceptions and were facing difficulties due to language barriers, students' poor mathematics background from early schooling, and the common notion that science and mathematics are naturally difficult to study and understand. This calls for more support to these teachers upon scaling up the project in this dimension.

General Pedagogical Knowledge

The qualitative findings in this category of KAP compiled under three key dimensions- equity and inclusion, classroom management, and assessments- demonstrated that all participant teachers had significantly improved their understanding. An example is the adoption of equity and inclusion strategies such as including students with differences in academic abilities in learning, students with disabilities, providing equal opportunities, etc. Thus, access to modules, their implementation, and participation in online CoP were adequate to improve teachers' knowledge in relation to equity and inclusion. However, the quantitative findings indicated mixed results. On the one hand, the CL4STEM implementation improved teachers' understanding of challenges that hinder teaching science and maths in secondary schools in Tanzania. The intervention also significantly improved female teachers' attitudes toward inclusion and equity. Furthermore, the modules and the participation in online CoP assisted teachers in understanding how to address a wide range of skills and abilities in the classroom. On the other hand, CL4STEM implementation did not improve teachers' knowledge of managing students with special needs and students with different social statuses.

With respect to classroom management, the qualitative findings indicated that teachers had positively improved in various aspects, including applying project-based knowledge, problem-solving, collaborative learning and using activities. In addition, teachers showed an improvement in their knowledge of disciplining techniques and ability to organise and manage multiple modes of interactions. Furthermore, teachers improved their understanding of space management and the behaviour of teachers. However, the quantitative results suggest that the intervention did not improve subject teachers' classroom management skills, especially their ability to organise and manage group activities. Assessments was the last KAP theme, the qualitative results of which indicated that CL4STEM had facilitated subject teachers to clearly understand issues regarding multiple assessment methods, the ability to use assessment to improve the learning process and the ability to design and use a variety of methods for assessment, including task-based assessments. The summary of results for all ten KAP themes is appended at the end of this conclusion.

Table 6.1: Summary of Change in Teachers' Knowledge, Attitudes and Practice

Theme	Change	Results
Subject Matter Knowledge	No	No observable change
Nature of Science/Math	No	No observable change
Instructional Strategies	Yes	Improved scientific thinking through observation and problem-solving Improved knowledge of resources and utilisation
Students Misconceptions and Conceptual Learning Difficulties	Yes	Struggling to spot and plan for misconceptions in teaching Support needed upon scaling up
Representation of the Content	Yes	Multiple forms of representation of content, e.g., using videos, hands-on activities and providing learners with interactive ways to access and engage effectively with the lesson towards Endline An increase in knowledge of locally available materials, identification and implementation in teaching. Ability to connect science to students' real life
Context for Learning	Yes	Adapting and using local resources in the local context More usage of hands-on activities in teaching
Curriculum Knowledge	No	No observable change
Equity and Inclusion	Yes	Providing equal opportunities to all students Addressing the academic needs of students with special needs in learning Identifying and understanding a wide range of student's skills and abilities in classrooms
Classroom Management	Yes	Ability to organise and manage multiple modes of interactions Improved collaborative learning and use of activities Adoption of various methods of classroom interaction
Assessments	Yes	Adoption of multiple assessment methods Ability to design and use a variety of methods for assessment, including task-based assessment.

The innovation diffusion study scrutinised seven categories against which participating teachers provided their views concerning CL4STEM implementation during Baseline, Midline, and Endline interviews and classroom observation. Voluntariness was the first category of the IDS analysis. In this category, teachers were asked about their choice to join the CL4STEM project, whether it was out of their own will or due to other circumstances, such as their participation being mandated by school administrations. In Tanzania, teachers are required to obtain permission from their heads of school to participate in any academic activity outside the purview of their routine work at school. Thus, it became evident that all teachers were selected by the respective heads of schools. However, after being given orientation for the project, the teachers had the choice to either continue with the project or drop out. The study showed a high degree of voluntariness among participants, as only a few teachers dropped out at the time of implementation.

With respect to relative advantage, the second category in IDS analysis, the results showed that from the Baseline through the Endline, CL4STEM was advantageous to teachers in relation to multiple aspects, including its utility in improving the quality of teaching and enhancing teaching effectiveness. However, responses testifying to the ability of this approach to allow faster teaching and greater control over teaching were not evident in interviews. Regarding compatibility, the third category in IDS analysis, the results showed that teachers perceived CL4STEM to be compatible with how they would like to teach and fit to their teaching styles. The study on image„ the fourth category in IDS analysis, showed that the rise in profile and status of teachers due to their participation in CL4STEM encouraged them to work harder and stimulate learning in their classes. However, it did not significantly impact other teachers in the school who had not participated in the project. Teachers who had not participated knew a project was going on, but generally, did not give much attention to it. However, they perceived the participating teacher's knowledge of new teaching skills.

With respect to ease of use, the fifth category in IDS analysis, the study results showed that teachers found it easy to participate in CL4STEM. They appreciated that the modules were easy to understand and that they could easily navigate the materials and associated activities in Moodle e-learning management system to study, communicate, ask questions and give or receive feedback.. It was also evident that participating teachers could easily communicate their involvement in CL4STEM to non-participants and convey that the project would be useful to them. In terms of demonstrability, the sixth category in IDS analysis that examined the degree to which the results of CL4STEM were observable to others, the results showed a very high overall effect which signified that it was not difficult for teachers to describe the project to others who did not participate in this study. Lastly, visibility is the 7th category in IDS analysis which shows the degree to which teachers could observe other teachers using CL4STEM. The study on visibility, conducted through surveys and interviews across all implementation phases, indicated that there were no observable changes in visibility of CL4STEM in the schools.

Table 6.2: Teachers' Perceptions

Themes	Perceptions	Perceptions
Voluntariness	Negative	The majority of participants perceived that their participation was mandatory.
Relative Advantage	Positive	The majority of participants perceived CL4STEM to be relatively advantageous
Compatibility	Positive	The teachers had an enhanced understanding of CL4STEM being compatible with their teaching by way of experiencing the pilot.
Image	Positive	There was a positive impact on the perception of teachers' image after participating in CL4STEM. Teachers shared examples of how others' perceptions of their teaching have changed since they participated in CL4STEM.
Ease of Use	Positive	The majority of participants believed CL4STEM strategies to be easy to use.
Results Demonstrability	Positive	There was a positive perception of teachers' abilities to communicate the results of participating in CL4STEM to others who were non-participants.

Visibility	No observable change	Teachers did not perceive observable changes in the visibility of CL4STEM in their schools.

The CL4STEM project has had a positive impact on the participating teachers in Tanzania. The project exposed them to a manageable professional development programme and added valuable lessons on knowledge of resources and their utilisation along with the use of new innovative pedagogical approaches and ICT in teaching and learning in simple and diverse ways they could manage in their local school contexts. Apart from using the Learning Management System (Moodle) to interact with the pre-developed modules, the Social Learning in CL4STEM, which refers to the participants acquiring knowledge and learning from interactions with each other, added an interesting contemporary practice. Its qualitative analysis indicated that the mobile-based CoPs for the common module and for all the subjects showed some common types of interactions, teachers sharing practice, giving reminders and offering support and feedback-through which teachers and teacher educators were able to engage in an authentic community to exchange ideas, tinker with new tools and technologies, discuss and share practice, and learn from each other. Thus with scalability advantages, the education system in Tanzania can, in future, borrow the tested Knowledge, Attitude and Practice (KAP) framework, blended mode of delivery and mobile-based CoPs from CL4STEM to conduct a similar online professional development programme in the country to make up the deficit of teacher development programmes which are often not undertaken due to budget and travel constraints.

References

Ball, D. L., Hill, H. C., & Bass, H. (2005). Knowing mathematics for teaching. *American Educator*, *Fall*, 14–22. https://doi.org/10.1016/j.cedpsych.2006.02.001

CAST (2018). Universal Design for Learning Guidelines version 2.2. Retrieved from http://udlguidelines.cast.org

Cochran-Smith, M., Lyte, S.L. (1999). Relationships of Knowledge and Practice: Teacher Learning in Communities. Review of Research in Education, Vol. 24, pp. 249-305. American Educational Research Association.

Cooley, L., & Linn, J. F. (2014). Taking Innovations to Scale: Methods, Applications and Lessons. *Management Systems International*, *September* 24. https://www.usaid.gov/sites/default/files/documents/1865/v5web_R4D_MSI-BrookingsSynthPaper0914-3.pdf

Daly, A. J. (2010). Mapping the terrain: Social network theory and educational change. *Social network theory and educational change*, 1-16.

Evens, M., Elen, J., & Depaepe, F. (2015). Developing Pedagogical Content Knowledge: Lessons Learned from Intervention Studies. *Education Research International*, *2015*(1), 1–23. https://doi.org/10.1155/2015/790417

George, A. A., Hall, G. E., Stiegelbauer, S. M., & Southwest Educational Development Laboratory. (2006). *Measuring implementation in schools : the stages of concern questionnaire*.

Grossman, P. L. (1990). The making of a teacher: Teacher knowledge and teacher education. New York, NY: Teachers College Press

Hall, G. E. (1974). The Concerns-Based Adoption Model: A Developmental Conceptualization of the Adoption Process Within Educational Institutions.

Hall, G. E., Dirksen, D. J., & George, A. A. (2006). Measuring implementation in schools: Levels of Use. Austin, TX: SEDL. Available from http://www.sedl.org/pubs/catalog/items/cbam18.html

Hamilton, M. (eds) International Handbook of Teacher Education. Springer, Singapore. https://doi.org/10.1007/978-981-10-0366-0_1

https://gephi.org/

Kind, V. (2009). Pedagogical content knowledge in science education: Perspectives and potential for progress. *Studies in Science Education*, *45*(2), 169–204. https://doi.org/10.1080/03057260903142285

Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge university press.

Loughran, J., Hamilton, M.L. (2016). Developing an Understanding of Teacher Education. In: Loughran, J.,

Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. Information systems research, 2(3), 192-222.

Panirsilvam, S. R. (2017). Literature Review: Scaling Up of Education Innovation and Their Impact on Students Learning Outcomes. *Sydney, NSW, Australia: Centre for Research on …*, *April*. https://doi.org/10.13140/RG.2.2.25120.28169

Ramchand, M. (2022). Pedagogic content knowledge of science: A framework for practice and construct for understanding teacher preparation. Contemporary Education Dialogue, 19(2), 281-303.

Rogers, E. M. (2010). Diffusion of innovations. Simon and Schuster

Sarangapani, P.M. (2011). Soft Disciplines and Hard Battles. Contemporary Education Dialogue 8(1) 67–84.

Shawer, S. F. (2022). Competency-based education. Retrieved on February 13, 2022 from: How to implement competency-based education – Nova Science Publishers (novapublishers.com).

Shulman, L. S. (1986). Those Who Understand Knowledge. *Educational Researcher*, *15*(2), 4–14.

Wenger, E (1998) Communities of practice: Learning, meaning, and identity. Cambridge: Cambridge University Press.

Winch, C (2004) What do teachers need to know about teaching? A critical examination of the occupational knowledge of teachers, British Journal of Educational Studies, 52:2, 180-196