Connected Learning for STEM (CL4STEM)

Knowledge Transfer

Process Documentation Report

BHUTAN | NIGERIA | TANZANIA| INDIA

The Connected Learning for Science, Technology, Engineering, and Mathematics (CL4STEM) project aims to pilot an innovation and research its effectiveness and potential scaling for building capacities of secondary school teachers in Science and Maths for fostering higher-order thinking with inclusion and equity in their classrooms. The CL4STEM pilot engages teachers in curated OERs based modules in Science and Maths and 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 focus on two broad areas. First, the Impact Study, analyses the impact of innovation on teachers' knowledge, attitudes, and practice for higher-order teaching and learning of science and maths in an inclusive and equitable manner. Second, the Innovation Diffusion Study, generates knowledge on the processes of adoption of the innovation for specific local contexts and the conditions that support scaling.

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

This study is funded by IDRC under the Global Partnership for Education Knowledge and Innovation Exchange (https://www.gpekix.org). Centre for Applied Sciences and Technology Research, Ibrahim Badamasi Babangida University, Lapai, Nigeria, is the lead of the CL4STEM project consortium which includes Samtse College of Education, Bhutan and Open University of Tanzania as the country partners. Tata Institute of Social Sciences, India is the technical consultant to the project.

Citation - CL4STEM (2022). Knowledge Transfer - Process Documentation Report. Mumbai, TISS

Report is available for download at https://www.connectedlearningforstem.org/
Any questions, suggestions or queries may be sent to us at: info.cl4stem@clixindia.org

Centre for Excellence in Teacher Education
Tata Institute of Social Sciences
Mumbai - 400088, India
chair.cete@tiss.edu
http://bit.ly/cetewebsite

Knowledge Transfer Team

Mathematics: Ruchi Kumar, Arushi Bansal, Anirudh Agarwal, Jeenath Rahaman

Science: Shamin Padalkar, Rafikh Shaikh, Deepika Bansal, Geetha M, Sarika Bansode

Knowledge Transfer Lead : Mythili Ramchand

Knowledge Transfer Coordinator : Emaya Kannamma

Design Thinking Team : Bindu Thirumalai, Jennifer Thomas

Universal Design for learning : Sujata Bhan and Apoorva Panshikar, SNDT, Mumbai.

Knowledge Transfer Support : Surbhi Nagpal

Acknowledgements

We are deeply grateful to the teacher educators from Nigeria, Tanzania and Bhutan engaged with the knowledge transfer. The science and mathematics teachers deserve our special thanks for providing feedback for the modules.

This report was a collaborative effort by Arushi Bansal, Anirudh Agarwal, Dr.Bindu Thirumalai, Dr.Deepika Bansal, Emaya Kannamma, Geetha M, Dr.Jeenath Rahaman and Dr.Sarika Bansode from the TISS knowledge transfer team, guided by Prof.Mythili Ramchand, Prof.Padma Sarangapani and Dr.Vikas Maniar. Thanks to Dr.Shamin Padalkar, Rafikh Shaikh, Dr.Ruchi Kumar and Dr.Tanushree Rawat for their valuable inputs and suggestions.

The team would like to thank Prof. Nuhu George Obaje, Prof. Steve Nwakeocha, Dr. Edephonce Nfuka, Dr. Richen Dorji and Abdullahi Abubakar Kawu for their support during the entire process.

We are grateful to Prof. Sujata Bhan, Dr. Apoorva Panshikar, Dr. Shikha Takker, Dr. Ritesh Khunyakari, Punam Medh, Radha Lakshminarayan and Shivani Pethe for their feedback on subject modules.

We thank the International Development Research Centre for funding this project and making this collaboration possible.

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List of Abbreviations/ Acronyms

CL4STEM : Connected Learning for STEM
CETE : Centre of Excellence in Teacher Education
CLIx : Connected Learning Initiative
CoP: Community of Practice
HOTIE: Higher Order Teaching with Inclusion & Equity
ICT: Information and Communication Technology
ITE-ST: Initial Teacher Education - Student Teachers
OER: Open Educational Resources
PCK: Pedagogical Content Knowledge
POE: Predict Observe Explain
RSC: Royal Society of Chemistry
RTICT: Reflective Teaching with Information Communication Technology
SNDT: Shreemati Nathibai Damodar Thackersey Women's University
STEM: Science, Technology, Engineering, and Mathematics
TEs: Teacher Educators
TISS: Tata Institute of Social Sciences
TISSx: OpenEdx Online Course
TPD: Teacher Professional Development
UDL: Universal Design for Learning

Introduction

The CL4STEM (Connected Learning for STEM) project seeks to strengthen the capacities of middle and secondary school science and mathematics teachers in Bhutan, Nigeria and Tanzania, and also with preservice student teachers (ITE-ST) in Bhutan to foster inclusive higher-order learning in their classrooms. It aims to pilot the Connected Learning Initiative (CLIx)[1] innovation, developed and scaled in India, in the new contexts of Bhutan, Nigeria, and Tanzania, through a South-South collaboration.

Teacher Educators (TEs)/faculty of teacher education are the key agents responsible for adapting the innovation and implementing it in the three afore-mentioned geographical contexts. They have employed the CLIx approach to Teacher Professional Development (TPD) which includes, a.) specially designed OERs to enhance teachers' Pedagogical Content Knowledge (PCK) and b.) mobile based Community of Practice (CoP) to promote peer group professional learning. In the context of each country, this involved:

1. Offering a course comprising a set of 13 CL4STEM modules to enhance teachers' PCK using open educational resources (OERs) and blended learning.
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 and plan for roll-out.

In alignment with the theory of change (Figure A) and to support teachers' PCK and inclusive practices, a conceptual framework was developed based on the literature of Shulman (1986) [2], Ball, Hill, & Bass (2005)[3], Grossman (1990)[4], Kind (2009)[5] and CAST (2018)[6]. The conceptual framework is aimed towards Science/Maths Teacher Knowledge for promoting Higher Order Thinking among learners with Inclusion & Equity (HOTIE). The conceptual framework consists of subject matter knowledge, pedagogical content knowledge and general pedagogical aspects. The table A elaborates the CL4STEM conceptual framework:

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[1]The CLIx initiative was seeded by Tata Trusts, Mumbai, and is led by Tata Institute of Social Sciences, Mumbai and Massachusetts Institute of Technology, Cambridge, MA, USA. In March 2018, the initiative won the prestigious King Hamad Bin Isa Al-Khalifa Prize for the Use of Information and Communication Technology (ICT) in the field of Education. For more details, see https://clix.tiss.edu

[2] Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4–14.

[3] Ball, D. L., Hill, H. H., & Bass, H. (2005). Knowing mathematics for teaching: Who knows mathematics well enough to teach third grade, and how can we decide? American Educator, Fall, 14-46.

[4] Grossman, P. (1990) The Making of a Teacher, New York: Teachers College Press.

[5] Kind, V. (2009). Pedagogical content knowledge in science education: Perspectives and potential for progress. Studies in Science Education, 45(2), 169-204.

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

Figure A :Theory of change

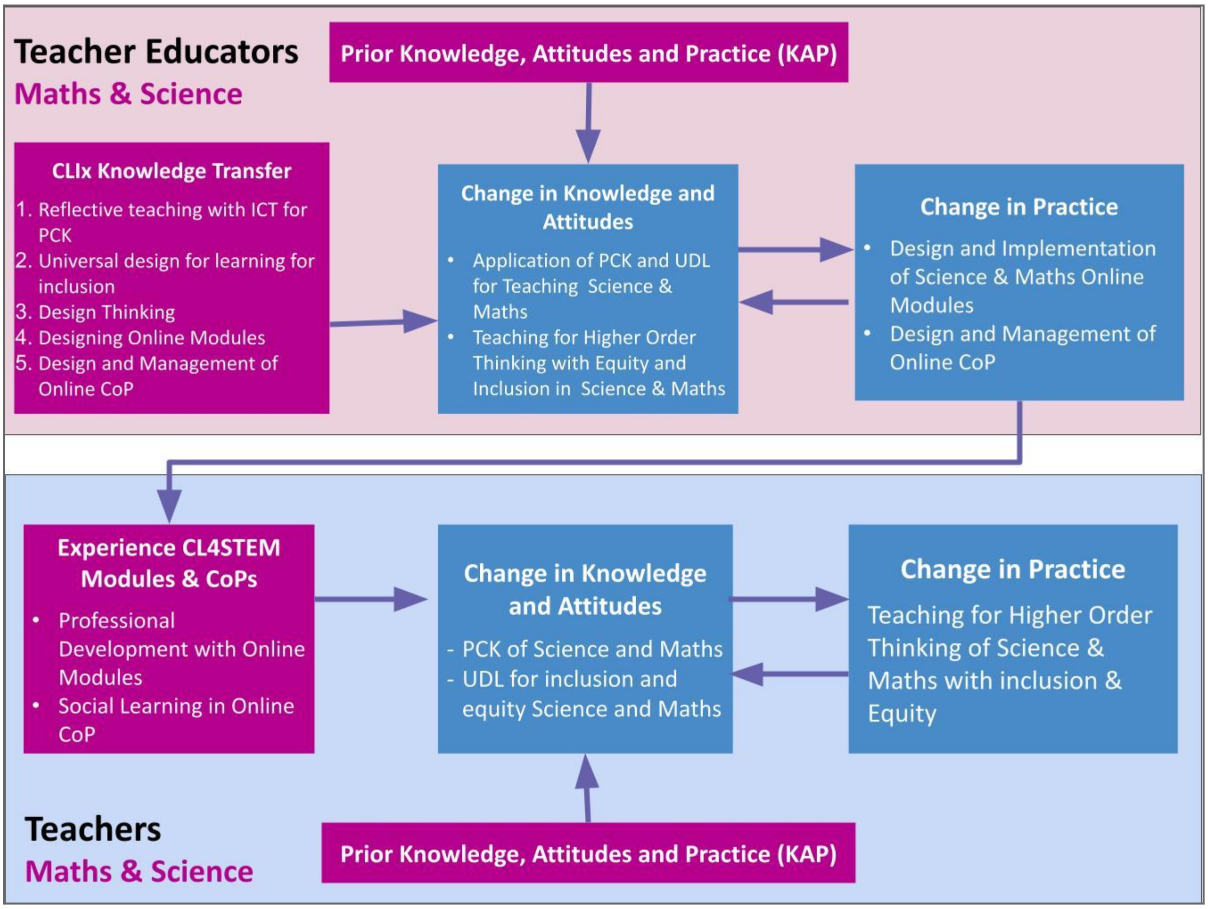


Table A. Science/Maths Teacher Knowledge, Attitude and Practice for Higher Order Teaching with Inclusion & Equity

Subject Matter Knowledge	
1.Knowledge of Science/ Maths Subject Matter	• The knowledge possessed by the teacher in one or more science or mathematics disciplines. - 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
2. Nature of Science /Mathematics	• Teachers' knowledge of the nature of science, such as science is empirical, it is situated in a particular historical, social, economic context, it requires creativity and imagination, 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 representing 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, including students' misconceptions and learning difficulties
4.Students' Misconceptions & Learning Difficulties	● Knowledge of students' prior-conceptions, errors, misconceptions/alternative conceptions, ways of students' thinking, 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 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 limits 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 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 the 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, 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
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

The process of knowledge transfer

The knowledge transfer process under Stage 1 was led by the faculty of TISS. Teacher educators of the three collaborating universities participated in virtual workshops and created 13 modules for teacher professional development based on the programme's theory of change (See Figure A). 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 quality of questions asked to develop higher-order thinking and adopt inclusive practices.
4. Management of a subject-based online CoP to share experiences and build contextual pedagogical content knowledge collaboratively.
5. Use of ICT in education, and its role in peer-learning and the professional development of teacher educators.

The knowledge transfer was completed in five phases (Figure B).

- Phase 1 was designed for TEs to experience an online practice-based reflective teaching courses 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 TEs were doing the course. During the length of the course, they 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 for an equitable and inclusive teaching-learning process. The sessions were facilitated by the faculty from Shreemati Nathibai Damodar Thackersey Women's University, Mumbai.
- Phase 3 consisted of a synchronous workshop to introduce the design thinking process and explore its potential to create meaningful, and pedagogically valid teaching-learning resources and modules for teachers. The process of using design thinking was envisaged to help TEs while they develop STEM modules.

- Phase 4 of knowledge transfer involved TEs from all 3 countries along with the subject teams from TISS developing contextually relevant modules for teachers of their respective countries.
- Phase 5 was meant to consolidate the experience of being a part of CoP through all the phases and introduce TEs to the management of a mobile-based CoP for teachers which enables the development of a social learning environment.

The following sections in this report details each phase of the knowledge transfer with their respective objectives and the nature of engagement with teacher educators across three countries. The figure below gives the timeline of all the five phases.

Figure B : Timeline of Knowledge Transfer

Phase 1 Experiencing CLIx OERs & courses for teachers

The broad goals of this phase was to let the teacher educators experience and engage with the CLIx OERs[7] and get acquainted with the Reflective Teaching with ICT (RTICT[8]) courses developed for teachers. Teacher educators were introduced to the CLIx and other exemplar OERs for maths and science teaching and learning to understand the pedagogical ideas adopted to design the OERs. The OERs were introduced through two modular courses of the RTICT programme run on the course management system - TISSx[9] for mathematics and science, namely, Reflective Mathematics Teaching (Geometric Reasoning)[10] and Interactive Science Teaching (Experimentation)[11].

These courses enabled teacher educators to :

- Identify the research-based pedagogical ideas incorporated in the OERs
- Develop Pedagogical Content Knowledge (PCK) on specific science and mathematics topics
- Identify the different features and pedagogies, and visualise the design elements for developing modules for teachers in the subsequent phase four

The coursework included submitting multiple assessments including multiple-choice questions, practice-based assignments, reflective reports and engagement on the discussion forum. The courses required teacher educators to implement/teach a lesson using one of the OERs and submit a reflective report on the experiences. These experiences were also shared on the Telegram CoP enabling a social and collaborative learning experience. This phase made the teacher educators experience the two components of CLIx TPD namely, the modules and the mobile based CoP.

1.1 Reflective Mathematics Teaching (Geometric Reasoning)

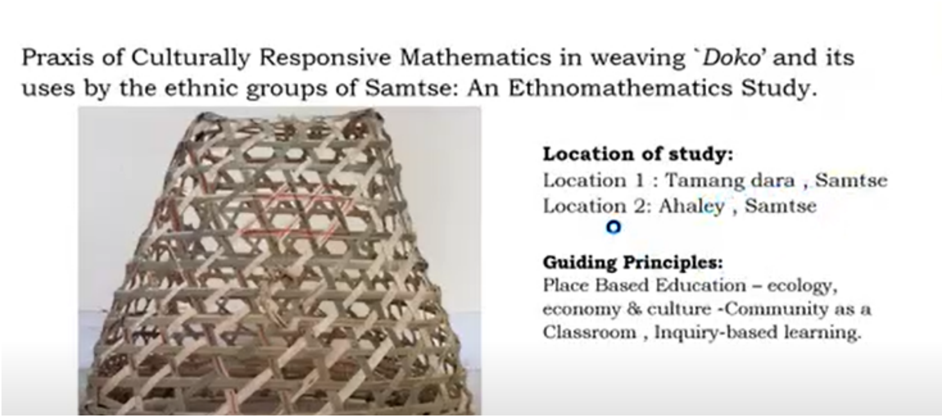
The Reflective Mathematics Teaching course provides an exemplary pedagogical context built on an OER based student module on Geometric Reasoning. The course exposes the main pedagogical principles to be followed in a maths classroom: a safe space to make mistakes, pairing and collaboration, and finally, an authentic and blended learning environment. Mathematics TEs experienced the *Reflective Mathematics Teaching (Geometric Reasoning)* course, aimed at developing the teachers' understanding of the core ideas of Mathematics, its processes and the interconnections within and across the mathematical domain. It helps to understand the value of engaging with student thinking in informing teaching; to meaningfully develop teaching plans by incorporating appropriate teaching-learning resources and to understand the process of becoming a reflective practitioner.

[7] Clix OER is a repository of high quality, interactiveEducational resources for high school students and teachers https://clixoer.tiss.edu/home/e-library
[8] Reflective Teaching With Information Communication Technology (RTICT) https://cpd.tiss.edu/rtict/
[9] https://www.tissx.tiss.edu/
[10] https://cpd.tiss.edu/rtict/courses/s-02a.html
[11] https://cpd.tiss.edu/rtict/courses/s-03a.html#

As a part of the exercise , the TEs had to complete the course, attempt quizzes, watch videos, engage with resources and reflect on the reading materials. They also had implementation and reflection assignments, where they had to implement a lesson plan shared in the course or OER of their choice and reflect on possible practices, content knowledge and student thinking.

Course participation was supported by weekly online workshop sessions led by subject domain leads from TISS. Eighteen mathematics TEs participated, of which 15 were males and 3 were females (one from each partner country). The course workshop sessions were also used to understand the context of the partner-country. TEs from Nigeria presented on the culture and standards of the curriculum of Nigeria. TEs from Bhutan presented on ethnomathematics in the Samtse College of Education, Bhutan. The presentation on “Praxis of culturally responsive mathematics in weaving DOKO” was about geometric patterns behind weaving baskets, the design variations and the practice of weaving in Bhutan.

Figure 1.1 Snapshot of a slide from the session on ethnomathematics



Knowledge

The course had survey forms with items ranging from knowledge and belief about student thinking to attitude towards various classroom practices. One of the major pedagogical principles the course focused on was the need for a safe place for students to make mistakes along with the teachers’ knowledge on students’ misconceptions as important elements of mathematics PCK.

In response to the questions posed to understand their knowledge about learning geometry, 25% of the participants chose “not being able to recognise the properties of any shape” and “not being able to identify similarities and differences of shapes” as areas of struggle while learning geometry. The least number of participants, 8.3%, chose “not being able to recognize that one shape can be a part of more than one class” as an area of struggle while learning geometry. During the post-test, the highest number of participants(40%) selected “not being able to recognize that one shape can be a part of more than one class” while none of the participants selected “incorrect categorisation of shapes” as an area of struggle.

Table 1.1.1 Areas of struggle while learning geometry

	Pre Course	Post Course
Not being able to remember the definitions	8.3%	6.7%
Not being able to recognize the properties of any shape	25.0%	6.7%
Not being able to identify the similarities and differences of shapes	25.0%	20.0%
Incorrect categorisation of shapes	19.4%	0.0%
Not being able to recognize that one shape can be a part of more than one class	8.3%	40.0%
Secondary class geometry focuses on the way to reach the answer rather than the correctness of the answer.	13.9%	26.7%

Regarding students' misconception about high school geometry, 9 respondents identified that "There is only one way to prove" as a major misconception. 7 responded that "Proof is to be developed based on the given information and properties of geometric objects" and "Proof requires arguments instead of calculations" as misconceptions. 6 TEs responded that "Examples work as proofs".

Context of students

Shulman (2015)[12] elaborates the context of students as one of the aspects of pedagogical content knowledge. Being aware of the context of the student becomes important for teaching. The course captures this understanding of the teacher educators using surveys and polls that address the socio-economic background of the students and their gender.

50% of the TEs reported that girls find mathematics difficult in comparison to boys, however, 30% of the TES were of the opinion that it is not true and 20% remain unsure. 35% TEs felt that not giving opportunities to girls to respond in mathematics classroom, will not impact the morale or learning process of the girl students. The response to survey questions regarding poor socio-economic background and situational questions, offers insights into the TEs opinion that the ability to learn mathematics remains unaffected by the socio-economic background of the learner.

The course had quizzes to test the teacher educators' understanding of the pedagogy behind using particular tools and to help ascertain whether the teacher is able to use the tools effectively in order to understand the gaps in student learning. While the questions

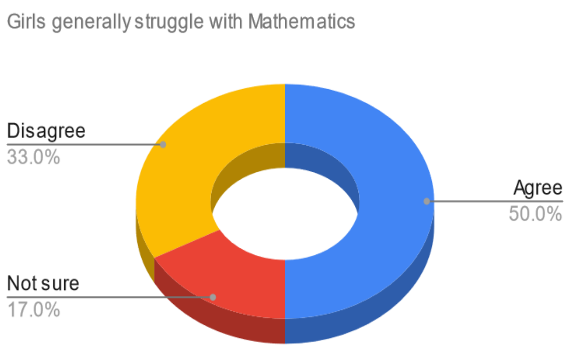


Figure 1.2 TE's opinion on girls struggle with mathematics

[12] Shulman, L. S. (2015). PCK: Its genesis and exodus. In Re-examining pedagogical content knowledge in science education (pp. 13-23). Routledge.

pertaining to subject matter ascertained the TEs content knowledge in mathematics, the questions on pedagogical knowledge were designed to capture the TEs' understanding of pedagogy and its origins, the important aspects of pedagogy, and the specifics of teaching geometry. The questions on anxiety about mathematics probed the reflection on growth and fixed mindsets. The fixed and growth mindset focuses on student thinking and it is required of the teacher to develop it for the students and their ability to think, their performance and general affinity towards mathematics. The understanding of student thinking was assessed by engaging the TEs with themes like geometrical reasoning, conceptual understanding using the van Hiele Model[13], student affinity, and their competency in handling ICT tools. The average scores of the TEs from the participating countries are as in table below.

Table 1.1.2 Percentage of average scores of TEs

Themes	Average score (percent)			
	Bhutan (5)	Nigeria (7)	Tanzania (5)	Total (17)
Application of ICT tools (6 items)	66.6	47.1	72.2	60
Content knowledge (12 items)	73	55	73	68
Grasp of the knowledge and practice about learning objectives (4 items)	80	83	94	85
Pedagogy (8 items)	92.5	62.5	92.5	80.1
Anxiety about mathematics (3 items)	73.3	66	86.6	74.3
Student thinking (5 items)	72	40	80	61

Attitudes

The participants were asked about their attitudes towards teaching and learning mathematics, specifically geometry. The responses are summarised in the table below.

Table 1.1.3 Change in TEs opinion on teaching-learning mathematics

% change from pre-test* to post-test**	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Procedures to solve geometry problems	+7.1	+20.4	-16.5	-31.9	+20.9
Listening carefully to the teacher explain the mathematics is the most effective way to learn mathematics	-8.2	+12.1	-8.2	-17.6	+7.1
Student solving textbook problems repeatedly is the best way to learn mathematics	+14.2	-18.3	-9.3	-1.6	0
It is essential that students express their ideas in classrooms to learn mathematics better.	-23	0	0	-1.6	+17

[13] van Hiele, P. (1957). An investigation of the Van Hiele model of thinking in geometry among adolescents. *New York, NY: City University of NewYork*.

Students learn best if they figure things out for themselves	-23	-15.3	+7.1	-17.6	+41.2
Best remedy when students make errors, is to make them repeatedly practice	-15.9	+5.5	+6.6	-17.6	+6.6
*n=13; **n=14					

Furthermore, the participants were asked their opinions on 'What is Mathematics' and 'Goals of teaching Mathematics' to understand their opinion on the nature of mathematics. In the pre-test, the highest number of respondents chose that mathematics means representing situations using mathematical symbols and identifying patterns in numbers, space and change. A similar majority was seen in post-test where, given the constraint of choosing a single option, most of the teacher trainers associated the explanatory nature of mathematics with its core meaning.

Table 1.1.4 TEs' opinion on 'What is Mathematics' in pre-post tests

Frequency	Pre-test	Post test
Highest	Representing the situations using mathematical symbols, Identifying patterns in numbers, space and change	Representing the situations using mathematical symbols
Lowest	Working with abstract concepts and ideas that have little or no connection with reality	Calculation with numbers and operations, Manipulation of symbols according to the mathematical rules, Working with abstract concepts and ideas that have little or no connection with reality

During pre test, while 6 out of 14 participants stated that the goal of teaching mathematics is to make students experts in basic operations, only 3 of them said the same in the post test. The number of people who focused on "getting good marks" also decreased in the post test. Having the students simply learn the procedures and formulae for solving the problems was another goal which saw a decline in takers during post tests. However, developing explanations for each procedure and why they work also saw a decline.

Table 1.1.5 TE's opinion on 'Goals of teaching mathematics' in pre-post tests

Frequency	Pre-test	Post test
Highest	Connecting mathematics taught in school with experience in daily life situations.	Connecting mathematics taught in school with experience in daily life situations.
Lowest	Being able to get good marks in exams as maths is a scoring subject.	Being able to get good marks in exams as maths is a scoring subject.

Almost all participants had answered that one of the main goals of teaching mathematics must be to ensure that the children employ the mathematical concepts taught in school in their daily experiences. This number remained unchanged in the post test. The number of teacher educators, who observed that developing reasoning and thinking skills among students is the main goal also remained unchanged. Scoring good marks in mathematics had the least number of takers in both pre and post tests.

Practice

As the course was practice based, TEs were expected to implement the lesson plan that was shared as a part of the module with their students. The expectations of the assignment were changed, considering the pandemic situation in the respective countries. Due to school closures, the lesson plans for high school students could not be implemented in full measure.

As part of the implementation of the lesson plan, the TEs used various resources of their choice for developing geometrical reasoning with school students or adults with no mathematical background. The concepts were aligned with the various levels of the Ven Helie model, where some implementations focused on the visualisation and identifying the properties of quadrilaterals, others focused on the analysis of drawing similarities and differences amongst the properties of various quadrilaterals.

The TEs used hands-on activities, and ICT tools like Geogebra and the Turtle logo to draw/construct the shape and tools like PoliceQuad, and CLIx OER to describe/classify/identify and verify their findings. Students, with whom the lessons were implemented, were also invited to make conjectures of their own. The TES also adopted hands-on activities from CLIx OER for the assignments. For example, a TE from Bhutan used matchsticks to construct quadrilaterals, while a TE from Tanzania used a 30 cm long ruler as a resource.

Reflection on practice

The TEs were required to reflect on their experience of implementing lesson plans. For the assignment, they shared their experiences with regard to the student's thinking and noted the changes observed. 10 TEs responded to the assignment, scoring an average of 6 out of 10.

Most of the participants were able to distinguish between the various Van Hiele stages of geometric understanding, and were able to provide relevant examples, wherever applicable, to support their claim for a particular student's level. It was seen that most of the participants were able to provide relevant student artefacts to accompany their claims, and these artefacts clearly matched the level of understanding that the participants had identified in their own reflections.

It was also seen that most of the TEs were able to help students reach the level of visualisation with help of the module. They were able to justify why the students were at a particular level, and more importantly, justify why they thought the students did not qualify for the next level on the van Hiele model. The evidence provided was apt and relevant. Some of the participants, however, did not articulate their reflections on the level of students thinking that was visible inside their classroom.

Reflections on the course experience

The sessions were conducted country-wise to reflect on the TISSx course experience. TEs across the participating countries asserted that the course is beneficial and necessary for teachers but implementation could be a challenge due to the lack of ICT competency among the teachers. Further, it could be difficult for teachers from rural areas who lack internet connectivity. The TEs shared that the teachers would be excited to use resources from the modules while teaching mathematics as it is a subject that is feared by students. Children have demonstrated a fear of geometry which can be the reason for not choosing mathematics for higher studies or can even be the reason for school-dropouts. TEs also appreciated and expressed their readiness to use the resources in the modules with their teachers and employ hands-on activities and ICT tools to make mathematical concept teaching more simple and interactive. As the module was focused on geometric reasoning, the TEs reflected on the importance of geometry in introducing reasoning, spatial and visual thinking and moving beyond the introduction of numbers.

All of the TEs struggled with implementing the modules among students, because they did not have access to students during the pandemic. Communication became a challenge in online interactions because the language accents were different across countries and posed problems in comprehension. The lack of stable internet for some TEs also aggravated the communication issue. The writing of key messages on a document shared during the online calls helped to ease some of the barriers in communication.

Through an engagement with the course and active discussions, TEs reflected on the importance of PCK. Teacher educators were able to participate in discussions, and made use of hands-on activities and tools like GeoGebra, the turtle logo and the PoliceQuad mission. The TEs participated both as teachers and as students to experience their points of view. Misconceptions among students, the teachers' readiness and competency to use the resources were discussed and reflected on as part of the discussions

Bhutan

The TEs observed that tools like the turtle logo are rather difficult to initiate with kids due to the coding language that the tool uses, whereas GeoGebra was found to be an easy tool to navigate where functions are accessible through simple clicks. The TEs from Bhutan shared that the geometrical curriculum in their country has been the same for 20 years and that there has not been much focus on geometry in the whole curriculum. The modules in the curriculum do not offer much in the way of critical thinking as emphasis is not laid on reasoning , but on procedures.

The TEs commented that these modules would sustain interest among the students. They also shared that the teachers in Bhutan rely mostly on "chalk and talk" and the Royal Education Board provides TLM for only primary schools and not for secondary schools.

Nigeria

TEs from Nigeria remarked that these modules would considerably help those learners who find geometry difficult. One particular TE suggested that it is necessary to develop a handbook for capacity building specifically for mathematics teachers who employ innovative ways of teaching and learning.

The only materials available for the use of teachers in Nigeria are mainly black boards and textbooks. There is a notable lack of ICT resources, except for the access to overhead projectors in a few instances. The TEs observed that content knowledge of the teacher is gauged only by professional degrees and certificates, and that continuous training is found to be lacking. They also shared that for enhancing pedagogical content knowledge, teachers should ideally employ multiple strategies to teach a particular concept , however, due to the large size of the class, they inevitably have to resort to the traditional lecture method.

The TEs shared that music, dance and sports can be used for activity-based learning and that references to religious practices can also be used for the same as religion is something that everyone relates to in Nigeria. So as to improve mathematics education in Nigeria, the TEs noted that the quality and quantity of teachers have to undergo advancement. They also suggested that adequate resources including ICT devices, textbooks and continuous training of teachers for capacity building and the use of innovative and creative handbooks for both teachers and students should be ensured for the same.

Tanzania

Several of the TE reflections mentioned that geometric properties are useful and that the TISSx platform is user-friendly. The TEs also shared some concerns regarding mathematics education in Tanzania such as the lack of right pedagogy. They said that the usual practice is to give a lot of exercises and homework without focusing on the development of conceptual understanding. An example shared was that of a teacher not using a number line for teaching integers and stating only the rules. Another drawback of the present system is that assessment is always exam-based, content-based instead of focusing on the comprehension of concepts. TEs shared that they find teachers rushing to complete subject matter with laying much less emphasis on conceptual understanding.

The students' and teachers' attitude towards mathematics was another concern which makes mathematics seem a rather difficult subject. There were concerns about ICT competency and resources available at their disposal in the country that allows teachers to integrate these resources in a physical space as well as their practices. The TEs mentioned that not all students have access to textbooks. The ratio is 5:1, which means only one textbook is available for every 5 students. It is also becoming difficult to retain the teachers as there are more lucrative jobs on offer. The TEs also mentioned that the curriculum can be expected to change by 2025.

Some TEs statement on the experience are given in the box below:

"This has been the greatest experience I have ever had. I was thinking how mathematics could be of interest to everyone. Starting with my Maths syllabus in my country. Nowhere it has been stated to use digital tools to facilitate teaching. The challenge I see is most of the teachers are not competent in the use of computers."

"Ruchi and the team, thank you so much for creating such a wonderful opportunity for us to learn lots of new ideas and ideologies, useful in our teaching career. We will retain and make use of these lessons to learn further. We will move our learning strategies from a fixed mindset to a growth mindset hereafter, more and more."

"Interactive teaching with games are some of the important things for us."

1.2 Interactive Science Teaching

Interactive Science Teaching course was offered to the Science TEs in the Phase 1 of knowledge transfer on the TISSx platform. The objectives of the course were that the participants will be able to

- Make their views about the nature of science explicit and revise their views on the same
- Appreciate the role of history of science in teaching science
- Understand the crucial role of experimentation and reasoning in science
- Contextualise experimentation and argumentation in science pedagogy in an authentic way
- Engage with modules based on a digital interface

The course contained 5 units titled - Nature of Science, Role of Experimentation in Science, Sound, Ecosystem, and Health and Disease. All these units were focused on developing the Pedagogical Content Knowledge of participants. These units contained reading materials, videos, discussions, and practice-based reflections, and a few assignments based on practice. For the units on Sound, Ecosystem, and Health & Disease, the TEs had to go through the CLIx OER students facing modules on these topics. In each of these units TEs completed multiple choice quizzes, entered open text responses and expressed the problems or concerns they had faced. At the end of the units, they had to create a lesson plan for module based implementation with students. These assessments were peer graded. Subject-wise weekly meetings were held to introduce the TISSx modules to the TEs. These sessions were also used as an opportunity to learn about the countries' contexts.

The TEs were presented with a rationale behind using TISSx (openEdx) platform and its advantages, such as its suitability for teachers, and accessibility from desktops, laptops and smartphones. They were taken through the TISSx features and their intended use in the Interactive Science Teaching course and were guided on how to navigate through different kinds of content (text, audio, video, quiz, discussion, Wiki, progress, assignments, distribution of units, and module implementation). Every week the TEs were taken through units on Sound, Ecosystem, and Health & Disease and were also introduced to the Clix OERs which were to be explored as part of the course.

The TEs were introduced to the Community of Practice(CoP) on Telegram, the messaging application.They were encouraged to use CoP to raise concerns, ask doubts, and have discussions on the content of the course. They were also encouraged to seek out ICTs or administration related queries on the CoP.

The following sections discuss some of the key outcomes of the engagement of TEs with the science course. At several places in the course, the TEs had to respond to either multiple choice questions or provide 'free text' responses to some open-ended questions. Towards the final assessment, they had to finish three different practice-based assignments related to the implementation of modules. In the first two subsections, responses of the participants to MCQs which highlight the observed trends in their subject content knowledge and pedagogical content knowledge performances are analysed. In the third subsection, qualitative analysis of shifts in their views on the nature of science, and best practices for science pedagogy are reported. The fourth subsection contains the salient features of the three practice based assignments done by the TEs, followed by post course feedback and reflections on the process.

Knowledge

Subject Matter Knowledge

The course had exercises which were based on the three CLIx OER modules on the - Ecosystem, Health and Disease, and Sound. Multiple choice based questions in these exercises have been designed to test subject matter knowledge and PCK of participants. In this part of the report, the responses of TEs on those items which specifically tested their subject knowledge are analysed. In the next section, their responses on items testing their PCK are analysed. Out of the 10 questions on each module, the Ecosystem had 7, Health and Disease had 6, and Sound had 8 questions on subject content knowledge. The average percentage for each module on only those items that examined the topic related content knowledge are as reported.

Table 1.2.1 Scores on module-based subject matter knowledge

% Average score	Bhutan	Nigeria	Tanzania
Ecosystem	78	70	76
Health and Disease	79	69	56
Sound	79	63	63

Table 1.2.2 demonstrates the break-up of the average score of TEs on the basis of gender and country.

Table 1.2.2 Gender-wise scores on subject matter knowledge

% Average scores	Bhutan		Nigeria		Tanzania	
	Male	Female	Male	Female	Male	Female
Ecosystem	76	82	72	57	75	81
Health and Disease	79	79	73	59	52	67
Sound	78	82	59	63	60	71

Pedagogical Content Knowledge

This section analyses the data on PCK related questions in each module. There were 3 questions on PCK in the Ecosystem module, and 2 each in Health & Disease and Sound modules.

Table 1.2.3 Country wise score of TEs on PCK

Average score	Bhutan	Nigeria	Tanzania	Overall
Ecosystem	80 %	77 %	77 %	78 %
Health and Disease	82 %	83 %	84 %	83 %
Sound	36 %	36 %	38 %	37 %

Table 1.2.4 shows the break-up of the average score of TEs on the basis of gender and country.

Table 1.2.4 Gender-wise average scores on PCK

Topics	Bhutan		Nigeria		Tanzania	
	Male	Female	Male	Female	Male	Female
Ecosystem	79 %	78 %	77 %	81 %	76 %	76 %
Health and Disease	82 %	100 %	90 %	50 %	70 %	84 %
Sound	34 %	41 %	36 %	30 %	38 %	35 %

Attitudes

In this section, analysis of the TEs response to the unit 1 on nature of science and post course survey is presented.

One of the components of the TISSx course on Science is to make the TEs reflect on and express their own views and beliefs about science, its nature and the best practices for teaching the subject. Teachers are often found to know their subject well, but have not had the opportunity to reflect on the nature of science, which is shown to have implications in their teaching. The course participants were asked to respond to open-ended questions such as ‘according to you, what is science?’ or, ‘what are the main characteristics of scientific knowledge?’ and, ‘what makes the most successful science teaching?’. This exercise was done both before and after the completion of a unit on the nature of science. The explicit aim of these questions was not to evaluate the TEs' performance but to help them articulate their implicit views on these topics, and to capture their learning.

Analysing the TEs' responses to the question 'what is science?', both before and after the unit, uncovered some clear patterns. Even before they began the unit, the TEs had rich and nuanced understandings of science and what it entails and how scientific knowledge is generated. They believed it to be a systematic study of the nature/world which helps to understand and explain the world. Science is understood to be related to curiosity, exploration and inquisitiveness. Only 2 out of 38 participants referred to science as a body of knowledge before the unit; but generally it was understood as a way of inquiry and knowledge generation about the world. Interestingly, only one TE wrote that science is a way to 'interpret' the world. No other TEs used interpretation in the context of science even after finishing the lesson.

After the TEs had engaged with the unit, one of the biggest changes to occur was in the relative significance they attached to the role of experimentation, observation, hypothesis framing and testing in the production of scientific knowledge. While 11 out of 38 responses had the term 'experiment' before the unit, 20 out of 35 responses carried the term 'experiment' in some form post the unit. There was a 29% increase in the number of TEs who believed that experimentation, observations, and framing and testing of hypotheses to generate scientific knowledge are essential parts of science. The empirical character of science emerged more strongly in the responses of TEs post their engagement with the TISSx course unit on nature of science. Another trend that emerged was that the TEs began to acknowledge that the replicability or repeatability of experiments is a necessary feature of science. While hardly any response before the unit contained a mention of this aspect of science, almost 9 out of 35 TEs had remarked that science is built through repeatable experimental results, signifying an increase of 25%. Relatedly, the responses post unit completion also alluded to the tentative and dynamic nature of science, an element that was missing in the earlier responses.

A striking observation was that 2 out of 38 responses to the question 'what is science?' were about how science is also about coexistence with nature. One of the TEs wrote (before the unit completion) that science is also about "learning to live in harmony with nature and taking care and appreciation of one's interdependence with our environment (sic)." And a second participant, after completing the unit, wrote that science "is the study of nature, flora and fauna and its coexistence." It is worth noting here that both of these TEs were from Bhutan, reflecting their strong cultural associations with nature and respect for it. While neither the unit nor the entire course promoted any environmental values, these responses open up a space for such conversations to enter into science teaching and learning.

A total of 35 TEs responses were analysed to the question, 'in your view, science is best taught by which ways? What makes the most successful science teaching"? before and after the unit on nature of science. After the TEs had engaged with the unit some observations were made in terms of change in their attitudes. 14 out of 35 TEs have responded that science can be best taught through experimentation, whereas 10 out of 35 responded that science can be best taught through observations and inquiry. Two TEs responded that being curious and inquisitive is also an important part of teaching science. Only one among the 35 responded that science can be best taught using simulations. Two TEs mentioned the use of hypothesis in teaching science whereas only one among 35 mentioned that science can be best taught through question answers. Only one out of 35 emphasised the engagement, commitment and participation of students in the science teaching process. One TE among 35 mentioned the values of academic integrity, learning from case studies and the ways of analysing current problems. One more notable response among 35 was recorded which said “Showing behavioural change by understanding and describing the issues is important in science teaching”. 6 among 35 were firm about their opinion and did not show any change.

One among the 35 TEs responded that developing in-depth understanding of complex scientific principles is important whereas, another one observed that connecting theoretical knowledge with real world application makes science successful. An interesting response from one of the Bhutanese TEs was as follows: “Scientific inquiry and responsibilities of the students is to carry out the scientific inquiry systematically and to be very true with their findings and must maintain academic integrity. Their inquiry should be genuine and they must feel they will contribute to society”.

Yet another striking response offered by a TEs was: “to make connections between the concepts, apply concepts to our daily life and be able to use the concepts to explain the phenomenon or process that we observe in the environment.” 2 out of 35 TEs responded that science can be best taught by activity-based learning, whereas another one responded learning by doing well-designed and thoughtful activities or discovery learning and problem-solving are the best methods to teach science. A TE from Tanzania also mentioned that science can be best taught by learning by doing, listening, writing and thinking. Deductive reasoning and experimentation were also mentioned by one of the TEs from Tanzania. 2 out of 35 TEs wrote that the teaching of science is about experimentation and verification. Only one out of the 35 focused on the need for science projects and one out of 35 mentioned that testing the existing knowledge, inquiry and arriving at new scientific knowledge are the methods of teaching science.

Practice

The practice component of assessment included implementation of one module and application of the pedagogic content knowledge they learned during the course. It was designed to encourage participants to change or improve their teaching and reflect on their teaching. In the context of this project, the TEs were encouraged to attempt this component of assessment so that they experience the design of the module in much more detail. There were three assignments under this component:

1. Module implementation reporting : Participants were asked to upload three photographs of the module they implemented.
2. Assignment based on module implementation : Participants were asked to describe their experience of module implementation and reflect on it based on a set of questions.

3. Final assignment : Participants were asked to design a TLM based on the history of science to communicate the nature of science to students or analyse three experiments or hands-on activities from their textbook.

Highlights of the responses of each assignment are given below.

Module Implementation Reporting

The TEs were required to implement any one of the three modules in the classroom or with a group of school students or student teachers and to upload 3 photographs of implementation. Below are few of the screenshots and images from the module implementation assignment that the TEs submitted,

Figure 1.3: Students performing Phet simulation from Ecology module (Bhutan)

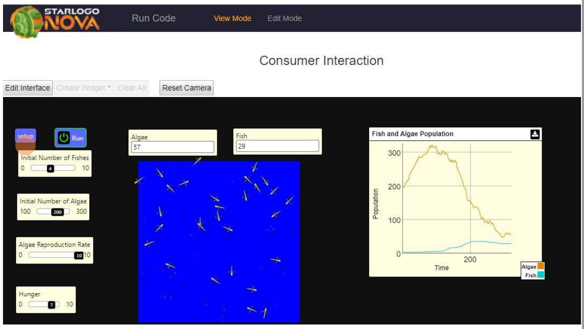


Figure 1.4: Students studying microhabitat from Ecology module (Tanzania)

Figure 1.5: Student performing hitting spoon inside the bucket activity from sound module (Bhutan)

Figure 1.6: Students measuring blood pressure (Bhutan)

TEs were required to write a reflection based on the module that they have implemented. 10 prompts were provided to write a summary of module implementation in 750 words. Among 59 participants, a total of 30 TEs responded to this assignment (Table 1.2.5). The following three questions were considered to analyse the responses.

- How did the aspects of nature of science, experimentation (or observations) and argumentation manifest in the modules? Give an example of at least one of them.

- How did students receive the module? Any specific observations on digital activities? Which parts did they enjoy the most? Which parts did they enjoy the least? Did boys and girls receive the module in the same way? Did students from any of the marginalised groups (low socio-economic background / religious or linguistic minority etc.) receive the module differently? What were the differences? What could be the possible reasons?
- How did you incorporate the three pedagogic pillars in your teaching? Give one example of each.

Table 1.2.5 Number of responses to module implementation assignment

	Sound	Ecosystem	Health and Disease
Bhutan (12)	3	5	4
Tanzania (16)	7	5	4
Nigeria (2)	0	2	0

A TE from Bhutan implemented an ecosystem module with his daughter as students were unavailable due to lockdown. Another TE from Tanzania implemented the same module for 6 hours with a group of students consisting of 3 boys and 5 girls. He responded,

"Nature of aspects of science was manifested in this implementation through the application of scientific methods in gathering the data and information, for example in studying the interaction patterns of ecosystem components. Experimentation and observations were manifested in the activities given, for example in introducing new concepts such as oxygen dissolving in water. The argumentation aspect was manifested in the module through providing facts and then giving scientific reasons to back them up, for example in the concept of human dependence on ecosystems. All learners, males and females alike, enjoyed the module and received it excitedly. They enjoyed the activities because they were hands-on and involved things in their everyday lives. There was no aspect of marginalisation due to socio-economic status, religious backgrounds or linguistic minority, because the concepts are applicable and understandable to all groups alike. All three pedagogic pillars were implemented. Collaborative learning was implemented by guiding learners to perform the activities together in groups, where they were learning from each-other. For example, the learners were given chances to mention what they observed outside the classroom in turns, while others in the group were recording what was explained. Learning by mistakes was implemented by allowing the learners to discuss the given questions in the module and get the answers by themselves before giving them the correct facts and answers. Authentic learning was implemented by linking the concepts to the environment around them and their everyday life. For example, the concept of human beings as part of the ecosystem and the ecosystem services."

To manifest the aspects of the nature of science a TE from Tanzania organised a field study where students were asked to collect and record data on the types of living and nonliving organisms found in the study area. They were further asked to explain the relationship between the living and nonliving organisms that they encountered during the field study. Thus, the students were able to visually experience and understand the concept of food chain and the food web. In argumentation, students were asked to explain why the bees were found only in some flowers. The three pedagogic pillars were incorporated by learning from mistakes, learning from real experience and collaborative learning. One particular TE carried out the same module with two boys and emphasised on experimentation and also noted that compared to boys, girls were more observant.

Final assignment

For the final assignment submissions, two options were provided as mentioned below:

Option 1: Preparing TLM based on History of Science: Under this option, the TEs were asked to take an episode from the history of science and prepare educational material for their students. The episode they would choose here should be different from the ones that are given in the course.

Option 2: A careful look at the experiments: For this, the TEs were asked to choose any chapter in their science book which has at least 3 experiments or hands-on activities and to conduct those activities in the classroom and write their experience with the help of 7 prompts in 750 words.

Table 1.2.6 Number of responses to final assignment

	Preparing TLM based on History of Science			**A careful look at the experiments**			Total
	Bhutan	Nigeria	Tanzania	Bhutan	Nigeria	Tanzania	
Physics	0	0	0	6	1	7	**14**
Chemistry	1	0	0	4	0	0	**5**
Biology	0	0	0	5	3	8	**16**
Total	**1**	**0**	**0**	**15**	**3**	**16**	**35**

The TEs worked on diverse topics and grade levels in their countries. All TEs have responded to the second option in Biology. In some cases, TEs did engage with student teachers. One of the Chemistry TEs worked on three experiments on Separation-Filtration, Distillation and Chromatography from class 10. They observed a slight difference which was that the girls did not ask as many questions as the boys. TEs reported that the students were given opportunities to observe, think, predict and improvise while working with the experiments. Only one TE in the entire cohort prepared a Teaching-Learning Material (TLM) and she had prepared it on the topic of ‘The History of Periodic Table’, suitable for teaching middle school students. The TLM was prepared with the objectives to enable students to appreciate the gradual development of the Periodic Table, together with the shortcomings and advantages of each version of the table up to Mendeleev’s. The TLM contained a number of comic strips, images and illustrations. It brought out the tentative nature of science very well , but still reflected a Eurocentric, male-centric history of science.

The topics for preparing TLMs in Physics were the measurement system, the story of lunar eclipse, the discovery of pulsars by Dame Jocelyn Bell Burnell, the story of John Dalton and the Archimedes principle. The TEs made use of images and illustrated stories to make the learning experience more impactful. The topics chosen for examining the experiments in the physics textbook were the existence of atmospheric pressure, separation of mixtures, factors affecting the induced emf, the application of Newton's laws of motion and the graphical interpretation of graphs. All Physics TEs noted that there was no perceivable difference in the way boys and girls participated. Although, one particularTE made a note that girls shied away from asking questions. All TEs noted there was opportunity for proposing hypotheses. Except in one case from Bhutan, all other TEs noted that there was no explicit information of student representation from marginalised communities. However, he also noted that there was no visible difference in the way the students from marginalised communities participated.

Reflections and feedback

At the end of the course, TEs had to submit a post course survey. The survey consisted of 11 items including 5 Likert scale questions, 3 multiple choice questions and 3 open-ended questions. The survey aimed to receive general feedback on the perceived usefulness of the course and self-report of any impact on their practice and attitudes.

30 TEs had completed the TISSx course, of which 24 had submitted the post course survey. Below are some responses as self-reported by the TEs on the usefulness of the course, the impact of the course on their practice and the attitudes towards using online platforms for professional development. All TEs reported that they found the course beneficial. 100 % (24) of the TEs reported that the course helped them in improving their knowledge in areas such as the subject matter of science, the nature of science, the importance of history of science, the role of experiments, and finally, the role of argumentation in teaching and learning science.

96 % (23) of the TEs reported that the course led to examples relevant to their practice. 83% (20) of the TEs reported that participating in this course motivated them to join more online courses, while the remaining 17% (4) TEs reported that they were not sure if the experience motivated them for more online courses. Additionally, one TE reported that the course offered some ideas on strategies for assessments.

TEs from across the countries expressed some challenges they faced in completing those assignments which required implementation of modules with some students. Due to the Covid-19 pandemic, it was difficult to find and work with students. This necessitated a change in strategy: the TEs could work with any children in their neighbourhood or implement the modules with the children in their homes. Additionally, a number of TEs had poor network connectivity due to which they struggled to finish the course on time. One of the TEs tested positive for COVID-19 and therefore could not finish the course on time. On account of these factors, the deadline for course completion was revised twice to enable all the TEs to finish the course. During the interactions, informal talks helped the participants to open up. Presentations on the culture and education (in particular teacher education)of each country triggered some fruitful discussions among the participants of different countries. The Friday Trigger Questions that were related to the course on the CoP on Telegram facilitated some discussions too. Finally, it was observed that the activity on designing an experiment to solve day-to-day life problems (for example, the cleaning of dust in homes) also generated active participation by faculty from all the countries.

Phase 2 Universal Design for Learning

Universal Design for Learning (UDL) is one of the pillars of the CL4STEM project. It refers to inclusive education, making education accessible to all no matter the context, background, and ability of the child. This framework is adopted to optimise and improve the teaching and learning process for all students. The UDL workshop was conducted for five days from 5 to 8 and also on 13 of July 2021. The facilitators for the session were Prof Sujata Bhan and Dr. Apoorva Panshikar from Shreemati Nathibai Damodar Thackersey Women's University, Mumbai, India.

The objectives of the sessions were:

1. To understand the concept of UDL
2. Apply the principles of UDL to plan instruction for an inclusive classroom
3. Understanding the guidelines for developing inclusive OERs
4. To critically evaluate the selected OERs on the principles of UDL

During the first three days, ideas of inclusion were shared through activities and lectures. On the fourth day, the participants were briefed on the presentation activity wherein teacher educators had to present their analysis of the courses on the TISSx platform, its features, and content that complied with the UDL principles. They were also asked to share suggestions as to how the platform can be made more aligned to the UDL guidelines[14]. On the fifth day, the TEs presented their analysis and the faculty from SNDT shared their feedback.

The sessions were attended by 59 Teacher educators from Bhutan (18) , Nigeria (21) and Tanzania (20). The sessions were also observed by Indian teacher educators and IT specialists and leads from the respective countries.

The workshop introduced inclusivity in the environment, both in terms of accessibility and the products that were created to make the physical space more accessible. The lecture further expanded on the environment from physical nitty gritties to inclusion with respect to cognitively and emotionally inclusive learning environments for the learners. Universal access to education was used as a reference point to initiate discussion into the classroom learning practices.

One of the sessions addressed the issues of barriers of learning in the classroom. Universal frameworks namely Universal Instructional Design (UID), Universal Design of Learning (UDL) and Universal Design of Instructions (UDI) which talk about access to learning, opportunity to learn and the process of learning were discussed. The UID and UDI model are found to be more teacher-centric whereas the UDL is a student-focused framework. It states that the rules, strategies and instructions and the focus of the framework are on the learners and the learning.

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

Table 2.1 Workshop Themes on Universal Design for Learning

Day	Themes
1	● Barriers to learning - physical (infrastructure) and social (attitudes) in schools and classrooms ● Relationship between working functions of the brain, the role of pedagogy and learners' engagement ● Horizontal structure of UDL - **access** (the foundation of learning) to more opportunities to attain the learning goal, **build**ing on the modes of expression, communication, action to help learners to **internalise**, and then further empower the learner to strategize ● History of UDL guidelines
2	● Discuss UDL guidelines for designing learning experience using Google Maps as analogy ○ start with a clear goal ○ encourage flexible means to achieve that goal ○ ensure all learners can access the materials and environment ○ making learning personally relevant ○ promote expert learning ● Apply UDL horizontal structure of access, build and internalise over the modes of engagement, representation, and action & expression. Group task to identify activities for each of the aspects.
3	● Lesson planning with UDL guidelines ● Reflect on traditional lesson plan and compare with UDL lesson plan ● Discuss difficulties teachers face - lack of material, large-sized classrooms ● Strategies to bring in change in teacher attitudes ● Framework for developing and choosing OERs for learners, focusing on certain disabilities and difficulties that learners might face ● Discuss Web Content Accessibility Guidelines ● Explore NCERT[15] rating scale to assess an OERs
4	Review courses on TISSx platform based on the UDL guidelines and NCERT check points ○ To analyse if courses on TISSx platform provide multiple means of representation, engagement, action and expression ○ Based on country contexts, discuss how these modules can be better aligned with the UDL principle
5	Presentation by mathematics and science teams of their review of courses and reflection of the process. The teams presented features used based on UDL for ○ Engagement ○ Representation ○ Action and Expression ○ Suggestions for higher alignment with UDL

Facilitators discussed neuroplasticity with teacher educators for understanding the relationship between working functions of the brain, the role of pedagogy and learners' engagement. How the issue of variability becomes overwhelming for the teacher was taken up for discussion and the framework of UDL was proposed precisely because it predicts this variability. The fundamental principle of inclusion is that the learning material, content and instruction has to be planned in a way such that there is variability in the class without

15 National Council of Educational Research and Training, India

labelling a learner as being deficit or as disabled in a certain manner. The relationship between the functioning of the brain, the role of the pedagogy, and the learners' engagement as discussed in the workshop is summarised in the table below:

Table 2.2 Summary of workshop discussions

Relationship between working functions of the brain, role of pedagogy, learners' engagement as discussed in the workshop			
Principle	Network	Learner	Instruction expectations/ prerequisites
Engagement *Why of learning*	Affective	Depends on how interest is gauged, keeping the learner motivated (intrinsically as well) & self regulated	Giving autonomy to learners, information should be relevant, supportive environment
Representation *What of learning*	Recognition	Depends on the perception of the information, should be able to recognise language, symbols, and structures	Flexible models, tactile, descriptions, spatial models, kinaesthetic experience
Action & expression *How of learning*	Strategic	How the child expresses their understanding/ knowledge - Communication, executive functions (retrieval from memory, strategizing)	Alternate means of responses

During the lesson planning using UDL, some of the important points that were reflected on as a cohort were: conviction is important to take one step at a time; teachers as a community should address the larger issues, questioning the state for their rights.

Many solutions were proposed for attitude change among teachers by the TEs, such as, the usage of organisers, internet and peer thinking strategies for managing large classrooms. In conclusion, it was found better to start with one mode at a time and then integrate more with eventual confidence and comfort around these strategies.

The feedback from Prof. Sujata Bhan urged the participants to reflect on what can be implemented rather than pondering on what difficulties that a teacher might face. Some of the possible strategies that were shared included the use of graphic organisers, simulations, Apps, videos and flipped classrooms that focus on probable instructions rather than feeling overwhelmed as a teacher with the framework. These strategies have been observed to be useful in managing the classroom and the learning as well. Many strategies like note-taking and the use of organisers were discussed by various participants as fundamentals for learning skills. It was established that traditional methods are as important as new strategies for ensuring inclusion. Some shared strategies for executive functions were cognitive behaviour modification and adopting training sequences with learners.

TEs from Bhutan and Tanzania asked the same question: '*do we need to take care of this in our normal class where we may not have special children*' as these countries have special schools and teachers trained specifically to these schools. Prof. Panshikar responded that

> "Assumption that our classroom is a diverse classroom which includes children with disabilities and if we are able to understand the needs of children with disabilities, it is going to help me reach, even a regular functioning child, far better."

Prof. Bhan brought in the context of local languages and pointed out that the case is difficult for the Nigerian population, as was acknowledged by a TE from Nigeria.

Outcomes

The pre course and post course surveys were conducted by the SNDT faculty Prof. Apoorva Panshikar and Prof. Sujata Bhan. The survey had 10 items on the knowledge regarding UDL. The key findings from the survey analysis were:

1. Training in UDL leads to significant gains in the knowledge about the concepts and application of the principles of UDL
2. Female teacher educators demonstrate significantly better gains as compared to their male counterparts
3. The difference in the gains pertaining to the knowledge about UDL varies according to years of professional experience. There exists a negative correlation between the gains and years of experience. Maximum gains were found in the participants below 9 years of experience, followed by participants with 10 to 19 years of experience, and the least gains were found in participants with more than 20 years of experience. The gains were significantly different for the least and most experienced groups of teacher educators.

The TEs reviewed the mathematics and science course on the TISSx platform and presented their review on the features, analysis based on UDL guidelines and NCERT checkpoints. They suggested changes to be made to the courses to fit their country contexts. The summary of their presentation is presented in the table below.

Table 2.3 Summary of TEs presentation

Mathematics	Science
Features	
The course provided experience of using technological tools and hands-on activities, critical thinking that emerged through engagement with activities. Self-paced, flexibility and autonomy to learners.	Simple language, contextualised content and activities, hands on and group activities, self-assessments, learner centred, use of local available material, illustrations, cartoons, audio and videos.
UDL Guidelines - Engagement	
CoP group activities, collaboration, games, activities, self-paced assessments. Opportunity to research, teach peers, resources to help subject phobia, tolerance for error	Videos, field trips (recruiting interest) experiments, collaboration, option for self-regulation

Representation	
○ Bhutan: graphics, images, different tools; audio/video ○ Tanzania: handbooks, conjecture making ○ Nigeria: examples and practical orientation of the module	Clear texts, clarity in language, short experiments, videos, simulations, puzzles, role play, games
Action and Expression	
Video/text/image-telegram, different types of questions, to construct (pen, geo, turtle logo, hands on), reflective journals	Projects, experiments, field work, interviews, option for expressive skills/fluency provided through observation activities, interviews, talking to people, writing stories and reports, drawings, designing experiments
Suggestions for UDL compliance in country contexts	
○ Course is lengthy ○ Space for mind map, organisers, drawing ○ Sign language, text to speech, subtitles in videos ○ Outdoor activities ○ Language inclusion-clearer language ○ Problem with MCQ was pointed out ○ Represent context of different countries, include more topics ○ Mobile compatibility ○ Lack of infrastructure in their countries were pointed out by Tanzania and Bhutan TEs.	○ Curriculum differentiation recommended ○ Online-offline availability of content ○ More use of ICT ○ Feedback on questions ○ Recap of previous lessons, simplification of content ○ Learning outcomes that are attainable and appropriate, and that are aligned with the learning competencies may be added to each course module as they seem to be absent

The overall feedback of the facilitators stressed on the importance of simple and clear language and contextualization, along with the necessity of ICT resources t in contemporary times. The feedback also noted that OER objectives and learning competencies should be mentioned in the SMART format.

“Do not sympathise students, instead encourage learners”- A TE from Bhutan

“Each and every aspect of learning must be designed and adjusted to suit the needs and requirements of individual learners” - A TE from Nigeria

Phase 3 Design Thinking for Education

Design thinking is both a process and a mindset. It is a creative, solution-based, and human-centred approach to solving 'wicked problems' (as conceptualised by Horst Rittlel in the 1960s) . By wicked problems, he meant problems which are ill-formulated, and in which information is confusing, and where the stakeholders and decision makers have differing opinions. The design thinking process is now used widely in education as situations with wicked problems often occur in education systems. The design thinking process starts with the people for whom it is designed and ends with new solutions that are made to suit their needs.

Design thinking for education was introduced through a three-day workshop. The purpose of this synchronous workshop was to introduce the design thinking process and explore its potential to create meaningful, and pedagogically valid teaching-learning resources and modules. The process of using design thinking was envisaged to develop a design mindset among teacher educators.

The participants had the opportunity to deepen their understanding of design thinking by enrolling for an asynchronous self-paced modular course on TISSx, and could submit the assignments and reflections on the design thinking process to earn a certificate.They were also asked to fill out a survey[16] to develop their metacognitive self-awareness about design thinking.

The 3-day workshop aimed to help participants:

- experience a session that was designed using principles of design thinking and UDL
- analyse and examine component parts of a teaching session like pedagogic pillars, interaction patterns, use of games and OERs
- explore and apply the 5 steps of design thinking to a specific teaching (pedagogic) problem

The workshop sessions were designed using the design thinking process. The sessions were piloted internally with all the CL4STEM research assistants/associates. The pilot enabled selecting activities, reorganising the schedule and especially preparing to demonstrate the hands-on activity over ZOOM. For example, as a result of the feedback from the RAs, two facilitators worked on the hands-on activity – a faculty demonstrated and facilitated the activity while an RA managed the video and technical aspects of ZOOM.

[16] This survey is taken from the research: Dosi, Clio; Rosati, Francesca & Vignoli, Matteo (2018). Measuring Design Thinking Mindset. DS 92: Proceedings of the DESIGN 2018 15th International Design Conference (p 1991-2002). https://doi.org/10.21278/idc.2018.0493
Table 31.

3.1 Inputs and Processes

Table 3.1 Design thinking workshop plan

Design thinking Workshop Plan	
DAY	EXPECTED OUTCOMES
August 10, 2021	• Participants experience a lesson plan designed (for middle school students) using the design thinking approach • Participants analyse and deconstruct the lesson plan to identify intended learning outcomes • Participants examine the versatility of OERs, games, online tools in teaching/reinforcing concepts
August 11, 2021	• Participants reflect on the pedagogic pillars that informed the lesson design • Participants can identify and can explain the 5 steps of design thinking (See Figure 3.1)
August 12, 2021	• Participants apply the design thinking process to create a solution for a specific design challenge (See Table 3.2).

Figure 3.1: An image from the presentation - showing steps of design thinking.

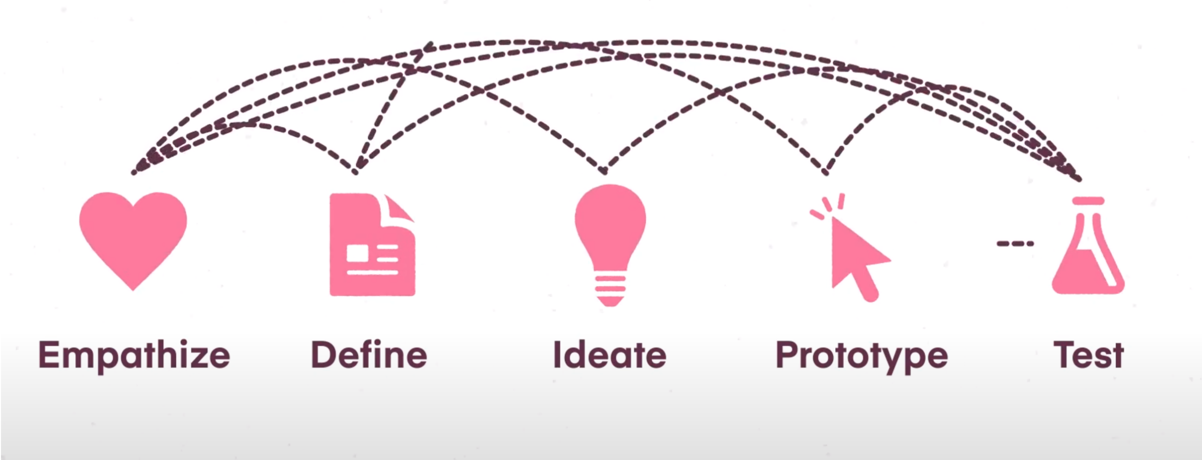


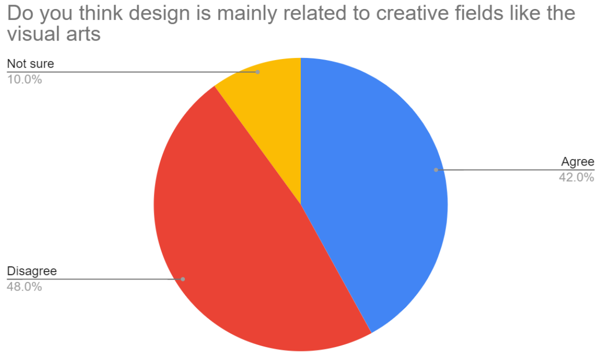
Table 3.2 Design Challenge to create a Prototype

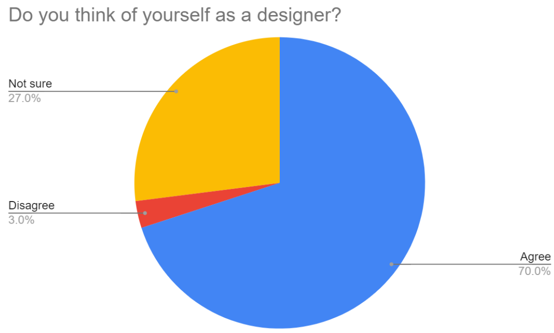
Prompt for the challenge : You have recently come in possession of an interesting collection of 50 books which are perfect for children aged 7 -15 years. The COVID-19 pandemic has made it difficult for many students to attend school in your community due to school closures. Therefore, you plan to open up a small community library in your home for children in your neighbourhood. Design a bookshelf / way of displaying the books which will arouse curiosity and interest in the children. Remember that your display should ensure: - Visibility of book covers and not just book spines - Accessibility for different age-groups - Support for books of different weights and sizes Remember, you have to use easily available, recyclable materials to create this space/display. You can use any material. Design a prototype (maybe for 6-10 books) using materials available around you. You can create a mini-version or make a rough sketch of the same.

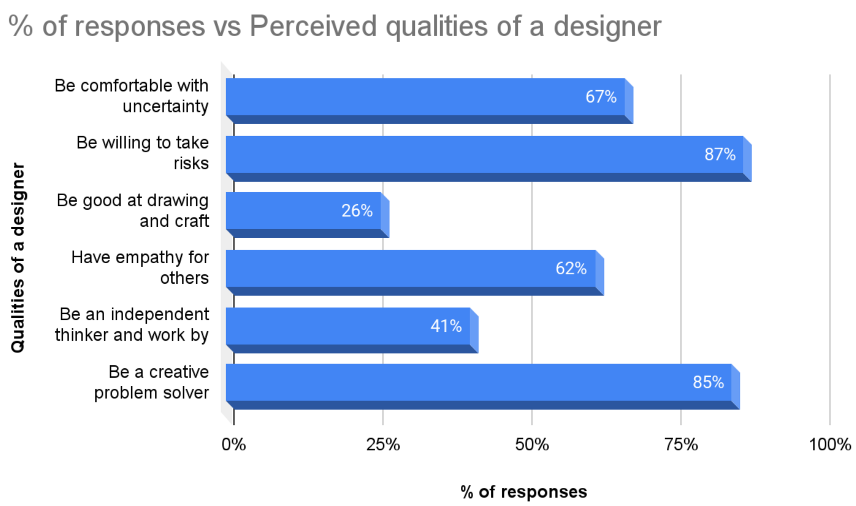
3.2 Outputs and Outcomes

Some of the responses to the activities conducted during the workshop are shown below:

Figure 3.2: Responses to poll during workshop







The TEs were taken through the importance of context in design thinking by reading an excerpt from the book *The Boy who Harnessed the Wind* written by William Kamkwamba. Figure 3.5 shows the Word cloud of the descriptive words typed in the chat box during the workshop.

Figure 3.4: Word cloud describing the young boy's scientific temper from the story

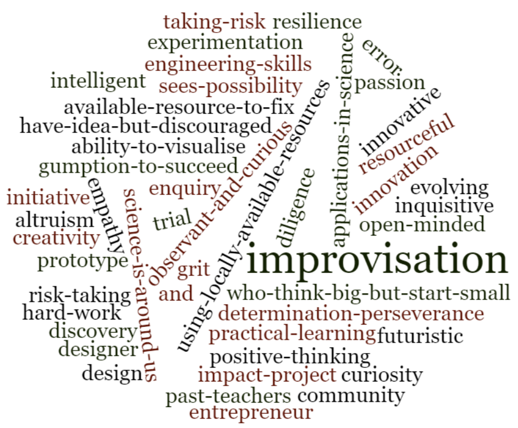
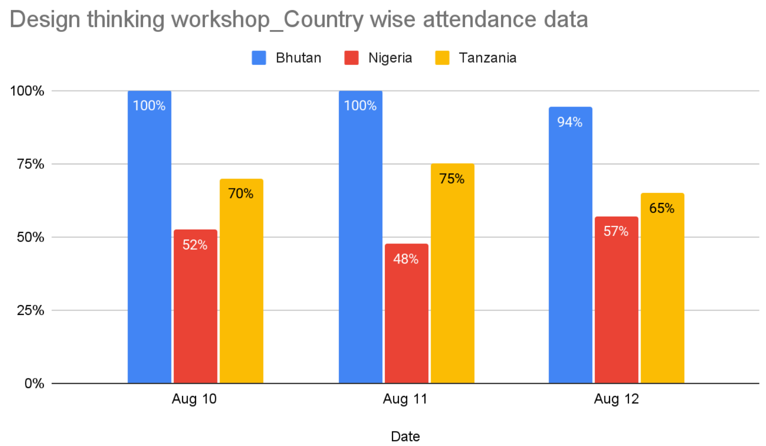


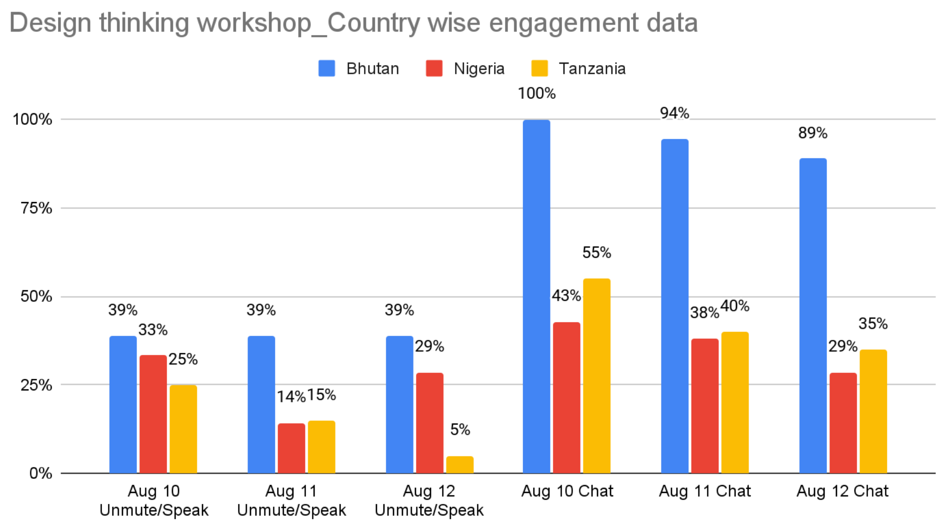
Figure 3.3: Word cloud of words given by TEs on design

Figure 3.5: Country wise attendance in the design thinking workshop



More than 90% members from the Bhutan team attended the workshop on all three days. The attendance for Tanzania was lower, with Nigeria having the lowest attendance. There were no clear trends seen in terms of an increase or decrease in attendance over time. The workshop attendance data was as follows: (See figure 3.6)

Figure 3.6 TE's workshop participation using chat and by unmuting



All the participating countries communicated mostly using the chat feature. Approximately 90% of the participants from Bhutan took part in the programme using chat. While only 55% of the TEs from Tanzania participated using chat on the first day, the percentage fell further on days 2 and 3. A similar trend was observed with the Nigerian team as well, with 43% members participating using chat on day 1, while only 38% and 29% members participating using chat on days 2 and 3 respectively. (See Fig 3.7)

Table 3.3 shows the response rate of the teacher educators for the survey on design thinking. The survey questionnaire (from Dosi, Clio; Rosati, Francesca & Vignoli, Matteo (2018) Measuring Design Thinking Mindset) was used as a self report tool on Design Thinking Mindset of the participants using 12 constructs. Each construct had self-assessing questions that test their preparedness and professional competence for design thinking. The TEs had to report on a 5 point Likert scale ranging from SA or strongly agree to SD or strongly disagree, where 'strongly agree' indicates a positive level of design thinking mindset. The table has the percentage average for each point on Likert scale for all three countries for the 12 constructs. The highlighted values (in yellow) are the average highest percentage values, under a given construct. It shows that the highest reporting lies in the range of strongly agree and agree for all the constructs in all three countries.

Table 3.3 Percentage of responses to survey on design thinking

SA - Strongly Agree | A - Agree N - Neither agree nor disagree D - Disagree | SD - Strongly Disagree all values in percentage	Nigeria (N=11)					Bhutan (N=23)					Tanzania (N=22)				
	SA	A	N	D	SD	SA	A	N	D	SD	SA	A	N	D	SD
Tolerance for - Being comfortable with Ambiguity - Uncertainty	22	33	16	11	18	9	60	18	10	3	16	56	12	8	7
Embracing Risk	5	41	18	5	32	15	59	15	11	0	16	61	9	0	14
Human centeredness	48	45	0	6	0	33	61	4	1	0	30	64	6	0	0
Empathy / Empathic	25	61	9	2	2	23	63	11	3	0	24	69	5	1	1
Mindfulness and awareness of process	33	52	12	0	3	13	72	12	3	0	26	67	6	2	0
Holistic view / consider the problem as a whole	30	67	3	0	0	16	68	13	3	0	21	71	6	2	0
Problem reframing	33	55	9	0	3	26	59	13	1	0	33	65	2	0	0
Open to different perspectives /diversity	59	32	0	0	9	43	46	11	0	0	57	43	0	0	0
Learning oriented	69	22	0	0	9	51	45	3	0	0	55	43	2	0	0
Experimentation/learn from mistake/failure	53	41	5	2	0	38	51	9	3	0	39	58	4	0	0
Creative confidence	48	45	7	0	0	10	75	11	4	0	42	58	0	0	0
Optimism to have an impact	45	55	0	0	0	42	48	10	0	0	45	52	2	2	0

Reflections

Participation of TEs: Throughout the workshop, there was increased participation from the TEs. 80% of the TEs used the chat feature at least once in the 3 days workshop and 50% of them spoke at least once during the session. One of the reasons could be that session 2 specifically focused on content based discussion. On day 1, Maths TEs raised concerns about choosing a topic from science in the session on design thinking, yet 11 out of 18 maths TEs participated in the chat discussions. The TEs also mentioned that they were introduced to some of the new features in digital medium such as freemind, PhET, poll etc. An example of chat conversation can be observed in the table

Table 3.4 Conversation among TEs from across countries

TE(Tanzania) : How do you take care of time when you have a prescribed syllabus to follow? **Facilitator**: Yes, that is a challenge but it is about finding those teachable moments despite the constraints of time and finding a balance between chalk and talk and hands-on. **TE (Nigeria)** : For large class, plan activities in group work **TE (Bhutan)** : overcoming large class challenges is to employ group work **TISS Faculty**: Active learning is not just being active physically but be active in mind together with others **TE(Tanzania)**: it is important to allow rotation of leadership of groups to speak about each activities.

Applying design thinking: As part of designing a prototype, the TEs were asked to design a prototype of a bookshelf. TEs from Nigeria and Tanzania exhibited novelty and shared interesting prototypes. Nigerian TEs suggested hanging a bucket filled with books from a tree. Fig 3.10: is one of the prototypes shared by the TEs.

However, the extent to which teacher educators were able to systematically and formally apply the design thinking process for developing the modules was limited, given the constraints of the online engagement.

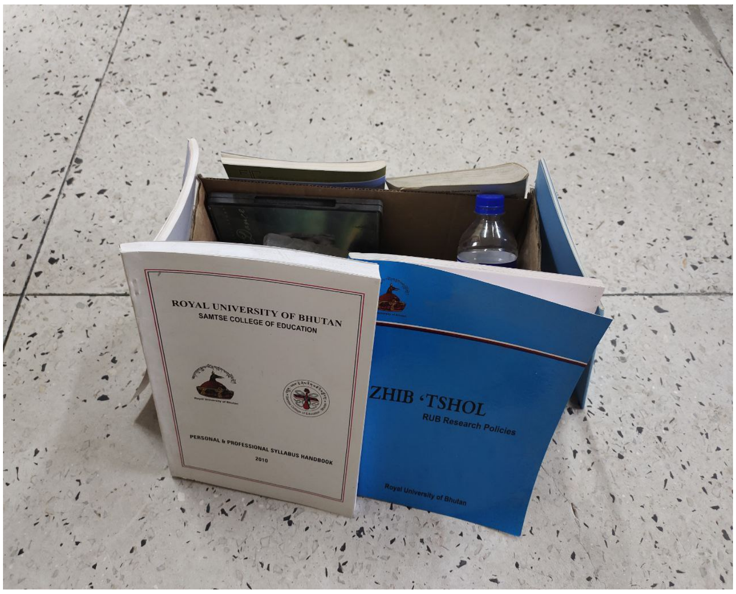


Figure 3.7 Prototype of bookshelf created during workshop

Phase 4: Module preparation by teacher educators

Phase 4 marked the beginning of the module preparation by teacher educators of the partnering countries. It started immediately after the completion of phase 3, from the mid of August, 2021 to mid-May 2022. This phase consisted of creating separate teams of TEs along with TISS members for each specific topic from science and maths. Then, the specific teams started meeting every week for ideation and the planning of module preparations for their respective topics.

The names of team members involved in the making of each of the mathematics and science modules are provided in the tables (table 4.1 & table 4.2) below:

Table 4.1 Mathematics modules team members

Topic	Country TEs			TISS
	Bhutan	Nigeria	Tanzania	
Proportions	Bijoy Subba, Ugyen Dorji	Salihu Abdulwaheed Adelabu	Faustine Nziku, Mustapha Kiswanya	Ruchi Kumar
Algebra	Purna Subba	Garba Shuaibu	Seleman Ismail, Mary C Swai, Aliyu Zakariyya	Anirudh Agarwal
Geometry	Man Singh Singer, Pema Drukpa	Ibrahim Abdullahi	Seleman Ismail, Michael Peter Kajala	Arushi Bansal*, Jeenath Rahaman

Table 4.2 Science modules team members

Topic	Domain	Country	Team Members	TISS
Electromagnetism	Physics	Bhutan	Karma Utha, Tandin Penjor, Ugyen Pem	Geetha M, Shamin Padalkar
Force and Motion		Nigeria	Haliru Ibrahim, J Yabagi, Yusuf Abdullahi, Yusuf Tanko Usman, Idris Kawo	
Work, Energy and Power		Tanzania	Paul Ikwaba, Jalal Simkoko, Yussuf Mhangwa, Salamba Kashinje	
Atomic Structure	Chemistry	Bhutan	Reeta Rai, Lhapchu Lhapchu, Nandu Giri, Kezang Choden, Sonam Rinchen	Deepika Bansal
Chemical Bonding		Nigeria	Ibrahim Aliyu Ahmed, Umar Musa Tanko	
Organic Chemistry		Tanzania	James Mutasingwa, Harrieth Hellar, Rweyendera Ngonge, Matobola Mihale,	

			Josephat Saria	
Genetics and Heredity		Bhutan	Ran Singh Tamang, Bal Bdr Mongar, Kinzang Dorji, Kinley	
Introduction to Ecology	Biology	Nigeria	Naomi John Dadi-Mamud, James Omunu, Mustapha Tajudeen, Samira Dahiru Hunkuyi, Mufida Bello Hussain	Sarika Bansode, Rafikh Shaikh
Cell Structure and Organisation		Tanzania	Agatha Mgogo, Hassan Mateka, Said Massomo, Neema Magambo	

The next section presents details about each module.

4.1 Common pedagogy module

The common pedagogy module introduces teachers to the general pedagogical principles and practices one should follow in a STEM (Science, Technology, Engineering, and Mathematics) classroom. The common module provides guidelines for teachers to plan lessons, set up activities and design instructional strategies and questions to use in a STEM classroom. This is the first module that a teacher has to complete before doing the subject specific modules, because it orients the participating teachers with the broad objectives of the CL4STEM pedagogy. The main components of the Common Pedagogy module are:

1. Introduction to the project and the guiding conceptual framework, along with the idea of community of practice
2. The main elements of the CL4STEM Pedagogical practices: Pedagogical Content Knowledge (PCK), Pedagogical Principles (from CLIx), Universal Design of Learning (UDL)
3. Significance of the context and resources, including local resources, classroom interaction, evaluation criteria, and the use of multiple representations
4. Finally, subject specific content, comprising two sections: one, about the science specific content like the nature of science and the language of science and the other, about the mathematics specific content like the processes and the need for proof in mathematics.

The "Common Pedagogy module" provides the basic foundation to teachers for the CL4STEM pedagogy and is primarily developed and compiled by the TISS members based on consultation with teams from other countries. The module also provides some broad ideas and goals of mathematics and science education.

4.2 Mathematics modules

The mathematics modules are divided into three domain areas of mathematics: algebra, geometry and proportions. An area of focus was selected from each of these domains based on mutual consideration. Given below are the areas of focus:

1. Algebra: Linear equations and inequalities
2. Geometry: Area, perimeter, and transformations
3. Proportions: Ratio, proportions and percentages

The weekly Thursday sessions of 2 hour each were planned to provide scaffolded support to the TEs in order to create modules for the NQTs. The sessions started off with a discussion on the selection of topics for the modules. The teams decided on three areas of mathematics - proportions, geometry and algebra. Under each area, one particular topic was selected which fell under the lower secondary curriculum. The teams chose fractions and percentages for proportions, linear equations for algebra and area-perimeter and transformations for geometry. Thereafter, the teams were introduced to the module template, i.e., the necessary part of the module, and the open source requirement of the resources. The teams then delved into a discussion on student thinking and misconceptions in each chosen area, and brainstormed pedagogical methods and resources to address the same. Subsequently, the TEs were tasked with module writing, and lesson plan creation with continuous support of the TISS team.

Frameworks and Templates

Multiple frameworks and templates were shared with the teacher educators in order to help them progress with the module and to ensure that important aspects of the module were not missed out and consistency was maintained across the modules. As such, the first framework shared with the TEs was the one with key characteristics of the module. A snapshot of the framework is given below

Table 4.3 Key characteristics for Maths modules

Elements	Sub-elements I	Sub-elements II	Examples of activities
Learning approach	Active and inclusive learning	1. Active learning 2. Differentiated learning-inclusive approach	Practice-based approach, self, and learners Social learning- activities to learn from each other
Knowledge theme	Knowledge deepening	1. Concepts and subconcepts 2. Real-life context 3. All types of representations 4. All identified misconceptions are dealt with	PCK, SMK, TPACK, Knowledge of Student Thinking (misconceptions)
	21st-century skills	1. Reasoning 2. Representation 3. Maths Talk (communication about Maths)	Nature of Mathematics Processes of Mathematics Growth mindset Understanding

		4. Collaboration	socio-mathematical norms
	Tinkering and Making	Hands-on activity	NA
Curriculum alignment	NA	Sequencing and mapping	NA
Grade Alignment	Grade 6-10	NA	NA
Licence	NA	1. OERs 2. CC	NA

As per the framework, the module must follow an active and inclusive learning approach, allow knowledge deepening, build 21st century skills, employ hands-on activities, be aligned with the country's curriculum and grades, and use open source resources.

Each topic specific module was divided into 4 parts:

1. Prepare
2. Present
3. Practice
4. Assess

The 'Prepare' section of the module constituted the introduction of the module, along with the pre-test for the teachers. Furthermore, it listed down the topics and learning objectives that the teachers would be expected to engage with during the module. Under the 'Present' section, the content was presented to the teachers. It consisted of a concept map of alignment between the content and the textbook topics, and an elaboration of the same with examples and case-studies. The elaboration included student misconceptions and their theoretical underpinnings, suggested pedagogical approaches, recommended activities and pedagogical pillars for teaching and learning. The 'Practice' part of the module consisted of curated lesson plans, created by the teacher educators, incorporating the activities and pedagogical pillars outlined in the previous section. These are supposed to be executed by the teachers in their classrooms. Moreover, this section expects teachers to create their own lesson plans in accordance with the template and samples provided.

The teachers were also expected to create a student assessment. In the last section 'Assess', the teachers were required to complete a post test and a reflection template which is also provided in the module. The answers to the post test and the reflection exercise help determine how much each teacher has learnt and also help ascertain the efficacy of the course. Apart from the support in the form of templates and frameworks listed above, the TEs were also provided with a module checklist, which outlined the necessary components of the module. The module checklist is shown below:

Module Description

The maths module has the following components and learning objectives:

1. Proportions - Fractions and percentages
    a. Learning Objectives
        i. Prior Knowledge of Ratios
        ii. Representation and modelling of percentages
        iii. Percentages as fractions and mixed numbers
        iv. Commercials Maths:
            1. Taxes
            2. Housing finance:
            3. Budget
2. Algebra - Linear Equations
    a. Patterns and algebraic expressions
        i. Identifying patterns using variables to describe pattern rules
        ii. Algebraic Expressions
        iii. Use symbols to form algebraic expressions
        iv. Simplifying algebraic expressions (basic four operations)
        v. Simplifying algebraic expressions (fractions, and brackets)
    b. Simple Equations
        i. Forming linear equations
        ii. Solving equations in one variable
        iii. Checking answers to equations
    c. Inequalities in one variable
        i. Concept of inequalities
        ii. Operations with inequalities
        iii. Graphical representation of inequalities
    d. Simultaneous equations
        i. Forming Equations
        ii. Solving equations in two variables
        iii. Checking answer to equations
3. Geometry - Area and perimeter
    a. Defining Units
    b. Standard and non-standard units
    c. Perimeter definition and formula
    d. Area definition and formula
    e. Transformations
    f. Variant and invariant properties
    g. Relationship between area and perimeter
    h. Special cases
    i. Contextual examples

Readings and Resources shared with TEs

The TEs were provided with various research based readings throughout the module creation phase and they were also encouraged to bring their own readings. A plethora of activities and online resources were also shared with the TEs. Each module team was guided by one member from the TISS team who provided on-ground support to the TEs in module preparation. This included helping them find resources that were relevant, interpret the said resources, facilitate weekly discussions and guide the module writing. For linear equations, papers by Andrews and Sayers (2012)[17], Bell (1995)[18] and Banerjee and Subramaniam (2004)[19] were discussed. The papers helped understand the various student misconceptions that are prevalent while learning linear equations and algebra, and helped the TEs identify similar issues in their own contexts. The TEs were then engaged in a discussion where possible activities to address these misconceptions were discussed, and some hands-on activities were provided as well. Similarly, for the geometry module, readings were provided for area and perimeter in order to understand student thinking and misconceptions better. Guven (2012)[20], Aktaş and Ünlü (2017)[21], Özerem (2012)[22] and Seago et al. (2013)[23] were discussed to help the TEs gain a better understanding of student thinking and misconceptions when it came to geometric transformations and geometry education. Under the proportion module, some of the major readings used were: Lamon (2012)[24], Van Den Heuvel-Panhuizen (2003)[25] and Rianasari et al. (2012)[26]. These readings focused on teaching fractions and percentages with proper understanding, and it helped the TEs engage with the ideas of student thinking in percentages. The readings also helped understand various pedagogical approaches that can be useful in addressing the said misconceptions.

In terms of resources, the TEs were introduced to the rich online world of resources: Nrich[27], GeoGebra[28] and PhEt[29] along with various topic specific online resources. The online interactive website, Mathigon, was used to generate ideas around activities in fractions, and was also used to generate online manipulatives for fractions and percentages. The TEs also shared some activities from their own experiences and classrooms and used a combination of these to explain necessary pedagogical pillars and create sample lesson plans for the

[17] Andrews, P., & Sayers, J. (2012). Teaching linear equations: Case studies from Finland, Flanders and Hungary. *The Journal of Mathematical Behavior*, *31*(4), 476-488.
[18] Bell, A. (1995). Purpose in school algebra. *The Journal of Mathematical Behavior*, *14*(1), 41-73.
[19]Subramaniam, K., & Banerjee, R. (2004). Teaching Arithmetic and Algebraic Expressions. *International Group for the Psychology of Mathematics Education*.
[20] Guven, B. (2012). Using dynamic geometry software to improve eight grade students' understanding of transformation geometry. Australasian Journal of Educational Technology, 28(2).
[21] Aktas, G. S., & Ünlü, M. (2017). Understanding of Eight Grade Students about Transformation Geometry: Perspectives on Students' Mistakes. Journal of Education and Training Studies, 5(5), 103-119.
[22] Özerem, A. (2012). Misconceptions in geometry and suggested solutions for seventh grade students. Procedia-Social and Behavioral Sciences, 55, 720-729.
[23]Seago, N., Jacobs, J., Driscoll, M., Matassa, M., & Callahan, M. (2013). Developing teachers' knowledge of a transformations-based approach to geometric similarity. *Mathematics Teacher Educator*, *2*(1), 74-85.
[24] Lamon, S. J. (2012). *Teaching fractions and ratios for understanding: Essential content knowledge and instructional strategies for teachers*. Routledge.
[25] Van Den Heuvel-Panhuizen, M. (2003). The didactical use of models in realistic mathematics education: An example from a longitudinal trajectory on percentage. *Educational studies in Mathematics*, *54*(1), 9-35.
[26] Rianasari, V. F., Budayasa, I. K., & Patahuddin, S. M. (2012). Supporting Students' Understanding of Percentage. *Indonesian Mathematical Society Journal on Mathematics Education*, *3*(1), 29-40.
[27] https://nrich.maths.org/
[28] https://www.geogebra.org/?lang=en
[29] https://phet.colorado.edu/

NQTs. The TEs were also encouraged to use both digital and non-digital activities and resources in the module.

Communities of practice and TE support

The module design phase was not only marked by active engagement with the TEs on a weekly basis and sharing of readings, it also comprised an active community of practice organised on Telegram. Each module team was part of a specific Telegram group, and they engaged with ideas and prompts on a regular basis. A mathematics group was also constituted for TEs from across the maths module. The TEs engaged with a prompt every Monday in an asynchronous manner, and listed down their ideas and opinions in the group. Furthermore, the group strived to engage with each other on various topics of interest and the module.

One of the ways in which engagement was driven was the Monday prompts. These prompts, communicated at the end of the day, were a way to engage the TEs between two Thursday sessions, and helped them stay in touch with the program. Moreover, specific questions were asked around the prompt, and TEs were encouraged to post their responses. During the Thursday meetings, the discussions were carried out in module groups, with each facilitator directing the group through the day's plan. This included a set of scaffolded activities, taking the TEs from narrowing down of learning objectives, to identifying student misconceptions, and curating appropriate activities. Thereafter, the TEs were supported in creating sample lesson plans using templates and multiple rounds of feedback and one-on-one discussions.

Reflections

Throughout Phase 4, weekly meetings were conducted to support the TEs in creating modules using the design principles they learned in the previous phase. The TISS team facilitated weekly sessions and their reflections were duly noted.

For the first lesson, TEs engaged with the PCK component regarding question creation and building on a concept. The 'Friday Trigger' was of a similar nature and the responses showed that PCK needs to be engaged further. A Google form was shared to curate topics of interest, and three probable topics were decided (algebra, geometry and fraction, proportion) for module creation. It was decided that the module would begin from lower secondary grades (7 and 8) because of the foundation of concepts. These topics were chosen as they form the basis for higher secondary mathematics. Given below is a snapshot of the topics of interest:

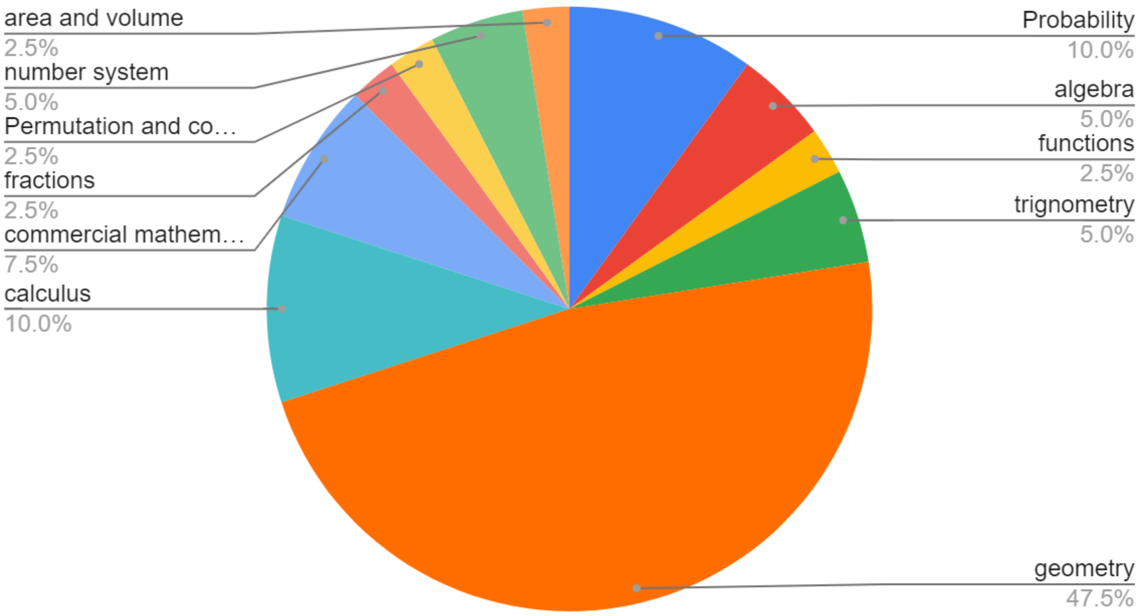


Figure 4.1 : Percentage distribution of topics of interest

Subsequently, the module template was shared along with the licensing requirements. The TEs engaged themselves in enlisting concepts and subconcepts in the breakout rooms for the topics of algebra, geometry, and fractions (topics chosen in session 1). This activity helps in concept mapping, which can later be part of the template. In the main room, participants gave feedback to each other on adding concepts and representations. Thereafter, concept mapping was discussed and participants from various countries came up with a common subtopic for geometry and the topic was discussed along the pointers of research, resources, and mapping. Survey items were discussed and it was decided that they would be taken up in the following session as well. Misconceptions on geometry, algebra, and fractions were also discussed.

Thereafter, the module creation activities began, and the TEs were expected to engage with readings and resources shared on the Telegram group. They were expected to explore the student misconceptions and the ways to address the same, either by using the resources that were shared or through the help of resources that they curated themselves. The TE engagement was difficult to maintain, and it was understood that more scaffolding was required to achieve the results. The breakout sessions were filled with pointed questions, after which the TEs took time to reflect and answer. However, it was observed that the TEs in the Algebra group were able to come up with insightful and meaningful inputs for the module, both regarding the student misconceptions as well as the possible ways to address the said misconceptions.

In some cases, it was observed that the TEs were not able to explore the resources on their own and the breakout sessions were used to discuss some of these resources. As such, a lot of the breakout rooms sessions were spent understanding the resources rather than discussing their pros and cons. However, as the module creation progressed, the TEs became increasingly aware of the resources, and were able to provide some inputs on their appropriate use. During the writing phase of the module, the TEs faced several challenges such as selecting appropriate resources and understanding the template of the module. The TISS team supported with regular inputs in the form of weekly discussions, one-on-one doubt clarification, scaffolding of module parts and continuous feedback. Overall, it was understood that some TEs were much more active than others.

4.3 Science modules

Session plans

The weekly Thursday sessions were designed to provide scaffolded support to the TEs to create modules for the NQTs. The sessions started with a discussion on identifying the criteria to select topics for module creation. The teams were asked to internally discuss aspects such as the scope of the module and the time taken to complete it, and the kind of media that would be incorporated into the modules. Once the topics for modules were identified, the teams made concept maps to design the module structures. A common template was shared with the TEs to help them in the module design process. It was pointed out that the modules should address common difficulties that students have in learning the topics and misconceptions held by them in that area. The TISS team collated a list of resources on each topic and shared it with the TEs, and they were also encouraged to read and engage with the relevant literature. For a few weeks, a part of the Thursday sessions was dedicated to discussing the resources and reading material. As and when the teams started to make progress on their module design, feedback on specific aspects of the modules was provided. It was also emphasised that the modules should have activities that promote locally available resources, given the variation in the countries' contexts. Once a draft of the modules was ready, each country presented their modules in the meetings. Feedback was provided by fellow TEs from other countries and the TISS team. The TISS team provided feedback on making the module interactive and more gender-inclusive and suggested ways in which the feedback could be incorporated. The TISS team and the TEs continued to interact on the shared google document to provide specific feedback and suggestions on content, resources, language, and scaffolding.

While the module creation was in its final stages, the TISS tech team facilitated sessions on UDL checklists, and the categories and guidelines the TEs should keep in mind while authoring the modules on Moodle. The technology teams from each country also presented their platform of choice and their preparations for authoring on Moodle. Towards the end, guidelines for piloting and timelines for piloting and authoring were discussed; the doubts and concerns of TEs were addressed in the meetings simultaneously.

Frameworks and Templates

The module creation process was centred around four key themes: contextual learning, diversity and inclusion, design thinking, and subject specific pedagogical content knowledge

(PCK), the elements of which are to be taken into account when designing the modules. The larger framework for PCK follows from Grossman (1992).

In addition to the module design template, two other templates were shared with the teams. The Lesson Plan or the Session Plan template and the Reflection template shared by the TISS team were to become a part of each module using which the NQTs would make their lesson/session plans to teach their classes, and record their reflections on the teaching process.

Strategies used for increased participation in workshops and CoPs

The module design phase was not only filled with active engagement with the TEs on a weekly basis and sharing of readings, it also comprised an active community of practice organised on Telegram. The science teams from all the countries were part of the Telegram group CL4STEM_TE_SCIENCE. The CoP was used by all the members to communicate and engage in discussions around relevant science education topics. While the TISS team used it to communicate meeting agendas, resources, readings etc. to the larger CL4STEM group from all the three countries, the TEs used it to spark discussions, raise concerns and share information and artefacts. Smaller, subject-wise (chemistry, biology, physics) groups were later created for clearer, more efficient and targeted communication with the TEs of a particular domain. The TEs from Bhutan utilised the subject specific CoP to communicate any kind of support they needed while they worked on finishing up their modules in the workshop mode in late December. The CoP was also used by the TISS team to communicate information related to the elements of the modules, and the progress of each team while designing them, in addition to sharing resources and other ideas. TEs from all the countries acknowledged and participate**GESI**d in the discussions in these subject-specific groups. Sometimes, communication with the TEs was carried out individually - via both texts and calls - if a task had to be done.

Scaffolding support/ Gender Equality and Social Inclusion issues

Different kinds of support and scaffolding were provided to the TEs to help them design their modules. In addition to topic-specific resources, samples of module-specific PCK questions to be used in pretest/post-test were also provided. The TEs were assisted in making their modules more inclusive. Three ways were suggested using which the modules could be more gender diverse. First, it was suggested that examples of women scientists (and gender-diverse scientists, if any) who contributed to the development of knowledge on any topic in or related to the module could be included. Her/Their contribution and its significance can be provided in a small box at the relevant place in the module. Second, the use of gender-inclusive language throughout the module was encouraged. For eg., in assessment questions, names of people could be made both male and female. For some questions, it was suggested that examples of non-binary individuals can be used with the use of appropriate pronouns. Third, the TISS team suggested that the illustrations should be inclusive, that men, women, and gender diverse people are to be represented in them. In case a module had only 1-2 images of individuals, they can be of women or non-binary individuals. The TEs were also asked to indicate how they included each of these suggestions and in which part of the module.

4.3.1 Physics modules

The TEs brainstormed to formulate criteria and topics for module creation. The criteria for selection of topics were as below:

1. Common to all the three countries
2. Doable
3. Aligned to curriculum
4. Challenging to teachers
5. Big ideas/ essential topics/ central topics
6. Limited resources available
7. Diversity of pedagogies, sub-domains, practical applications, grade level

Some of the potential topics identified for module creation in the initial meeting were:

1. Archimedes Principle, Law of floatation (difficult topic to teach)
2. Introduction to Particle physics (note: classification of particles, nanotechnology, and, in Bhutan, particle physics is only at the introductory level)
3. Introduction to Vectors, vector analysis
4. Force and motion - laws of motion
5. Work energy and power
6. Sustainable energy sources
7. Introduction to Astronomy - Planetary objects

Readings

Literature[30] on PCK, assessment, content and context were identified for discussion and sharing. The TEs were requested to volunteer to lead the discussion. In the first week, a TE from Bhutan summarised the paper - "Why do things move? Interdisciplinary paths to exploring motion" by Smitha B. This paper was particularly chosen to bring forth the discussion on thinking of concepts beyond the prescription in physics textbooks. The paper explores how the concept of motion can be discussed from an interdisciplinary approach. In the consecutive week, as TEs did not volunteer, RAs presented key points from two of the readings - 'Assessment of Students' Scientific and Alternative Conceptions of Energy and Momentum Using Concentration Analysis' and the concept of force. The TEs from Tanzania felt it was useful to share the reading as it had examples of questions that supported contextual understanding and application of formula. Another paper taken up for discussion was on free body diagrams. TEs from Bhutan shared experiences of using free body diagrams with their student teachers.

[30] Gale, J., Koval, J., Ryan, M., Usselman, M., & Wind, S. (2019). Implementing NGSS engineering disciplinary core ideas in middle school science classrooms: Results from the field. Journal of Pre-College Engineering Education Research (J-PEER), 9(1), 2.
Jadhao, V. G., & Parida, B. K. (2004). The Concept of Force. epiSTEME-1, 11(3), 31.
Rehn, D. A., Moore, E. B., Podolefsky, N. S., & Finkelstein, N. D. (2013). Tools for high-tech tool use: A framework and heuristics for using interactive simulations. Journal of teaching and learning with technology, 31-55.
Dega, B. G., & Govender, N. (2016). Assessment of students' scientific and alternative conceptions of energy and momentum using concentration analysis. African Journal of Research in Mathematics, Science and Technology Education, 20(3), 201-213.

Resources shared with TEs

Throughout the module creation phases, various resources for teaching, practices, reference, simulations, experiments etc. were shared pertaining to topics chosen for module creation. TEs were also invited to share resources that they have tried previously and contextual resources that they would like to discuss more The TEs were taken through the criteria and also the rubrics developed at TISS (Connect Open Online Learning - Open Educational Resources - COOL-OER[31]) for creating open resources. They were also made familiar with the exercise of checking the shared resource against these COOL criteria.

During one of the sessions, PhET simulation[32] was prompted by an RA for discussion. They discussed how the resource can be integrated and used in module creation. While discussing the checklist, TEs made an observation that the simulations themselves were not inclusive of students with visual challenges. A way around is to create a video of the simulation with voice-over, or engage buddy students to work with, or employ image description. The team from Bhutan had previously used PhET simulation, so they discussed further about developing instruction sheets for teachers to facilitate teaching using PhET simulation.

Electromagnetism : Created by the Bhutanese team

This module contains 4 units:

- Unit 1. Magnetic field around a current carrying conductor
- Unit 2. Magnetic field produced by a current carrying circular loops
- Unit 3. Electromagnetic force and application in dc motor and ac generator.
- Unit 4. Exploring the electromagnetic induction

The module covers two broad concepts of electromagnetism i.e. electricity and magnetism and the connection between the two. Literature and teacher's experience suggest that students often find it very difficult to understand the topic because of its abstract nature. Efforts have been made to add experiments such as the use of lab and simulations, application toys, discussion around observations and experimental set ups. Step-by-step instructions to set up the activity, discussion prompts, possible mis-conception among students on the concept, errors in observation/calculation have been provided in the module. Few important experiments are provided to demonstrate the relations between electricity and magnetism, magnetic field around the current, direction of magnetic force around the current carrying conductor etc. Predict Observe Explain (POE) strategy has been discussed explicitly throughout the module. Worksheets with prompts for writing using POE are provided. Problem exercises based on mathematical expressions and application based exercises are also included. Opportunities to carry out/demonstrate/test some of the experiments using both physical lab and through simulations are the strength of the module.

[31] https://clixoer.tiss.edu/cool/oer
[32] https://clixplatform.tiss.edu/phet/en/simulation/forces-and-motion-basics.html

Force and Motion: Created by the Nigerian team

This module contains 4 units

- Unit 1 : Motion
- Unit 2: Graphical Representation of motion
- Unit 3: Force and its types
- Unit 4 : Newton's laws of motion

The Nigerian team chose to work on force and motion topics. Force and motion was one of the big ideas discussed across grades in physics. The module aims to provide teachers with multiple representations to discuss the topic, provide ideas to brainstorm and also address common misconceptions/alternative conceptions on the topic. Literature suggests that students have many alternative conceptions due to day-to-day observation of mechanics in their life. So, students tend to use these rationale over Newtonian laws while discussing the topic. However, adding sufficient PCK to identify and address misconception has not been achieved in this module.

The strength of the module lies in the kinds of exercises provided with examples from day-to day-life to discuss the topics. It also offers a number of science toys that can be made out of cheap and easily available materials. These toys are suggested for discussing Newtonian laws. Multimedia resources are yet another set of useful resources used for the representation of motion, opportunities to interpret and to plot the graphs. The module covers representation of motion, types of force and its application and Newton's laws of motion in detail.

Work Energy and Power : Created by the Tanzanian team

This module also contains 4 units and each of these units are divided into lessons. It is expected that teachers can go through each lesson in an hour's time. The units and lessons under these units are as below:

- Unit 1: Energy : Forms of energy; Energy transformation
- Unit 2: Work : Mechanical work; work done by electrical energy; thermal energy
- Unit 3: Power : Mechanical power; electrical power; heat dispersion

In each of these lessons, the concept is discussed, formulae, units and dimensions are introduced along with problems to solve, and PCK aspects are discussed. The module lays emphasis on providing discussion prompts and graphic organisers for teachers to practise and reflect on their teaching strategies. Thinking and writing prompts are provided for students to add their observations, predictions and analysis. Demonstrations, activities and simulations are provided in each unit for discussion. The module explicitly discusses errors made by the students in applying the concept,or in applying the formulae in mathematical problems and also the errors made during calculations.

Reflections

The weekly Thursday calls were intended to introduce teachers to diverse resources, readings to discuss PCK, and contextualisation, along with providing them feedback on their working modules. However, after a few sessions, the TEs raised concerns about not having enough time to work on the module writing. As a result, considerable time during the weekly Thursday meetings was spent on the task of writing. Feedback on the modules were provided as comments and suggestions on the documents itself. The TEs also mentioned the lack of time to go through all the readings that were shared. This seemed to have hampered the process of understanding PCK in general and also specific to the topics. Specific resources that aided the recommended PCK were tagged in the module, however time for collective discussion on the same was not sufficient. This limitation is observed in the module as well.

The Tanzanian team worked on the shared google document, hence it was easier to provide them with continuous feedback throughout the engagement. The Nigerian team had challenges with network connectivity. There were considerable barriers in online communication with the team to finalise the module.

4.3.2 Chemistry modules

Readings

Research literature pertaining to the chosen topics and relevant to the country contexts was shared and discussed with TEs during the weekly meetings. The objective for having these reading-based discussions was to enhance the PCK of TEs in their chosen topics for module creation. The readings were aimed to help the TEs familiarise themselves with some common misconceptions held by students in the chosen topics and to learn about some effective strategies to address them, all of which would feed into designing effective modules.

Three papers were read and discussed by the chemistry team in total. Two of them were on the teaching and learning of atomic structure and one on Organic Chemistry. One of the papers, Niaz et al (2002)[33], discussed how argumentation and discussion can facilitate conceptual learning under the topic of atomic structure and provided ways of engaging students in those discussions. The other paper on the same topic showed how students should learn chemistry by moving from the macroscopic level of reality, to molecular and atomic level, and then finally to the electronic and nuclear level. The author (Nelson, 2002)[34] argues that this approach helps students appreciate chemistry as a practical subject which has wide applications. While discussing this paper, the TEs from Bhutan asked for other ways in which Atomic Structure can be taught using this approach. The TISS team discussed with them an approach mentioned in a chapter written by an Indian scholar on chemistry

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[33] Niaz, M., Aguilera, D., Maza, A., & Liendo, G. (2002). Arguments, contradictions, resistances, and conceptual change in students' understanding of atomic structure. Science education, 86(4), 505-525.
[34] Nelson, P. G. (2002). Teaching chemistry progressively: From substances, to atoms and molecules, to electrons and nuclei. Chemistry Education Research and Practice, 3(2), 215-228.

education (the book is under publication) and shared the chapter with the Bhutan team after getting permission from the author, Vijayasimha (in press)[35]. The paper on organic chemistry (Nartey & Hanson, 2021)[36] documented some perceptions of high school students and teachers in Ghana on those aspects of organic chemistry which they found difficult. It also offered some suggestions on how the teaching and learning of organic chemistry can be made more interesting.

Resources shared with TEs

Initially a list of resources was prepared which contained both open-licence and copyrighted websites/resources relevant to the topics that were chosen by the TEs for module creation. These resources included open licence textbooks, games, simulations, puzzles, concept maps, worksheets, images and videos. Later on, specific resources were shared as and when they were asked for by the TEs from the three countries. Content from various chemistry textbooks was shared which could be utilised in the modules. While the TEs had engaged with the OERs designed by the TISS team, they were also encouraged to revisit them to gather ideas on the organisation of their own modules. Materials developed by the Royal Society of Chemistry (RSC), England were shared with the TEs to learn more about common misconceptions in their chosen topics and ways to address them. In addition to the resources for the content of the module, examples of module specific pre test and post test questions were also provided.

Atomic Structure: Created by the Bhutanese team

The atomic structure module prepared by the Bhutanese chemistry team consists of the following four units:

- Unit 1- Introduction to Atom
- Unit 2 – Evolution of Atomic Models
- Unit 3 - Subatomic Particles and Isotopes (Nuclides)
- Unit 4 - Periodic Table

The module was designed to increase the pedagogical content knowledge (PCK) of newly qualified chemistry teachers by using open educational resources (OERs) on atomic structure. This module's content is expected to aid the teachers' understanding of atomic structure and its associated concepts, as well as their pedagogical knowledge of teaching atomic structure. Aside from the PCK, this module was designed by incorporating the principles of Universal Design for Learning (UDL) to make chemistry teaching and learning inclusive in order to accommodate the learning needs and abilities of all learners. At the same time, this module emphasises the use of technology in teaching, learning and assessments.

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[35] Vijayasimha, I. (In Press). An Inquiry-Based Approach to Learning Chemistry. In S. Padalkar, M. Ramchand, R. Shaikh and I. VijayaSimha (eds.), Science Education: Developing Pedagogical Content Knowledge. Routledge.

[36] Nartey, E., & Hanson, R. (2021). The differential perceptions of selected Ghanaian Senior High School (SHS) students and teachers about organic chemistry. African Journal of Chemical Education, 11(2), 110-128.

The course content for this module was created using Bhutan's Science Curriculum Framework for Key Stages III and IV. The module progresses from the historical conception of the ideas of atoms, molecules, elements, and compounds to the formulation of various atomic models, structural components of the atom, atomic number, mass number, isotopes, electronic configurations, and arrangements of elements in the periodic table. A number of research-based strategies for addressing common misconceptions among students about the above-mentioned concepts have also been presented. Finally, the module introduces teachers to lesson planning, various interactive modes of assessment, and reflection writing about the lessons taught.

Chemical Bonding: Created by the Nigerian Team

The chemical bonding module prepared by the Nigerian chemistry team consists of the following four units:

- Unit 1- Chemical bonding
- Unit 2- Ionic bonding
- Unit 3- Covalent bonding
- Unit 4- Other types of bonding

This module is designed to facilitate the learning of chemical bonding among secondary school students in Nigeria. It starts with a discussion on what chemical bonding means and provides an excursion into the history of the development of the currently accepted theory of chemical bonding. It then moves onto a discussion on why atoms bond, Lewis structures of molecules, the role of valence electrons in bonding, and concepts such as electronegativity and electron affinity. In the second unit on ionic bonding, formation of ions is discussed with the concept of oxidation state. A number of exercises have been given for the NQTs to apply the concept and also use them in their classrooms with the students. The next unit on covalent bonding discusses its formation, properties and types. The last unit focuses on hydrogen bonds, van der waals bonds, dipole-dipole forces and metallic bonds.

The strength of the module lies in the simple activities that can be done using low-cost, locally available materials in all kinds of context. These activities have been designed to model the ways in which bonding brings two chemical particles together. They also offer a way for the teachers to start a discussion on modelling and its significance in science education. The module also includes a number of exercises for NQTs to practice on.

Organic Chemistry: Created by the Tanzanian team

The organic chemistry module prepared by the Tanzanian chemistry team consists of the following three units:

- Unit 1: Introduction to Organic Chemistry
- Unit 2: Hydrocarbons
- Unit 3: Properties of Hydrocarbons

The Tanzanian team decided to work on the topic after researching about the topics which students and teachers in Tanzania found challenging . The structure of the module is closely aligned with the structure of the topic in the Tanzanian school syllabus for Form 3[37] and Form 4.The topics covered in the first unit are the meaning and importance of organic chemistry, and the origin and importance of organic compounds. The next unit discusses various aspects of hydrocarbons with dedicated lessons on the classification and nomenclature of hydrocarbons. The final unit moves onto the physical and chemical properties of hydrocarbons along with the lessons on preparation and purification of hydrocarbons. Each unit is followed by self assessment questions which are quite creative and deviate from the simple question-answer format. Some of the questions are in the form of flowcharts that need to be completed and concept maps. Some of them can be converted into hands-on activities and even be performed as simple paper-pen worksheets too. The module content is detailed and comprehensive with plenty of ideas for teachers to start classroom discussions. It also includes relevant case studies which illustrate how concepts in chemistry can be applied to and used for understanding real life phenomena.

Reflections on the process

The module creation process could have moved faster had the interactions between teams were in-person instead of online. Taking time to meet and work collaboratively on the module in the online mode was challenging for some TEs. Because of this challenge, the weekly meetings were discontinued for a while so that the TEs could utilise that time to focus on module creation. If time was not an issue, a lot more of the literature on misconceptions could have been covered within the group so that everyone could benefit further from the research insights.

4.3.3 Biology modules

Readings:

The TEs were provided with various readings and resources throughout the module creation phase. Each module team was guided by a member from the TISS team, and provided on-ground support. The TEs were provided with some readings based on PCK and common misunderstanding in biology such as, “Doing the lesson” or “doing science”: Argument in high school genetics by Jimenez-Aleixandre et al (2002)[38], Misconceptions in biology education and conceptual change strategies by Mehmet Bahar (2003)[39], and Common origins of diverse misconceptions: Cognitive principles and the development of biology thinking by John D. Coley and Kimberly D. Tanner (2012)[40]. Research papers such as these address the common misconceptions in biology, their origin and treatment. Each session discussion was facilitated by country leads followed by question-and-answer sessions. Topic-related research papers were also shared with the TEs to gain deep understanding of the content and also of the topics selected for module creation. The list of research papers also

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[37] Form 3 and Form 4 refers to Tanzania books for grade 11 and 12 respectively.

[38] Jiménez-Aleixandre, M. P., Bugallo Rodríguez, A., & Duschl, R. A. (2000). “Doing the lesson” or “doing science”: Argument in high school genetics. Science education, 84(6), 757-792.

[39] Bahar, M. (2003). Misconceptions in biology education and conceptual change strategies. Educational Sciences: Theory & Practice, 3(1), 55-64.

[40] Coley, J. D., & Tanner, K. D. (2012). Common origins of diverse misconceptions: Cognitive principles and the development of biology thinking. CBE—Life Sciences Education, 11(3), 209-215.

includes: Kooloos et. al. (2014)[41] which emphasises anatomical knowledge gained through a clay-modelling exercise compared to live and video observations; Wulandari et. al., (2020)[42] where expert views on the depth of ecological concepts at the elementary and middle school levels are presented; Khunyakari, R. (2021)[43] which explains the importance of modelling and designing a cell into a board game; Hasiloglu, M. A., & Eminoglu, S. (2017)[44] which is about identifying cell-related misconceptions among fifth graders and removing misconceptions using a microscope; Haga, S. B. (2006)[45] that included a list of teaching resources for genetics; and Reindl, K. M et al (2015)[46], focusing on virtual cell animation collection and tools for teaching molecular and cellular biology.

Resources shared with TEs

The TEs were taken through the CLIx OER to get them familiarised with the available resources. They were introduced to the nuances of copyright information and the methods to use it accordingly. Nigerian TEs were provided with all CLIX OER resources as their selected topic is identical to the CLIX OER.To familiarise themselves with genetics (in the case of Bhutan), and cell structure and organisation (in the case of Tanzania) the TEs were provided with a list of online resources, such as websites, videos, quizzes, simulations etc. Some standard reference books were also provided as additional material for the teachers. They include the Campbell book on biology, Blackwell Ecology From Individuals to Ecosystems, Gene IX by Lewin, Pierce Genetics conceptual Approach and Structure of DNA and chromosomes. Similarly some topics from NCERT (India) were also provided to be used as reference material.

Level of participation in CoPs and Strategies used for more participation in workshops and CoPs:

CL4STEM group was the main group for communication, discussion and sharing research papers, resources etc. Subject specific Telegram groups were also created to facilitate proper communication and discussion over module related topics and queries. The TEs from Nigeria faced network connectivity issues and were unable to attend weekly meetings and

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[41] Kooloos, J. G., Schepens-Franke, A. N., Bergman, E. M., Donders, R. A., & Vorstenbosch, M. A. (2014). Anatomical knowledge gain through a clay-modeling exercise compared to live and video observations. Anatomical Sciences Education, 7(6), 420-429.

[42] Wulandari, S., Rustaman, N. Y., Widodo, A., & Aryantha, I. N. P. (2021, March). Expert Views on the Depth of Ecological Concepts at the Elementary and Middle School Levels. In Proceedings of the 6th International Seminar on Science Education (ISSE 2020) (Vol. 541, pp. 655-660).

[43] Khunyakari, R. (2020, January). MODELLING IN DESIGN-AND-MAKE: SYNTHESIS OF A BIOLOGICAL CELL INTO A BOARD-GAME. In Proceedings of epiSTEME 8 conference, Homi Bhabha Centre for Science Education, Tata Institute of Fundamental Research, Mumbai.

[44] Hasiloglu, M. A., & Eminoglu, S. (2017). Identifying Cell-Related Misconceptions among Fifth Graders and Removing Misconceptions Using a Microscope. Universal Journal of Educational Research, 5(n12B), 42-50.

[45] Haga, S. B. (2006). Teaching resources for genetics. Nature Reviews Genetics, 7(3), 223-229.

[46] Reindl KM, White AR, Johnson C, Vender B, Slator BM, McClean P (2015). The Virtual Cell Animation Collection: Tools for Teaching Molecular and Cellular Biology. PLoS Biol 13(4): e1002118. doi:10.1371/journal.pbio.1002118

could not be active on Telegram groups. To mitigate these issues and to facilitate proper communication, conversation was transferred over to email.

Scaffolding support

Throughout the module creation phase, TEs were provided with different kinds of support and scaffolding. Various research articles, websites, and online resources were provided to the TEs to help them design their modules. Apart from the common Telegram groups, subject-specific groups were also created to discuss module related queries, resources etc. During the Thursday sessions, topic-specific breakouts rooms were created to give the TEs full support, help and cooperation.

Module description: Objectives, Concepts, Assessments

Introduction to genetics and heredity: Created by the Bhutanese team

Learning objectives:

- To understand the importance of genetics in biology, genetic inheritance and laws of inheritance.
- To elaborate and establish relationships between terms like chromatin, chromosome and chromatid, and gene, structure and chemical composition of DNA
- To identify relationships (similarities & differences) between gene, chromosome and DNA, and distinction between chromatin, chromosome and chromatid
- To know causes of variation and inheritance
- To know definitions of cloning, selective breeding, and genetic engineering, applications of genetic in farming
- To understand multiple means of content presentation, activity, and assessment.

The topic was divided into three units with different subtopics.

- Unit I: Basics of Genetics: (Introduction to genetics, Chromosome structure, Types of Chromosomes, Chromosome, Gene and DNA structure and chemical composition)
- Unit II: Variation and Inheritance: (Introduction to concepts of genetic inheritance & variation, Causes of variations
- Unit III: Introduction to concepts of cloning, selective breeding and genetic engineering

Cell Structure and Organisation: Created by Tanzanian team

This topic has four units with different learning objectives under each unit.

- Unit I: The cell

  Learning Objectives:

➔ Explain the meaning of the cell correctly and describe various types of cells from plants, animals and other living organisms
➔ Differentiate unicellular and multicellular organisms

- ➔ Trace the discovery of the cell and trace the historical development of the cell theory with respect to the modern cell theory.

Subtopics: Meaning of cell, Activity about the history of cell discovery, Cell theory

- Unit II: Types and characteristics of the cell

  Learning Objectives:

- ➔ Describe the differences and similarities between Prokaryotic and Eukaryotic cells .
- ➔ Explain the differences and similarities between animal and plant cells. Draw and label the basic structures of animal and plant cells. Outline the characteristics of the cell

Subtopics: Prokaryotic cells, Eukaryotic cells

- Unit III: Eukaryotic cells in Details: Animal and Plant cells

  Learning Objectives:
- ➔ Identify and name at least five organelles common to both animal and plant cells. Describe the function(s) of cell organelles
- ➔ Illustrate and differentiate the characteristics of plant and animal cells.
- ➔ Observe and identify different parts of animal and plant cells through the microscope

Subtopics: The animal cell, The function of parts of an animal cell, The plant cell, The function of organelles of a plant cell. Similarities and differences between plant and animal cells

- Unit IV: Cell differentiation

  Learning Objectives:
- ➔ Explain the concept of cell differentiation and describe the importance of cell differentiation.
- ➔ Describe the differences between cells, tissues, organs and body
- ➔ Draw and label tissue systems in monocots and dicots

Subtopics: Importance of cell differentiation, Specialised animal cells, Specialised plant cells

Ecology: Created by the Nigerian team

- Unit I: Understanding the concept of Ecology
  - Subtopics: Definition and Basic concepts: (Biosphere, Habitat, Niche, Population, Biome, Recycling, Food chain, Energy transfer, Environment, Population, Community).
- Unit II: Organisation of Ecosystems
  - Subtopics: Sampling of ecosystems: Measurement of ecological factors
  - Trophic Levels: Food chain, energy transformation
  - Nutrient cycling: Carbon, water and O2
- Unit III: Ecological interactions

  - Subtopics: Mutualism, Parasitism, Commensalism, Amensalism, Succession
  - Overcrowding: Factors that may cause overcrowding, Measures adopted by nature to avoid overcrowding, Limiting factors of an ecosystem
- Unit IV: Pollution
  - Subtopics: Definition and causes of pollution,
  - Types of pollution: Water pollution, Soil pollution, Air pollution, Preventive measures for pollution

4.4 Review Process

The review process consisted of several rounds over the span of four months from the second week of January to mid-May 2022. Once the respective teams prepared their assigned modules, the TISS team internally reviewed them based on a checklist (see table 4.4.1). The checklist consisted of different components of Knowledge, Attitude, Practice and UDL compliance and the review team analysed whether they were addressed in the module's main sections.

Table 4.4.1 Review checklist

Module sections	UDL Com-pliance	Knowledge			Attitude			Practice	
Pretest		1.1. Content Knowledge	1.2 Pedagogical Content Knowledge (PCK)	1.3 TPACK	2.1 Learners	2.2 Learning	2.3 Curriculum & resources	3.1 Inclusion & Equity	3.2 Higher Order Learning
Content									
Activities									
Lesson Plan									
Reflection on practice									
Post-test									

After the internal review and addressal of the missing components in separate modules, they were sent sequentially to the SNDT faculties (who were part of the UDL sessions in the last phase) to check for UDL compliance. Each module received independent reviews based on its content and this process was spread over the span of 11 January to 31 March 2022 .

The next round of review was done by trialling the module on 19 January 2022, during the CL4STEM research workshop. The CL4STEM Research Workshop in Arusha, Tanzania, happened face-to-face from Jan 17-21, 2022. For trialling the module, the participating teacher educators related to the specific domain, selected some activities from their respective modules, a day before some teachers visited the workshop on 19 January 2022. The visiting teachers were asked to attempt the pre/post-test and the selected activities to write their feedback on the trial sheet[47]. Roughly 1-3 trial sheets were collected per module from each subject area. The trial mainly tested for the curricular, contextual and language appropriateness, resource availability and cognitive suitability. Necessary changes were made based on the UDL and the trial feedback.

After this, teams from the participating countries began authoring different modules on their country-specific Moodle platform. At this stage, the TEs were guided to do a pilot run of all the modules with two different teachers trying out each module. TEs were provided with the piloting guidelines[48] that included two sections: one for the TEs to fill and the other for the teachers to fill in after trying the module on Moodle. The piloting feedback for each module is broadly compiled in the table below (Table 4.4.2):

Table 4.4.2 Highlights from module piloting

Module	Bhutan	Nigeria	Tanzania
Maths (Algebra)	1. All materials provided are appropriate and relevant 2. Though gender-sensitive, it must be more inclusive to students with disabilities 3. The module facilitates meaningful teaching. The resources and materials are relevant and can be used as teaching-learning materials(TLM)	1. All topics are related to the curriculum 2. Most of the examples are from real-life activities 3. Activities are time-consuming	1. Some topics are beyond the scope of the subject and the state syllabus 2. Challenges-access to technology and the internet 3. The module had enough activities to ensure engagement and learning
Maths (Geometry)	1. Accessible language 2. Examples are useful in explaining misconceptions 3. More examples are recommended with real life connections to the students.Teachers' challenges - Internet connectivity and availability of sufficient resources	1. The language and flow of the module is accessible and easy to understand 2. Some activities in the module are not attainable given materials availability and resources 3. Some concepts of the curriculum were not included in the module	1. The pre-test and the content of the module is quite accessible 2. The module did not adequately include the students with disabilities 3. There was clarity in the language of the module and there was availability of appropriate examples for understanding
Maths (Proportions)	1. Examples are relatable to daily classroom behaviour and it has addressed gender	1. The module is relevant conceptually, curriculum wise and	1. Some activities are not appropriate given the lack of technology and

[47] See Annexure I
[48] See Annexure II

	diversity in an encouraging way for the female learners 2. Meets needs of students who cannot work individually, however doesn't talk about students who are comfortable working individual 3. The module is feasible in terms of infrastructural availability	grade-wise, with appropriate examples for understandings 2. Given the issue of digital connectivity, some activities and resources must be replaced 3. The module enriches the teacher's knowledge of the subject,and how to transmit the knowledge to students	internet infrastructure 2. The content, at some places, does not map to the Tanzanian state curriculum 3. The language of the module is accessible and the flow of the module is well designed. Moreover, the examples used are clear and understandable
Physics (Electromagnetism)	1. The language used is understandable, examples used were appropriate and the experiment and questions were gender inclusive 2. Since the module includes digital tools, it is inclusive to an extent. However, it might not be inclusive for students who are visually impaired 3. Challenging to students and classrooms with lack of ICT resources	1. The language of the module is accessible and simple, with easy to do activities and a discussion on misconceptions 2. The content is good , but not self explanatory 3. Though the practicals are easy to perform, there is a lack of visual representation for better understanding	1. The flow and length of the module is appropriate and the language accessible 2. The examples were found to be complex and abstract as opposed to simple, real-life 3. The module helps the teacher develop interest and expertise in topic and its pedagogy
Physics (Force and Motion)	1. The language is simple and understandable, with real life and contextualised examples 2. The activities are designed based on taking care of the learning abilities of students 3. The activities do not provide an option to cross check answers and make corrections. Grading is missing which may lead to decreased interest in carrying out the task	1. The context of the school is well enveloped and is as per the ability of students and the resources 2. Content needs to be better adapted for children with disabilities 3. Useful in building the intended teacher practice and knowledge of the PCK	1. The flow is not abundantly clear 2. The examples are complex and abstract as opposed to simple, real-life 3. The content does not conveniently incorporate the needs of students with disabilities

Physics (Work Energy Power)	1. Simple, understandable, and contextualised 2. Few concepts have not been broken down enough for easy comprehension 3. Useful in developing teacher's interest and knowledge of the topic	1. Language is accessible and simple, with easy to do activities 2. Context of the school is well enveloped in the module 3. Implementation faces the challenge of acquiring and maintaining e-learning equipment	1. The content is accessible 2. The content does not conveniently incorporate the needs of students with disabilities 3. Challenges include access to technology and the internet
Chemistry (Atomic Structure)	1. Language used is simple and easy to comprehend 2. Need to include more everyday examples 3. Though the resources required are easily accessible, the availability of digital tools are constrained	1. Challenges may include large class size and inadequate resources 2. The activities used are interesting and provide tools for diagnosis of lapses in understanding 3. More activities and non-digital examples and resources must be included	1. The flow and length of the module is appropriate and the language accessible 2. The reflection questions and the content in the module are relevant and appropriate 3. More conceptual examples need to be added
Chemistry (Chemical Bonding)	1. Language used is simple and comprehensible 2. The activities are appropriate and materials required are obtainable from the environment 3. The procurement of equipment for digital resources and large class sizes would be a challenge	1. The language, contents and examples are good and gender sensitive. 2. Physically challenged students, especially vision impaired students are not accommodated. 3. Non-digital materials should be used as an alternative instructional materials	1. The flow and length of the module is appropriate and the language accessible 2. Some activities do not need a digital component 3. The tools and resources used in module are locally available
Chemistry (Organic Chemistry)	1. The language used is simple and common examples have been used to explain the	1. More non-digital resources must be added 2. The time duration	1. The flow and length of the module is appropriate with accessible language

	concepts 2. There are few laboratory-based activities where students can learn concepts practically. 3. The module, given the class sizes in Bhutanese classrooms, is well suited for implementation	and length of the module is appropriate 3. The module covers the curriculum, conceptual, contextual learning and the needs of the students	2. More conceptual examples are needed in the module for better understanding 3. The assessments must also include conceptual questions to gauge the conceptual understanding of the learner
Biology (Cell Structure and Organisation)	1. Simple language with several pictures to illustrate the meaning 2. Does not explicitly provide instructions and ways to include students with disabilities 3. It is useful in building teachers' knowledge and understanding of the content and PCK	1. The language is accessible with simple and easy demonstrations and to apply 2. The module is equitable for all, except for blind students 3. Resources mentioned are available, though power failures are an issue	1. The module is easy to understand and has accessible language 2. Some of the activities are not suitable for large class sizes 3. The module is not entirely contextualised to include students with disabilities
Biology (Ecology)	1. The language is simple with germane examples 2. The lesson plans do not explicit address gender diversity or inclusion of students with disabilities 3. Activities are apt for the different learning interests among the students	1. The language, and content are appropriate and in line with the curriculum 2. The examples used are student centred, and the grouping during activities is gender sensitive 3. The major challenge while implementing would be access to ICT resources	1. Accessible language and relevant content, along with useful information 2. Assessments are fair and appropriate 3. Easy to execute and suitable for all learners
Biology (Genetics)	1. Language used is simple and understandable and the examples given are relatable 2. Though there are some portions regarding gender, there isn't much about gender diversity or inclusion of students with	1. The language is simple, easy to comprehend and laconic 2. The number and quality of activities and examples were appropriate 3. The modules were simple enough to accommodate all	1. The module has accessible language, relevant content and appropriate examples 2. The module is not time-consuming and easy to complete 3. The module is

	disabilities 3. The module helps in developing pedagogical practices and develop teachers' higher order thinking.	learners	useful in developing the pedagogical processes of the teachers

Besides the reviews mentioned above, external subject-expert reviewers were invited to re-examine the modules for their content. Based on the reviewer's suggestions, minor to significant edits were done in each module. Each module's pre/post questions were revised to distribute eight content and seven PCK questions across modules. The teams, including the country partners for each module, met online to finalise these changes. Finally, they were authored on the respective country's moodle. The TISS team also reviewed the Moodle authoring and suggested changes for the final sign-off by the first week of May.

Contextualisation/ Adaptation

Country-specific contextualisation or adaptation was a part of the module preparation throughout this phase. It was made possible by the use of local names, currencies, units, situations and artefacts from country-specific local contexts. All the modules have used pictures from their country's context wherever applicable. To highlight some specific examples: the ecology module in biology has an activity where students go out on a field trip or walk to observe the local flora and fauna and use it to learn ecology. The same module has a case study from Nigeria about lead pollution and how the story unfolds (see figure 4.2). The Geometry module in maths also has the context of Manila cards (see figure 4.3) from Tanzania to introduce the concepts of area and perimeter through square units. Glossaries were also added at the end of the maths modules to define unknown words or concepts.

Figure 4.2: Contextualisation in Ecology Module

All that glitters may cause pollution; the story of Lead Poisoning in Zamfara State, Nigeria

Figure 4.3:Contextualisation in Geometry Module

Phase 5 Managing Community of Practice

The latest research on teacher professional development suggests the importance of creating social learning environments for teachers to implement and sustain curricular reforms. A mobile-based community of practice (CoP) enables development of a social learning environment. By participating in a CoP, teachers are able to share their practice, discuss issues related to practice and find solutions to local problems. A practice-based approach to professional development can facilitate meaningful discussions around the implementation of the CL4STEM modules by teachers. It helps in improving their understanding, confidence and fostering autonomy in their practice by enabling reflection on the practice in a collaborative and safe environment among subject experts and teacher educators.

The CLIx TPD experiences and findings of teachers' mobile-based online CoP which have been studied through an action research (Thirumalai, 2022) are as follows:

- Through the active management of the CoP by teacher educators , teachers were able to
    - share their pedagogical content knowledge that was situated in their local context
    - seek solutions to technical, infrastructure and pedagogical issues faced during implementation
- Teachers actively shared their experiences of implementing the CLIx modules and learning activities in their schools/classrooms, thus making their practice public and open to the entire community.
- The CoP enabled a strong connection between university teacher educators, subject experts and teachers thus enabling continuous and high quality pedagogical support for teachers.
- Overall, the CoP was seen to build teachers' confidence to implement EdTech and active learning pedagogies in their schools/classrooms, generate practical knowledge of classroom practice and pedagogical content knowledge that was contextual.

In the session, the CLIx TPD experiences of usage and learning through teacher communities of practice were shared. The session also included activities and ideas for teacher educators on how to manage a teacher CoP.

Table 5.1 Objectives of CoP sessions

#	Session	Objective
1	Introduction to CoPs & insights from CLIx CoP	Present evidence from the study of CLIx CoP, that includes objectives, management, roles and responsibilities and brief findings
2	Objectives of the CoP	Brainstorm on what the CL4STEM CoP objectives should be and who would be responsible for accomplishing them

3	Management of CoP	How to create prompts for facilitating a PCK discourse How to facilitate CL4STEM module learning & related practice
4	Technical /Backend Management	How to manage the groups – administration tasks, managing the backend data, creating polls and using some features of Telegram
5	Way forward	CoP Management Plan 1) Objectives 2) Roles & Responsibilities

Sample CLIx CoP Management Plan

Objectives

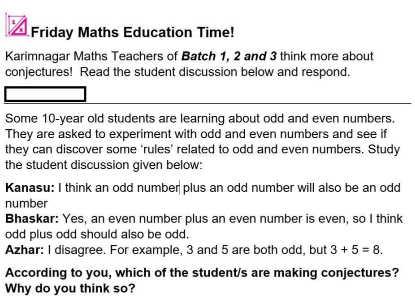
The main objectives of the online community of practice, conceptualised in the action research (Thirumalai, 2022, p 85) were:

1. To strengthen vertical linkages of professional learning and motivation through **continuous engagement** between teacher educators, subject domain experts and teachers
2. To strengthen horizontal linkages of professional learning and motivation by **promoting** professional interaction among peers
3. To strengthen motivation to **take learning into practice** and enhance practical relevance of learning and **seek support** and motivation in the process.

Roles & Responsibilities of Teacher Educator

Creating and posting prompts for facilitating PCK discourse

1. Create a repository of prompts (see example) to facilitate PCK discussions related to the module topic
2. Post prompts weekly on a selected day of the week
3. Encourage teachers to respond to the prompts and actively respond to teachers who reply to the prompts
4. Encourage teachers to connect the ideas to their classroom practice and experiences

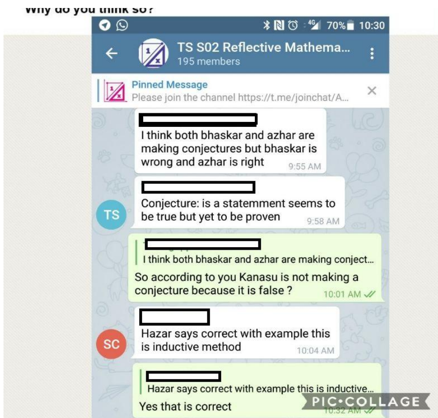

Friday Maths Education Time!

Karimnagar Maths Teachers of ***Batch 1, 2 and 3*** think more about conjectures! Read the student discussion below and respond.

Some 10-year old students are learning about odd and even numbers. They are asked to experiment with odd and even numbers and see if they can discover some 'rules' related to odd and even numbers. Study the student discussion given below:

Kanasu: I think an odd number plus an odd number will also be an odd number
Bhaskar: Yes, an even number plus an even number is even, so I think odd plus odd should also be odd.
Azhar: I disagree. For example, 3 and 5 are both odd, but 3 + 5 = 8.

According to you, which of the student/s are making conjectures? Why do you think so?



Facilitating and encouraging participation in CLIx modules

1. Encourage the teachers to implement ideas and activities learnt in the modules and session plans they created in their classroom; share photographs, reflections and student's responses and work.
2. Nurture an environment where teachers feel safe to discuss their issues, make mistakes and innovate; encourage reasoned feedback that is constructive and avoid criticism.
3. Encourage dialogue among peers by asking teachers to comment on each other's session plans and expedite the sharing of ideas.
4. Motivate teachers by highlighting and responding to good ideas or practices shared by them
5. Nudge teachers to complete their module on Moodle platform and help them share their issues related to implementation.
6. Some teachers choose to share their experiences personally with teacher educators. In such cases, reshare interesting responses back in the CoP group anonymously.

Backend Data

1. Keep a record of the number of posts made by each participant on a weekly basis to distinguish between active and passive participants.
2. Maintain a record of interesting dialogues among teachers and teacher educators for research purposes.

Annexure I

CL4STEM Modules trialling guidelines

2022

(A minimum of two teachers should trial the pre tests, post tests and activities for each module)

Module Name: ___________________________

After going through pre tests, post tests and activities in the module, please fill in your experience based on the following parameters:

a. **Pre and post test:** Number of survey items_______ Time spent:_________minutes

Pre and post test	Highly suitable	Suitable	Moderately Suitable	Slightly suitable	Not Suitable
1. Curricular relevance					
2. Contextual relevance (names/currencies/situations/examples relatable to teachers)					
3. Language					

Suggestions for improvement (mention survey item numbers):

____

____

b. **Activities on module:** Activities tried___________________________________

Time Spent:

Activities on module	Highly suitable	Suitable	Moderately Suitable	Slightly suitable	Not Suitable
1. Curricular relevance					
2. Contextual relevance					
3.Availability of resources (in your school)					

4.Suitability to cognitive ability (for school students)					
5.Language					

Which grade level do you think is this module suitable for?
Why?___________________________

____

____

Suggestions for improvement:____

____

____

c. Teachers trial of activities with school students

Grade level __________ Number of students___________Module Name: _________________

Activities tried____

Activities on module	Highly suitable	Suitable	Moderately Suitable	Slightly suitable	Not Suitable
1. Curricular relevance					
2. Contextual relevance					
3.Availability of resources (in your school)					
4.Suitability to cognitive ability (for school students)					
5.Language					

Suggestions for improvement

Any other remarks and suggestions

Annexure II
CL4STEM Piloting Guidelines

Piloting means a small scale implementation of the modules developed to be tested for its feasibility before the actual large scale implementation. For piloting, a minimum of two teachers per module is to be selected, who will be different from the actual set of teachers for CL4STEM. Since the piloting is country-specific, teacher educators (TEs) along with implementation teams from each country will take charge of identifying teachers for each module. Each country team will write a report on the pilot and share it with the subject teams. The main purpose of piloting is to test and check for the factors listed below to incorporate the required changes for successful implementation.

Section 1 (To be filled in by the teacher educator)

Please also talk to the two teachers AFTER they complete going over the module and fill this section up.

1. Whether the module is accessible to the users? If not, what specific changes need to be made?
   Accessibility to be assessed in terms of:
   a. Language of the module
   b. Examples
   c. Activities mentioned
   d. Availability of the resources
   e. Availability of digital tools
   f. Difficulty level of content
2. What challenges do teachers foresee in implementing the practice lesson plan in the classroom? What specific adaptations have to be made for implementation?
   a. Class-size
   b. Differences or diverse students needs
   c. Infrastructural requirements
3. Does the module seem relevant and adequate? If not, what specific changes need to be made?
   Relevance and adequacy in terms of:
   a. Concepts covered in the module
   b. Curriculum followed in the country
   c. The grade for which the modules are designed
   d. The context of the school in which the teachers teach
   e. Ability of the students they teach
   f. Their own competence in teaching the topic that the module covers

4. Is the time duration for the module appropriate? If not, what specific changes need to be made?
   Please note the appropriate amount of time by taking note of:
   a. How long does it take to complete the whole module?
   b. How long does it take to complete each unit in the module?

   c. How long does it take to complete the activities mentioned in each module?
5. Are teachers able to respond to the assessment questions in the module, especially pre tests and post tests? If not, what specific changes need to be made?

Section 2 (To be filled in by teachers)

TEs will distribute the *CL4STEM Modules pilot reporting* sheet below to each teacher of the pilot study. The TEs need to make sure that the teachers have access to the Moodle platform with the module, required materials and resources to do the activities given in the module. They have to ensure that the two teachers complete every single activity in the modules assigned to them. However, under difficult circumstances, TEs could allow teachers to complete just the mandatory part of the module, which are:

1. Pre test
2. Two key activities (can be picked by the TEs)
3. Lesson plan
4. Post test

CL4STEM Modules Pilot Reporting

Module Name		Date	
Teacher name		Time	
School name		Country	
Total time spent in minutes			

After going through the module, please rate your experience based on the following parameters and provide your suggestions for improvement

	Strongly Agree	Agree	Disagree	Strongly Disagree	*[49] **Reason for the rating**	Suggestions for improvement (*Specify section or activity number wherever possible)*
1. The content of the module is accessible in terms of language used						
2. The content of the module is accessible in terms of the examples given						
3. The content of the module is addressing gender diversity						
4. The module is meeting the needs of students from diverse socio-economic backgrounds						
5. The module is meeting the needs of students with different learning needs						
6. The activities in the module are attainable in terms of availability of						

[49] Very important. Please do not leave this column blank.

time						
7. The activities in the module are attainable in terms of availability of materials and resources (including digital tools, where required)						
8. The activities in the module are catering to different difficulty levels of students						
9. The module is appropriate for all students, including those with disabilities						
10. Completing the module will be feasible in terms of infrastructural availability, including access to computing devices						
11. Conducting the lessons in the module is conducive for a given class-size						
12. The module is conducive in the context of my school						
13. The module is feasible in terms of the time-duration needed to complete all the activities and assessment						
14. Completing the content of the module is easy in terms of the cognitive abilities of my students						
15. The content of the module is meeting the needs of my students						

16. The module is adequate in terms of meeting the curricular expectations						
17. The module is adequate in terms of providing conceptual clarity						
18. The module is adequate in terms of adapting to the context of the school I teach in						
19. The module is adequate in terms of meeting the diverse needs of all my students						
20. The module helps me, as a teacher, in developing Pedagogical process/ Teaching practices						
21. The module helps me, as a teacher, in developing higher order thinking/cognitive abilities						
22. The module helps me, as a teacher, in developing interest in the topic						
23. The time allotted for the whole module is reasonable for me, as a teacher, to complete going through it.						
24. The pre test/ post test provided in the module is good						
25. The activity of submitting lesson plan is useful						

26. The formative questions given in the module are relevant						
27. The reflective question items given in the module are useful						
28. The assessment system provided in the module is fair to all						
29. The module is equitable to all						
30. The module is easy to access						
31. The module is flexible to use						

32. Which class/ grade level do you think modules will be suitable?

33. Any other suggestions and comments (*Can these activities be done with all the students? If not, then what are the challenges that might be expected? What strategies can be used to complete the activities with all the students in the class?*)