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

CL4STEM Project Phase II Scaling Open Educational Modules Report
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The module implementation reports presented here are an outcome of the *Connected Learning for Teacher Capacity Building in Science, Technology, Engineering, and Mathematics (CL4STEM) project*, which aimed to enhance the capacities of secondary STEM teachers to foster higher-order thinking and promote inclusion and equity (HOTIE) in their classroom practices. The CL4STEM project is funded by the International Development Research Centre (IDRC) under the Global Partnership for Education Knowledge and Innovation Exchange (GPE-KIX). It is a South-South collaboration among higher education institutions from Tanzania, Nigeria, and Bhutan, which curated subject-specific, contextualised Open Educational Resources (OER) modules to support the professional development of teachers in enhancing their knowledge, attitudes, and practices (KAP). These OERs were created based on the Connected Learning Initiative (CLIx) model, which was implemented in India by the Tata Institute of Social Sciences (TISS).

The OER modules were hosted on the Moodle Learning Management System (LMS) and PD was supported by scaffolding their progress through the LMS and a social learning platform, Telegram chat group. Each OER module was implemented over six weeks, with teacher participants expected to dedicate approximately 5 hours per week. Since the design of the PD programme was practice-based, teacher participants were required to complete pre-tests and post-tests, design two lesson plans, implement them, conduct peer or supervisor-observed teaching sessions, and write reflections on their experiences.

This report documents the teachers' experiences and the lessons learned throughout the modules implementation. It highlights the outcomes of their engagement with the modules, including their achievements, professional growth, and the knowledge-sharing and learning dynamics within the Telegram chat group.

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Disclaimers

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Module 1: Introduction to Genetics & Heredity

1.1 Introduction

The module on Introduction to Genetics and Heredity was curated by Biology teacher educators at Samtse College of Education in collaboration with Biology curriculum developer from the Department of Curriculum and Professional Division (DCPD), Ministry of Education and Skills Development (MoESD). The course content for this module was designed using Bhutan's Science Curriculum Framework for Key Stages III and IV. This module aimed to support the professional development of participating teachers by enhancing their subject matter knowledge, pedagogical content knowledge (PCK), use of technology, and inclusive pedagogies to accommodate the learning needs and abilities of all learners. The content in the module is expected to enhance teachers' understanding of genetics and hereditary, associated concepts, as well as their pedagogical knowledge of teaching the concepts. Apart from PCK, the module is designed by incorporating the principles of Universal Design for Learning (UDL) to make Biology teaching and learning inclusive, accommodating the learning needs and abilities of diverse learners. Similarly, this module emphasises the use of technology in teaching, learning, and assessments.

a. Timeline of implementation in the country

According to the research calendar, the module was scheduled for a six-week implementation. The module was opened to the participants on March 13 and closed on April 14, 2024.

b. Learning objectives

At the end of the module, participants were expected to:

(i) explain the basic principles of genetics;
(ii) draw and describe the detailed structure of chromosome;
(iii) distinguish the types chromosome based on function and structure;
(iv) elaborate the detailed composition of chromosome;
(v) explain the causes of variation and its impact on the phenotype of an organisms;
(vi) outline the steps involved in genetic engineering;
(vii) explain the principles and the steps involved cloning; and
(viii) contextualise the application of genetic engineering to their day to day life.

c. Number of units

Three units namely basics of genetics, variation and inheritance, introduction to concepts of cloning, selective breeding and genetic engineering.

d. Concepts covered

Genetics, gene, dominant and recessive allele, sex chromosomes, autosomes, karyotype, nucleotides, bases, sister chromatid, non-sister chromatid, inheritance, variation, genetic engineering, cloning.

e. Resources - activities, readings

The activities included were MCQ, Interactive Videos, Discussion, Drag and Drop, Quiz. Wherever required and possible PDF materials were provided to enhance understanding of concepts. Further, some videos were also made available to enhance understanding of the concepts.

f. Nature and purpose of assessments

Formative and summative assessments were employed throughout the module to evaluate the participants' learning progress. The module began with a mandatory pre-test consisting of 45 multiple-choice questions (MCQs) focused on three key themes: learners, content, and teaching-learning. Participants were required to complete this pre-test within one hour before proceeding with the module. Each of the four units included various formative assessment activities such as quizzes, short answer writing, reflections, and practical activities with students. At the end of the module, participants were required to complete a similar 45-MCQ post-test, also within an hour. Additionally, participants had to submit two lesson plans on concepts related to the module's content and one reflection after implementing these lesson plans. Beyond tutor assessments, participants' lesson plans and recorded teaching sessions were evaluated by an assigned peer. Out of the 38 teachers involved, eight were selected as a focus group sample. Their lesson plans and teaching were evaluated by the tutor, officials from the Ministry of Education and Skills Development (MoESD), and their supervisors. All evaluations were conducted using a standardised rubric that emphasised learners, content, and teaching-learning effectiveness.

1.2 Course completion rate

1.2.1 Overall completion

Out of 38 teachers, all successfully completed the pre-test, reflection tasks, and post-tests, demonstrating full engagement in these key areas. However, for the session planning task, 37 teachers participated, with one teacher not completing this component.

1.2.2 Assessment completion rate

The assessment completion data indicates a high level of participation among the teachers. Out of 38 teachers, all completed the pre-test, reflection, and post-test assessments, demonstrating a 100% completion rate for these components. However, for the session planning task, 37 out of 38 teachers completed it, resulting in a slightly lower completion rate of 97.4% for this specific task (Table 1.1). Overall, the data highlights a strong commitment to the assessments, with only one teacher not completing the session plans.

Table 1.1: *Teachers' assessment completion rate*

Activities	Teachers who completed tasks	Completion Rate (%)
Pre-test	38	100%
Session plans	37	97.4%
Reflection	38	100%
Post-test	38	100%

1.3 Time spent on the course platform

Teachers were expected to spend a total of 30 hours to complete the module, with a weekly commitment of 5 hours. According to the data, one teacher did not attempt all the activities despite several reminders, while another spent less than 5 hours to complete the tasks. Among those who did complete the module, 1 teacher spent less than 5 hours, while 11 teachers committed between 5 and 10 hours. The majority of teachers (22 teachers) have completed their activities between 10 and 20 hours to completing the module. Additionally, 3 teachers spent between 21 and 30 hours on the tasks, while no teacher exceeded 30 hours (Table 1.2). This suggests that most teachers found the 10 to 20-hour range sufficient to complete the module, with a smaller number investing either significantly less or slightly more time. It should be noted that teachers invested significant time in developing lesson plans, implementing them, recording videos for peer review, and writing reflection reports—activities that were not tracked by the Learning Management System (Moodle).

Table 1.2: *Time spent by teachers on Moodle platform*

Hours spent	Teachers	Total
Less than 5	2	2
5 to 10	11	11
10 to 20	22	22
21 to 30	3	3
More than 30	0	0
Total		**38**

1.4 Change from pre- and post- test

Average total score in pre-test – 59 %
Average total score in post-test – 56%

The analysis of pre- and post-test data reveals a slight decline in teachers' proficiency levels after completing the module. While no teachers were in the **Novice** category (0-25%) during the pre-test, 2 fell into this range in the post-test. The **Emerging** category (26-50%) saw a small increase from 5 to 7 teachers, and the **Proficient** range (51-75%) dropped from 31 to 28 teachers. Additionally, the **Accomplished** category (76-100%) decreased from 2 teachers in the pre-test to none in the post-test, highlighting a reduction in higher proficiency levels.

The slight decline in overall scores may be attributed to external factors. Teachers were balancing regular teaching duties with the module, dealing with time constraints and weak internet connectivity, particularly in rural areas. Furthermore, there was no reduction in their school workload, limiting their capacity to focus on professional development. These factors suggest that the module maintained baseline proficiency but did not provide adequate support for substantial improvement or higher achievement. Addressing these contextual challenges will be essential for the success of future professional development programs.

Table 1.3: *Category of teacher participants based on pre-test and post-test data*

Proficiency Level	Score Range (%)	Pre-test (n=38)	Post-test (n=37)
Novice	0-25	-	2
Emerging	26-50	5	7
Proficient	51-75	31	28
Accomplished	76-100	2	0

Despite this overall decline, theme-based descriptive analyses of pre- and post-test scores indicated positive outcomes in some areas of the targeted competencies. These specific improvements suggest that the module was effective in enhancing certain skills, even though overall proficiency levels did not increase uniformly. The details of this theme-based analysis are presented in the subsequent paragraph.

1.5 Detailed analysis of pre-post-test data

The analysis of the pre-test and post-test data indicates that the OER module on Genetics and Heredity had a mixed impact on the targeted competencies. While the intervention was successful in some areas of the targeted competencies, its overall effectiveness varied. Notably, the module significantly enhanced participants' ability to evaluate resources for diverse content representations. This positive outcome is corroborated by other data sources such as classroom observations, lesson plans development, and reflections, which collectively indicate a beneficial effect on professional development. Analysis of pre-test and post-test data reveals notable differences in average mean scores and standard deviations, reflecting changes in understanding and proficiency. Detailed examination of the data highlights both progress and opportunities for further development in participants' skills following the intervention. Tables 1.4, 1.5, and 1.6 provide a comprehensive summary of the data analyses, including descriptive statistics, changes in mean scores, standard deviations, and effect sizes, offering a clear representation of the intervention’s impact.

In Theme K1.2, while there was a slight decrease in the ability to recognise participants' prior conceptions and misconceptions, this change points to the potential for refining instructional strategies to better address this critical skill. The increase in standard deviation suggests that some participants made strides, indicating variability that can be harnessed for targeted support.

In Theme K1.3, the data reveals a positive trend with a modest improvement in recognising areas of difficulty that participants face, reflected in the increase from a pre-test mean of 0.46 (SD = 0.40) to a post-test mean of 0.52 (SD = 0.41) (Table 1.4). This progress underscores the impact of effective strategies provided during the training, which helped participants better understand and identify student challenges.

Theme K2.1 shows a small yet meaningful improvement in understanding the nature of science, with the mean score increasing slightly from 0.75 (SD = 0.42) to 0.76 (SD = 0.42) (Table 1.4). This suggests that the intervention (e.g. workshop) was successful in enhancing participants' insights into this fundamental aspect of teaching, though the progress was modest.

Although Theme K2.2 saw a slight decrease in the ability to identify big ideas, key concepts, and theories, the overall strong baseline score suggests that participants already had a solid foundation in this area. The data provides an opportunity to explore new ways to reinforce these concepts during future training sessions. Similarly, the small decline in Theme K2.3, where participants' ability to explain the goals of teaching the subject decreased, indicates an area where more focused intervention can lead to meaningful improvements.

In Theme K2.4, while there was a slight reduction in the ability to sequence and connect concepts within subjects and across grades, this finding highlights an opportunity to strengthen participants' understanding of how to effectively organise and relate concepts across different educational levels.

The ability to evaluate resources for multiple forms of representing content (Theme K3.1) saw a minor decrease, yet this indicates the importance of continuing to explore diverse educational resources and finding ways to boost confidence and skills in this area. Similarly, in Theme K3.2, the slight decline in selecting instructional strategies to support multiple forms of participants' engagement points to the value of providing additional practical examples and strategies that can be immediately applied in the classroom.

Finally, in Theme K3.3, although there was a notable decrease in the ability to choose multiple tools of assessment to encourage multiple modes of expression, this significant change presents a clear direction for future focus. By addressing this area with targeted interventions, there is a strong potential to elevate participants' competence in utilising diverse assessment tools, ultimately enhancing the learning experience.

Overall, these findings offer a valuable roadmap for continuous improvement, with clear indicators of where further support and development can yield positive outcomes in participants' teaching practices.

Table 1.4: *Summary of Pre-test and Post-test Scores by Theme*

Theme	Measure	N	Mean	SD	Change
K1.2 Recognise Students' Prior Conceptions and Misconceptions	Pre-test	38	0.67	0.42	-0.07
	Post-test	38	0.60	0.43	
K1.3 Recognise Areas of Difficulty That Students Face	Pre-test	38	0.46	0.40	+0.06
	Post-test	38	0.52	0.41	
K2.1 Understand Nature of Science	Pre-test	38	0.75	0.42	+0.01
	Post-test	38	0.76	0.42	
K2.2 Identify 'Big' Ideas, Key Concepts, and Theories	Pre-test	38	0.80	0.28	-0.04
	Post-test	38	0.75	0.32	
K2.3 Explain Goals of Teaching the Subject	Pre-test	38	0.31	0.43	-0.03
	Post-test	38	0.27	0.41	
K2.4 Sequence and Connect Between Concepts	Pre-test	38	0.42	0.38	-0.04
	Post-test	38	0.38	0.35	
K3.1 Evaluate Resources for Multiple Forms of Content	Pre-test	38	0.59	0.41	-0.04
	Post-test	38	0.54	0.47	
K3.2 Select Instructional Strategies for Student Engagement	Pre-test	38	0.44	0.39	-0.03
	Post-test	38	0.40	0.43	
K3.3 Choose Multiple Tools of Assessment	Pre-test	38	0.86	0.30	-0.32
	Post-test	38	0.54	0.47	

Note: SD = Standard Deviation.

The descriptive statistics in Table 1.5 below offer insightful details on the participants' pre-test and post-test performance across various themes, highlighting areas of growth and valuable directions for future focus.

For Theme K1.3, which pertains to recognising areas of difficulty that students face, the data shows a positive mean change from 0.46 (SD = 0.40) in the pre-test to 0.52 (SD = 0.41) in the post-test. This improvement, along with a small increase in the standard deviation, suggests that participants made progress in identifying student challenges, with some variation in how different individuals benefited from the intervention.

In Theme K2.1, focused on understanding the nature of science, there is a slight increase in the mean score from 0.75 (SD = 0.42) to 0.76 (SD = 0.42). This positive change, accompanied by a small reduction in the standard deviation, indicates that participants not only improved their understanding but also became more consistent in their knowledge of this critical subject.

Although some themes, such as K2.2 (identifying big ideas, key concepts, and theories) and K3.1 (evaluating resources for multiple forms of content), show slight decrease in mean scores and standard deviation. These findings suggest that while there may be areas for improvement, the participants maintained a relatively consistent level of understanding, which can be further enhanced through targeted support.

The most significant area for potential growth is in Theme K3.3, which involves choosing multiple tools of assessment. The data shows a decrease in the mean score from 0.86 (SD = 0.30) to 0.54 (SD = 0.47), coupled with an increase in the standard deviation. This indicates that while some participants may have struggled with this concept, there is a clear opportunity to focus on enhancing their ability to utilise diverse assessment tools effectively.

Overall, the descriptive statistics from Table 1.5 reflect both the progress participants have made and the opportunities that exist for further development. The small changes in both mean scores and standard deviations across most themes highlight the potential for continued growth, with the data providing a valuable guide for refining future interventions to support participants in their professional journey.

Table 1.5: *Descriptive Statistics for Pre-test and Post-test Scores*

Theme	**Pre-test Mean**	**Pre-test SD**	**Post-test Mean**	**Post-test SD**	**Mean Change**	**SD Change**
K1.2 Recognise Students' Prior Conceptions and Misconceptions	0.67	0.42	0.60	0.43	-0.07	0.18
K1.3 Recognise Areas of Difficulty That Students Face	0.46	0.40	0.52	0.41	+0.06	0.08
K2.1 Understand Nature of Science	0.75	0.42	0.76	0.42	+0.01	0.12
K2.2 Identify 'Big' Ideas, Key Concepts, and Theories	0.80	0.28	0.75	0.32	-0.04	0.06
K2.3 Explain Goals of Teaching the Subject	0.31	0.43	0.27	0.41	-0.03	0.10
K2.4 Sequence and Connect Between Concepts	0.42	0.38	0.38	0.35	-0.04	0.03
K3.1 Evaluate Resources for Multiple Forms of Content	0.59	0.41	0.54	0.47	-0.04	0.05
K3.2 Select Instructional Strategies for Student Engagement	0.442	0.39	0.40	0.43	-0.03	0.03
K3.3 Choose Multiple Tools of Assessment	0.86	0.30	0.54	0.47	-0.32	0.16

Note: SD Change = Standard Deviation of Change.

The analysis presented in Table 1.6 below highlights areas of both progress and valuable opportunities for growth in participants' understanding and skills. While the effect sizes are generally small, the data reflects meaningful insights that can guide future improvements.

For instance, Theme K1.3, which focuses on recognising areas of difficulty that students face, shows a positive change, with the post-test mean increasing from 0.46 to 0.52 (Table 1.6). Although the effect size is small, this indicates that participants made progress in this area, suggesting that the intervention helped enhance their ability to identify student challenges.

Similarly, in Theme K2.1, which addresses understanding the nature of science, there is a slight increase in the mean score from 0.75 to 0.76 (Table 1.6). This small but positive shift indicates that participants gained some additional insight into this essential concept, reflecting the effectiveness of the workshop content in reinforcing their understanding.

While some themes, such as K2.2 (identifying big ideas, key concepts, and theories) and K3.1 (evaluating resources for multiple forms of content), show slight decrease in mean scores, the small effect sizes suggest that these areas remain well within reach for further improvement. The decreases offer valuable feedback on where the training can be refined to better meet participants' needs.

The most notable area for growth is in Theme K3.3, which involves choosing multiple tools of assessment. Although there was a medium effect size with a decrease in the mean score, this highlights a clear opportunity for targeted intervention. By focusing on this area in future training, participants can be better equipped to use diverse assessment tools, ultimately leading to more effective and inclusive teaching practices.

Table 1.6: *Change in Mean Scores across themes*

Theme	**Pre-test Mean**	**Post-test Mean**	**Change**	**Effect Size**
K1.2 Recognise Students' Prior Conceptions and Misconceptions	0.67	0.60	-0.07	Small
K1.3 Recognise Areas of Difficulty That Students Face	0.46	0.52	+0.06	Small
K2.1 Understand Nature of Science	0.75	0.76	+0.01	Small
K2.2 Identify 'Big' Ideas, Key Concepts, and Theories	0.80	0.75	-0.04	Small
K2.3 Explain Goals of Teaching the Subject	0.31	0.27	-0.03	Small
K2.4 Sequence and Connect Between Concepts	0.42	0.38	-0.04	Small
K3.1 Evaluate Resources for Multiple Forms of Content	0.59	0.54	-0.04	Small
K3.2 Select Instructional Strategies for Student Engagement	0.44	0.40	-0.03	Small
K3.3 Choose Multiple Tools of Assessment	0.86	0.54	-0.32	Medium

Note: Effect Size is categorized based on Cohen's d

Overall, the analysis from Table 1.7 provides a constructive framework for ongoing development. The small changes in mean scores across most themes indicate that participants are building on their existing knowledge and skills, and with continued support, they have the potential to make even more significant strides in their professional growth.

Summary

The trend across themes in the analysis of pre-test and post-test data for the Genetics and Heredity OER module highlights both progress and opportunities for further growth. Significant improvements were achieved in Theme K1.3 (recognising student difficulties) and Theme K2.1 (understanding the nature of science). While Themes K2.2 (identifying key concepts) and K2.3 (explaining teaching goals) showed slight declines, these areas present valuable opportunities for targeted refinement. Minor decreases in Themes K3.1 and K3.2 suggest areas where additional support can further enhance skills in evaluating and selecting instructional resources. The most notable area for future focus is Theme K3.3, where there is a clear opportunity to strengthen participants' use of diverse assessment tools. Overall, the findings reflect meaningful progress and indicate areas where continued development can further enrich participants' teaching practices.

1.6 Practice (Session plans and reflections)

The data, derived from the assessment of teacher participants' lesson plans and reflections, provides valuable insights into their instructional practices across three categories: Learners, Content, and Teaching and Learning.

In the **Learners** category, teachers are actively addressing students' prior conceptions (Mean = 1.19, SD = 0.46) and misconceptions (Mean = 1.19, SD = 0.46), which is critical for enhancing understanding, though promoting inclusion and equity (Mean = 0.00, SD = 0.00) shows room for improvement (Table 1.7). In the **Content** category (see Table 1.7), teachers are effectively facilitating higher-order thinking (Mean = 1.24, SD = 0.66) and using processes in science and mathematics (Mean = 0.94, SD = 0.62). However, there is moderate engagement in planning to build students' competencies (Mean = 0.84, SD = 0.50). In the **Teaching and Learning** category, teachers excel in using multiple representations of content (Mean = 1.54, SD = 0.51) and instructional strategies for active learning (Mean = 1.46, SD = 0.56), indicating strong efforts to engage students (Table 1.7). Opportunities for improvement lie in using locally available materials (Mean = 0.82, SD = 0.77) and linking conceptual content to students' everyday life experiences (Mean = 0.88, SD = 0.55).

Overall, the findings reflect a thoughtful approach to teaching, with clear strengths in fostering active learning and engagement, while also highlighting areas where teachers can enhance their practices further.

Table 1.7: *Mean and SD of Key Themes Related to Learners, Content, and Teaching and Learning Practices*

Category	Theme	Mean	SD
a. Learners	P1.1 Promote inclusion and equity	0.00	0.00
	P1.2 Build on students’ prior conceptions	1.19	0.46
	P 1.3 Address misconceptions and areas of difficulties	1.19	0.46
b. Content	P2.1 Use processes on science and mathematics	0.94	0.62
	P2.2 Facilitate higher order thinking	1.24	0.66
	P2.3 Plan to build students’ competences to meet the goals of teaching science/ mathematics	0.84	0.50
	P3.1 Use instructional strategies for active learning	1.46	0.56
	P3.2 Use multiple representations of content	1.54	0.51

c. Teaching and Learning	P3.3 Create opportunities for multiple modes of expression	1.38	0.49
	P3.4 Use locally available materials	0.82	0.77
	P3.5 Link conceptual content to students' everyday life experiences and prior knowledge	0.88	0.55

SD: Standard Deviation

In section 5a, 5b and 5c describe the patterns emerging from the major themes and give at least 2 examples/ evidence/ direct quotes per category.

a. Learners

In promoting inclusion and equity within the classroom, the participants' lessons demonstrated a strong commitment to creating engaging opportunities for all students. These opportunities were facilitated through a variety of interactive activities and collaborative group work, ensuring that every student had the chance to actively participate. Several lessons began by asking questions designed to connect with students' existing knowledge and experiences, thereby tapping into their prior conceptions. This approach not only helped in engaging students from the start but also made the learning process more relevant to their everyday lives. Moreover, some lessons effectively addressed common misconceptions by actively exploring students' preconceptions. This was achieved through the use of multimedia resources, such as videos, and real-life examples that provided concrete contexts for understanding abstract concepts. These strategies helped clarify misunderstandings and reinforced accurate knowledge, further supporting an inclusive and equitable learning environment.

Participant 5000 "I tried to encourage the slower groups to do their work faster by asking all the groups to announce "Bingo," as they completed their work".
Participant 5004 "Creating a safe and inclusive space was beneficial. By recognizing signs of anxiety or low participation, I provided support through encouragement, reassurance, and positive reinforcement. This not only boosted confidence but also reduced learner stress through flexible learning options and accommodations".

Participant 5006 "To address any potential emotional stress and ensure a supportive learning environment, I provided ample time for the students to finish their assigned tasks. This approach helped maintain a relaxed and productive atmosphere throughout the lesson".
Participant 5014 "Provided help in the form of scaffolding, reinforcement and clarification. Instructed well to not stress out a lot before the onset of the activity".
Participant 5022 "Some children are very introverted and never open up when asked questions. Although I tried my best to include them, it was difficult. Those children who are less exposed to the outside world are supposed to be introvert".

Participant 5033 "Students were not placed like in a typical classroom setting. The activities were all individual though a discussion or two were taking place informally.
-student providing wrong answers were quite anxious, however, they were not directly pointed out as wrong but rather later explanation was provided".

b. Content

Several participants' lessons effectively promoted higher-order thinking by incorporating critical and thought-provoking questions throughout the instruction. These questions encouraged students to go beyond mere memorisation and engage in deeper analysis, synthesis, and evaluation of the material. By challenging students to think critically, the lessons fostered an environment where learners could explore complex ideas, consider diverse perspectives, and develop well-reasoned arguments.

In addition to open-ended questions, participants also utilised multiple-choice questions to assess students' understanding and promote active engagement with the content. These questions were strategically integrated into activities and discussions, providing opportunities for students to apply their knowledge, analyse different options, and justify their choices. This combination of questioning techniques helped to create a dynamic learning environment where students could develop critical thinking skills and deepen their comprehension of the subject matter.

Participant 5006 “I made sure to cover all essential lesson components, including recapitulation, introduction, development, and closure, by integrating the design thinking approach. This approach not only structured the lesson effectively but also encouraged creativity and critical thinking among the learners”.

Participant 5005 “during a debate on why siblings can look different, students applied their knowledge to argue based on evidence and reasoning. These activities promoted critical thinking and reinforced scientific inquiry, illustrating core scientific practices in a practical and engaging manner”.

Participant 5022 “Students were asked to spell the answers after the activity. Provided feedback”.
Participant 5030 “I did pre-test and post-test using google form. Compared to the pre-test many misconceptions were done away with. Basic questioning at the end session also revealed that they understood the relationship between three genetic entities”.

Participant 5030 “different students had different answers regarding the location of chromosomes, DNA and genes. Students did not really know their relationship until after their group work”.

c. Teaching and Learning

Through various modes of expression, including the use of technology, worksheets, textbooks, and visual aids like pictures. By integrating these different resources, the lessons catered to various learning styles, allowing students to engage with the content in a manner that best suited their preferences and needs. For instance, technology was often employed to create interactive and multimedia-rich experiences, while worksheets and textbooks provided structured, text-based learning opportunities. Visual aids, such as pictures, further supported learning by offering visual representations of key concepts.
In addition to these resources, some teachers creatively incorporated locally available materials to construct models, making abstract concepts more tangible and easier to grasp. This hands-on approach not only made the lessons more engaging but also encouraged students to use their imagination and creativity.

Participant 5000 “Children were allowed to use phones in the group at the beginning of the lesson to guess the structure of chromosomes. Children used the app Mentimeter to answer the MCQ. Online video was used to supplement the lesson and also use multiple media to impart information to the children. Flashcards were used to show answers so that children could not only hear the answers but also see them and could easily carry out assessments of group work. A worksheet (to label the different parts of a chromosome) was used after the topic on the structure of chromosomes to help children assess their learning by recalling what they have learned in class”.

Participant 5005 “I utilised a variety of resources, including modelling clay in different colours, chart papers, markers, Xerox paper, a projector, a laptop, a whiteboard, and board markers. These resources effectively met the needs of the learners as intended”.
Participant 5006 “Throughout the lesson, I utilized a range of teaching aids including a whiteboard, markers, paper, projector, PowerPoint presentation, a video clip, laptop, and a speaker. These resources helped to enhance student engagement and understanding of complex concepts in genetic engineering and recombinant DNA technology”.
Participant 5014 “This integration of visualization through videos and hands-on activity facilitated a comprehensive exploration of the intricate relationship among chromosomes, DNA and genes”.

Participant 5033 “Nearpod was used for the class. The class was engaging as most of the lesson was student-based activity. Because of nearpod all the students' responses were available and therefore it was easier to understand where students' understanding on the topic lies”**.**

1.7 Social learning in CoPs

1.7.1 Frequency of posts by participants

Table 1.8: *Frequency of posts by participants*

Role	Number of posts
Teacher participants	401
Teacher Educators	97
Total	**498**

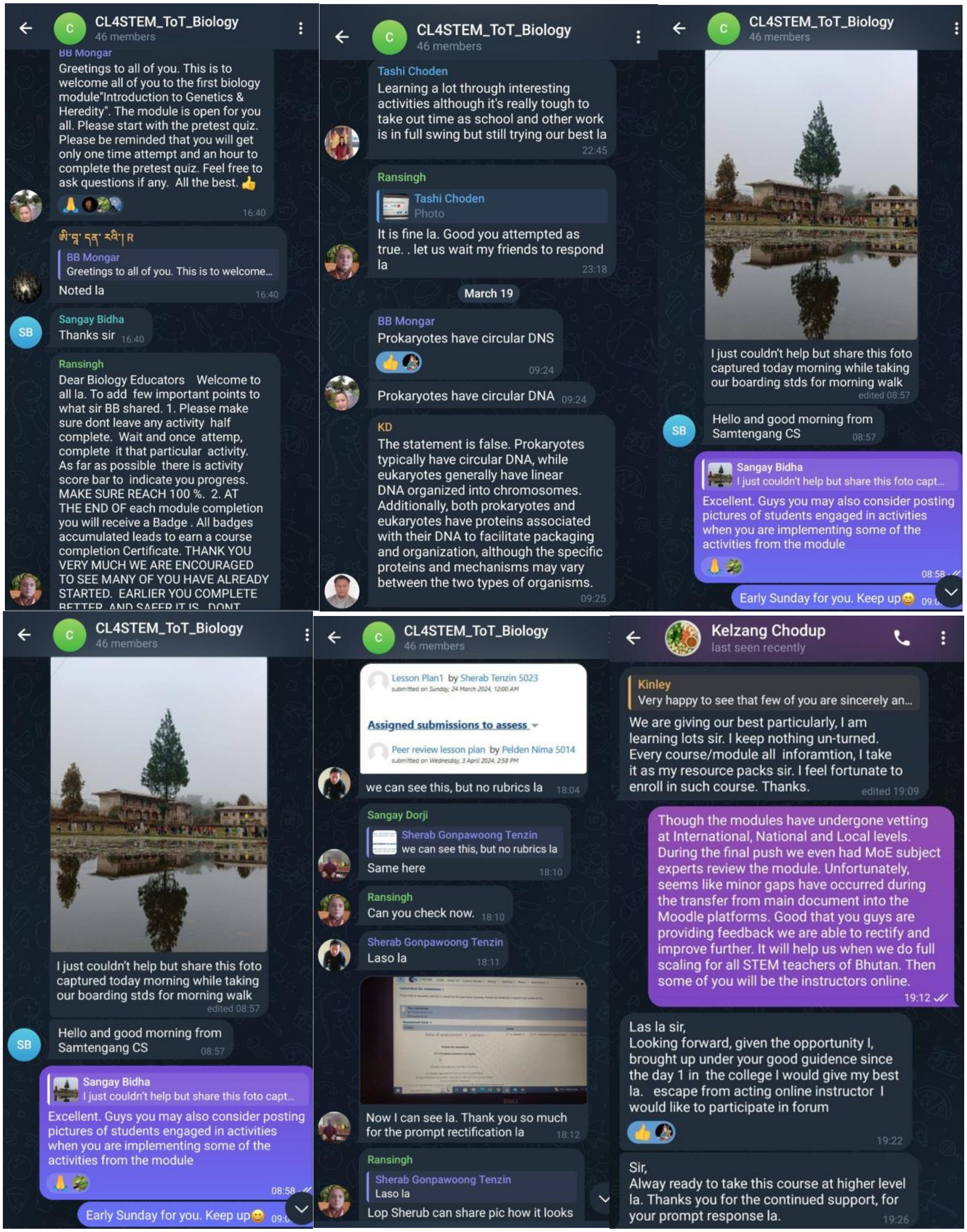
1.7.2 Frequency of posts by contents and types

Table1.9: *Frequency of posts by contents and types*

Frequency of posts by content	Number of posts
PCK	15
UDL	10
Technical	101
Communication/ Administrative	372
Total	**498**
Frequency of posts by type	**Number of posts**
Text only	450
Images	45
External Links to other resources	1
Others (voice)	2
Total	**498**

1.7.3 Qualitative dialogues/ discussion threads

The engagement in CoP has been very vibrant. The interaction has been active both ways. The following are some of the selected screenshots of the CoP conversations:


CL4STEM_ToT_Biology
46 members
BB Mongar
Greetings to all of you. This is to welcome all of you to the first biology module"Introduction to Genetics & Heredity". The module is open for you all. Please start with the pretest quiz. Please be reminded that you will get only one time attempt and an hour to complete the pretest quiz. Feel free to ask questions if any. All the best.
16:40
BB Mongar
Greetings to all of you. This is to welcome...
Noted la
16:40
Sangay Bidha
Thanks sir
16:40
Ransingh
Dear Biology Educators Welcome to all la. To add few important points to what sir BB shared. 1. Please make sure dont leave any activity half complete. Wait and once attemp, complete it that particular activity. As far as possible there is activity score bar to indicate you progress. MAKE SURE REACH 100 %. 2. AT THE END OF each module completion you will receive a Badge . All badges accumulated leads to earn a course completion Certificate. THANK YOU VERY MUCH WE ARE ENCOURAGED TO SEE MANY OF YOU HAVE ALREADY STARTED. EARLIER YOU COMPLETE
CL4STEM_ToT_Biology
46 members
Tashi Choden
Learning a lot through interesting activities although it's really tough to take out time as school and other work is in full swing but still trying our best la
22:45
Ransingh
Tashi Choden
Photo
It is fine la. Good you attempted as true. . let us wait my friends to respond la
23:18
March 19
BB Mongar
Prokaryotes have circular DNS
09:24
Prokaryotes have circular DNA
09:24
KD
The statement is false. Prokaryotes typically have circular DNA, while eukaryotes generally have linear DNA organized into chromosomes. Additionally, both prokaryotes and eukaryotes have proteins associated with their DNA to facilitate packaging and organization, although the specific proteins and mechanisms may vary between the two types of organisms.
09:25
CL4STEM_ToT_Biology
46 members
I just couldn't help but share this foto captured today morning while taking our boarding stds for morning walk
edited 08:57
SB
Hello and good morning from Samtengang CS
08:57
Sangay Bidha
I just couldn't help but share this foto capt...
Excellent. Guys you may also consider posting pictures of students engaged in activities when you are implementing some of the activities from the module
08:58
Early Sunday for you. Keep up
CL4STEM_ToT_Biology
46 members
I just couldn't help but share this foto captured today morning while taking our boarding stds for morning walk
edited 08:57
SB
Hello and good morning from Samtengang CS
08:57
Sangay Bidha
I just couldn't help but share this foto capt...
Excellent. Guys you may also consider posting pictures of students engaged in activities when you are implementing some of the activities from the module
08:58
Early Sunday for you. Keep up
CL4STEM_ToT_Biology
46 members
Lesson Plan1 by Sherab Tenzin 5023
Assigned submissions to assess
Peer review lesson plan by Pelden Nima 5014
we can see this, but no rubrics la
18:04
Sangay Dorji
Sherab Gonpawoong Tenzin
we can see this, but no rubrics la
Same here
18:10
Ransingh
Can you check now.
18:10
Sherab Gonpawoong Tenzin
Laso la
18:11
Now I can see la. Thank you so much for the prompt rectification la
18:12
Ransingh
Sherab Gonpawoong Tenzin
Laso la
Lop Sherub can share pic how it looks
Kelzang Chodup
last seen recently
Kinley
Very happy to see that few of you are sincerely an...
We are giving our best particularly, I am learning lots sir. I keep nothing un-turned. Every course/module all inforamtion, I take it as my resource packs sir. I feel fortunate to enroll in such course. Thanks.
edited 19:09
Though the modules have undergone vetting at International, National and Local levels. During the final push we even had MoE subject experts review the module. Unfortunately, seems like minor gaps have occurred during the transfer from main document into the Moodle platforms. Good that you guys are providing feedback we are able to rectify and improve further. It will help us when we do full scaling for all STEM teachers of Bhutan. Then some of you will be the instructors online.
19:12
Las la sir,
Looking forward, given the opportunity I, brought up under your good guidence since the day 1 in the college I would give my best la. escape from acting online instructor I would like to participate in forum
19:22
Sir,
Alway ready to take this course at higher level la. Thanks you for the continued support, for your prompt response la.
19:26

1.8 Teacher Educator's reflection on the overall implementation (Moodle and CoP)

1.8.1 Participation of teachers

Creation of CoP was useful, phone call, constant reminder individually and in group and activities to be completed; face to face orientation on OER was effective as we could meet in person so besides orientation, we were also able to clarify their misconceptions immediately in person and building rapport was seen to be a success. Additionally, often reminding the participants about their professional responsibility to complete tasks have also been useful".

1.8.2 Challenges

Completion of the activities on time was a challenge; we had to send repetitive reminder as the participants were also heavily engaged in their teaching and other works; connection with pre-in-service was difficult as they were on vacation and some had network connection issue; implementation of lesson plan was a challenge as the participants found it difficult to adjust with the topics; pre-service participants found it more challenging on the implementation as they were on vacation, getting timely response from the participants. We also had a couple of pre-service participants whose mobile phone and laptop were broken, therefore, they had resource constraints.

Minimal participation in the CoP. The possible reasons are Bhutanese by nature are passive and do not ask many questions nor contribute. Further, for many Telegram is a new feature as the majority of participants are more familiar with other social media platforms such as WeChat and Facebook. However, now the popularity of Telegram is gaining momentum amongst all.

1.8.3 Surprises

Poor response from the pre-service participants. The reason we assume is because of the structure of the tools as it was more relevant for in-service teachers.

1.8.4 Any changes required in the module design

Decrease the number of lesson plans to one this will enable accomplishing thorough and detailed collaboration between the participant and tutor on the selected concept and PCK.
Focus more on assessment.

Module 2: Ecology

2.1 Introduction

This Ecology module was originally developed and maintained by the Nigerian team for fresh teacher graduates as target users in order to equipping them to teach Ecology to Grade IX students. The biology team at Samtse College of Education, in collaboration with a subject specialist from the Ministry of Education and Skills Development revised this module to adapt it for use in Bhutanese classrooms by biology teacher participants. The concepts chosen for the module are central to introductory Ecology and were selected because of their potential contribution to teachers' professional development in enhancing their subject matter knowledge, pedagogical content knowledge-PCK, integration of technology, and inclusive pedagogies. Such aspects aim at ensuring that students' varied learning needs and abilities are catered for. It tries to develop participants into knowledgeable people who would have an understanding with which they could engage, solve problems, and make decisions about the natural world. Besides strengthening PCK, it has imbedded principles of UDL in the module for inclusivity in biology teaching and learning by catering to diversity in learners. Furthermore, technology infusion in teaching, learning, and assessment has been specified in the module.

a. Timeline of implementation in the country

According to the research calendar, the module was scheduled for a six-week implementation. The module was opened to the participants on May 6 and closed on July 16, 2024.

b. Learning objectives

The goal is to develop a sophisticated understanding of interconnectedness with respect to ecology by first examining the nature of science through historical contributions of Raymond Lindeman. This includes explanations of key ecological terms such as environment, habitat, and niche and examination of the structure and components of ecosystems. Learning Objective In this learning objective, the student will define what an autotroph is, a heterotroph, and a trophic level. Students will analyse the structure of food chains and food webs. The objective is also to explain the organisation of living things by describing the terms population, community, ecosystem, and habitat and by listing the different levels of organisation in order from least to most complex. Students will distinguish an ecosystem from a community, define the term interaction, and describe positive and negative interactions among organisms. Knowing the different types of interactions, as well as the very concept and causes of pollution, will finally enable students to explain various types of pollution and their consequences for ecosystems.

c. Number of units

Five units (Nature of science through ecological studies, Basic ecological concepts, Hierarchical organization, Environmental pollution)

d. Concepts covered

Interaction, intra-action, biosphere, ecosystem components, food chain, food-web ecology, synecology, autecology, habitat, ecological niche, organism, population, community, mutualism, commensalism, parasitism, predation, competition, types of water pollution.

e. Resources - activities, readings

The activities included were MCQ, Interactive Videos, Discussion, Drag and Drop, Quiz. Wherever required and possible PDF materials were provided to enhance understanding of concepts. Further, some videos were also made available to enhance understanding of the concepts.

f. Nature and purpose of assessments

In the module, there are formative and summative assessments throughout to evaluate participants' learning. The pre-requisite of the module was a pre-test at the start, which included 45 MCQs on the key themes: learners, content, and teaching-learning. They were given one hour for this pre-test to access the module. Each unit consisted of several in-process assessment activities, including quizzes, short answer writings, reflections, and practical activities with the students. At the end of the module, the participants took a similar 45-MCQ post-test within an hour. Besides, participants were asked to prepare two lesson plans based on the concepts developed within the module and one reflection after implementation of the plans. In addition, the participant’s peer-reviewed lesson plans and recorded teaching sessions assigned from a colleague apart from the assessments by the tutor. Of these 38 teachers, a sample of eight was selected as the focus group whose lesson plans and teaching were assessed by the tutor, officials in MoESD, and their supervisors. All the assessments were supported by a uniform rubric while evidence focuses on learners, content, and effectiveness in teaching and learning.

2.1 Course completion rate

2.1.1 Overall completion

Thirty six (36) participants completed the course successfully.

2.1.2 Assessment completion rate

Table 2.1: *Teachers’ assessment completion rate*

Area of assessments	Teachers	Total
Pre-test	36	36
Session plans	36	36
Reflection	36	36
Post-tests	36	36

2.3 Time spent on the course platform

Majority of the participants (56.7%) spent between 5-10 hours to complete the course while 27.02% of the participants took time between10-20 hours.

Table 2.2: *Time spent by teachers on Moodle platform*

Hours spent	Teachers	Total
Less than 5	6	6
5 to 10	21	21
10 to 20	10	10
21 to 30	-	-
More than 30	-	-
Total		37

2.4 Change from pre- and post- test

The findings from the analysis of pre-test and post-test scores in the OER Ecology module for secondary biology teachers reveal a significant overall improvement in participant performance. The average score increased from 15.28 to 26.39, reflecting an approximate gain of mean difference 11.11 (Figures 2.1a &b). This positive shift was observed across the board, with pre-test scores ranging from 4 to 20 and post-test scores extending from 14 to 32. Notably, even low-performing teacher participants demonstrated progress. For instance, the lowest pre-test score of 4 improved to 16 after the intervention. High-achieving teacher participants also benefited, as evidenced by a substantial increase from a pre-test score of 20 to 31 post-test score. Despite these improvements, variability was noted in individual progress. Some participants, (e.g., participant 6), showed remarkable gains from 19 to 32, while others, such as participant 33, experienced a decrease from 18 to 14, indicating that some faced challenges that hindered their progress. Overall, the analysis of pre-test-post-test data suggest that the teaching strategies employed-such as active learning, addressing misconceptions, and linking content to participants' everyday experiences were effective in enhancing understanding and retention of ecological concepts. The intervention not only improved immediate scores but likely facilitated better retention of knowledge. Furthermore, the data indicate that the intervention fostered an inclusive learning environment, as evidenced by improvements across all participant categories, regardless of their initial performance levels. These findings underscore the positive impact of innovative feedback and teaching strategies, highlighting the need for continued adaptation and enhancement to meet diverse educational needs in future practices.

Figure 2.1a: *Mean of Pre-test vs. Post-test Scores (n=36).*

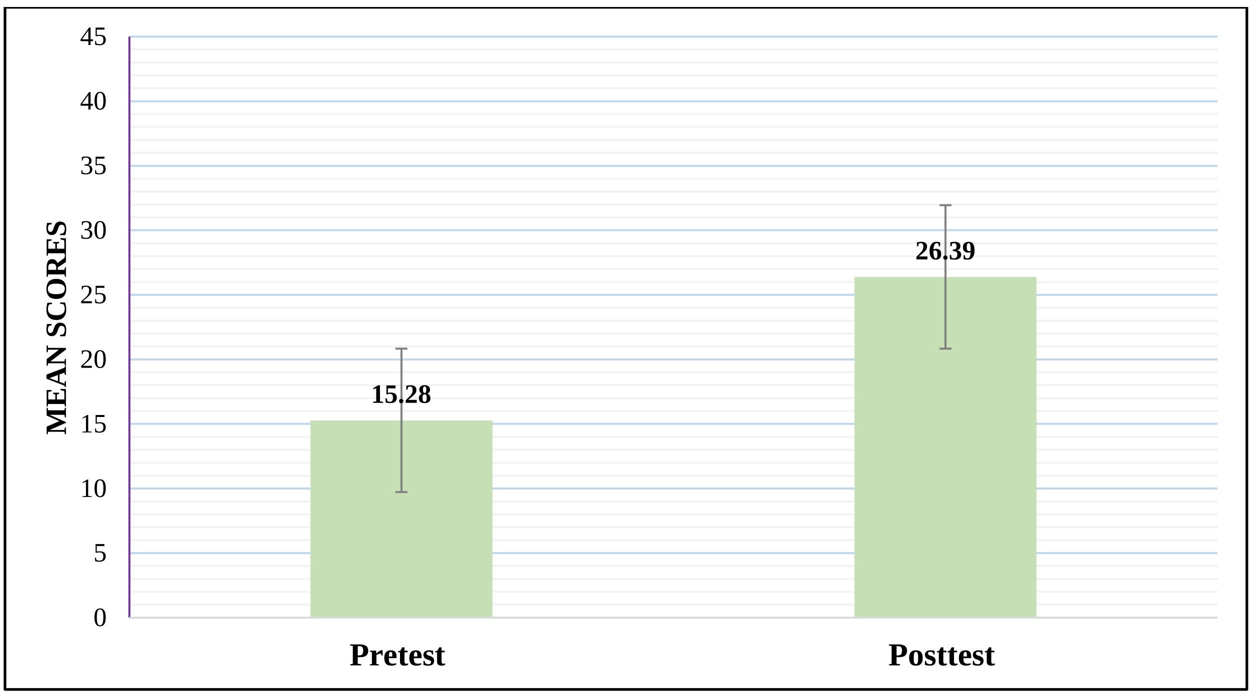


Figure 2.1b: *Line graph showing the distribution of **Pre-test** and **Post-test** scores for participants (n=36).*

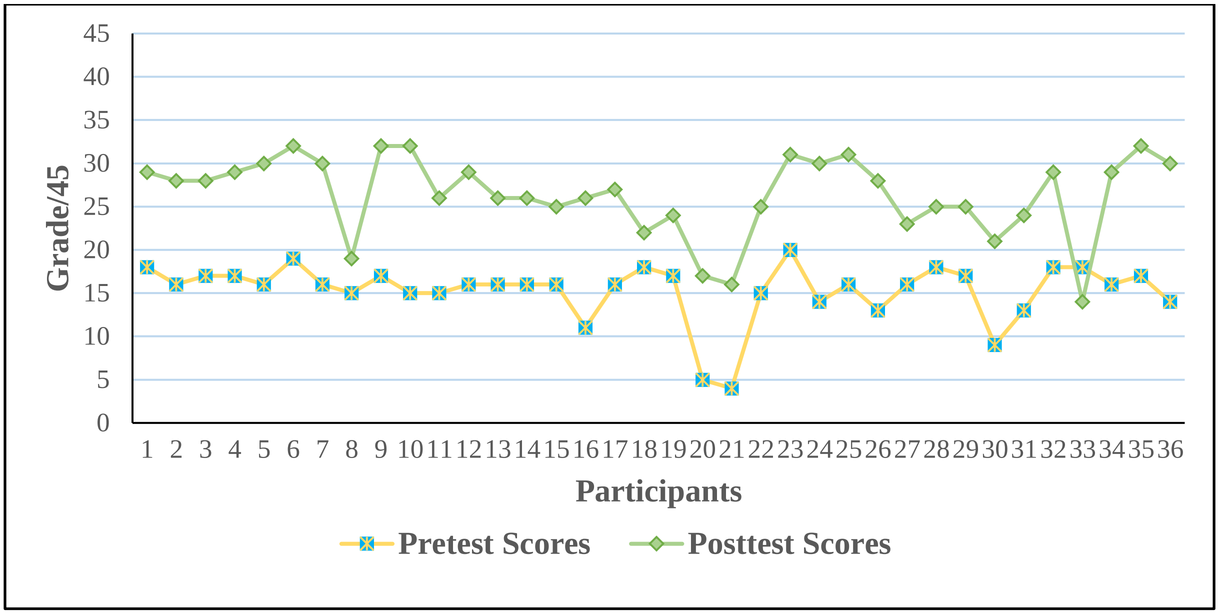


Table 2.3 summarises the proficiency level of teacher participants based on pre-and post-test scores. In the pre-test, 36 participants completed the test, with 6 at the Emerging level, 29 at the Proficient level, and 1 at the Accomplished level. In the post-test, 36 participants also completed the test, with 6 remaining at the Emerging level and 30 achieving the Proficient level. Notably, no participant fell within the Novice level for either the pre-test or post-test, and none reached the Accomplished level in the post-test. What this means regarding the interpretation of these findings is that teacher participants were consistent in their distribution and no large improvement or regression occurred into the higher or lower achievement levels between the categories of proficient and emerging. This would indicate that the majority of the participants retained a high mastery of the concepts, a subset still requires further instruction to move beyond the emergent stage to proficient and none of the participants mastered beyond accomplished.

Table. 2.3 *depicts the category of teacher participants based pre-test and post-test data*

Proficiency Level	Score Range (%)	Pre-test	Post-test
Novice	0-25	-	-
Emerging	26-50	6	6
Proficient	51-75	29	30
Accomplished	76-100	1	-

2.5 **Practice** (Session plan and reflections)

The quantitative data presented in Table 2.4 below provides insights into teachers' practices (session plans and reflections) across the categories of Learners, Content, and Teaching and Learning, based on their lesson plans and reflections.

In the **Learners** category, teachers effectively promote inclusion and equity (Mean = 1.21, SD = 0.69) and build on students' prior conceptions (Mean = 1.12, SD = 0.57), though more focus is needed on addressing misconceptions (Mean = 0.80, SD = 0.69) as shown in Table 2.4.

In the **Content** category, teachers demonstrate moderate application of science and mathematics processes (Mean = 1.03, SD = 0.76) and higher-order thinking (Mean = 1.10, SD = 0.66), while planning to build student competencies (Mean = 0.84, SD = 0.67) remains an area for improvement (Table 2.4).

The **Teaching and Learning** category reveals strong implementation of active learning strategies (Mean = 1.56, SD = 0.59), multiple representations of content (Mean = 1.54, SD = 0.59), and diverse modes of expression (Mean = 1.51, SD = 0.62). However, the use of local materials (Mean = 1.01, SD = 0.65) and linking content to real-life experiences (Mean = 0.95, SD = 0.70) show moderate application. Overall, while there are strengths in active learning and diverse instructional techniques, addressing misconceptions and planning for competencies remain areas for further development, as shown in Table 2.4**.**

Overall, the findings indicate a strong foundation in teaching practices, especially in active learning and diverse representation of content, while identifying areas where more consistent focus is needed, particularly in addressing misconceptions and planning for student competencies.

Table 2.4: *Mean and Standard Deviation (SD) of Key Themes Related to Learners, Content, and Teaching and Learning Practices (n=36)*

Category	Theme	Mean	Standard Deviation
1. Learners	P1.1 Promote inclusion and equity	1.21	0.69
	P1.2 Build on students' prior conceptions	1.12	0.57
	P 1.3 Address misconceptions and areas of difficulties	0.8	0.69
2. Content	P2.1 Use processes on science and mathematics	1.03	0.76
	P2.2 Facilitate higher order thinking	1.1	0.66
	P2.3 Plan to build students' competences to meet the goals of teaching science/ mathematics	0.84	0.67
3.Teaching and Learning	P3.1 Use instructional strategies for active learning	1.56	0.59
	P3.2 Use multiple representations of content	1.54	0.59
	P3.3 Create opportunities for multiple modes of expression	1.51	0.62
	P3.4 Use locally available materials	1.01	0.65
	P3.5 Link conceptual content to students' everyday life experiences and prior knowledge	0.95	0.70

The quantitative findings above indicate strong teacher practices in promoting inclusion and employing active learning strategies, which are corroborated by qualitative insights below:

2.6 Thematic Analysis of Lesson Plans and Reflections

The following report presents a thematic analysis of lesson plans and reflective reports derived from an ecology module, organised around three overarching themes: Learners, Content, and Teaching and Learning. This approach allows the nuances of how these elements interconnect and contribute to the overall teaching and learning process to be examined. By giving central focus to these themes, the study attempts to contribute to a robust evidence base concerning the impacts on PCK in these teacher participants of the module.

The **Learners theme** refers to the needs and backgrounds of students and how teachers make modifications in their strategies in order to build an inclusive and equitable learning environment for all their students. This analysis displays the level of awareness of, and response to, the distinctive differential challenges of the students' circumstances in terms of gender, socio-economic status, and differential abilities. The teachers are, through differentiated instruction and application of UDL principles, consciously creating an inclusive space conducive to active participation and engagement of all learners.

The **Content theme** probes the currency and accessibility of the content delivered in the ecology module. The analysis takes into consideration how well the content aligns with the students' prior knowledge and life experiences. It does go on to emphasise, however, that incorporation of media and other resources, like videos and real-life examples, exploring the ecosystem locally, makes learning even more relevant and allows for deeper connections with the subject itself. This thematic focus also explores how teachers address misconceptions and scaffold learning in such a way that concepts are understandable and engaging for all students.

The third theme of **Teaching and Learning** considers the kind of teaching strategies utilised within the classrooms and how overall effective these are in ensuring student engagement with teaching and learning. The analysis reveals that the most striking features are active learning methodologies, such as collaborative group work, hands-on activities, and inquiry-based approaches. These techniques guarantee that students develop critical thinking and problem-solving skills, provide an avenue for peer learning, and stimulate dialogue among peers. It also points to OER integration as an important factor enhancing teachers' PCK by creating dynamic and varied learning experiences, able to accommodate different learning styles.

The result of this thematic analysis therefore suggests that the use of OER has brought very profound positive impacts on the PCK of the teacher participants. By looking at the interplay of learners, content, and teaching methodologies, this report provides an insight into a range of ways in which educators may enrich their practice toward creating an inclusive, high-achieving learning environment. This report underlines the importance of continuous professional development and reflective practice in supporting teachers to adopt approaches that will make a difference in improving the experiences and outcomes of their learners.

2.6.1 Learners

a. Equity and Inclusion

In promoting inclusion and equity within the classroom, the participants' lessons demonstrated a strong commitment to creating engaging opportunities for all students. The following examples demonstrated how participants creates opportunities for students to participate, pays attention to students who need help and have special needs, and does not discriminate / exclude based on socio-economic and linguistic background and abilities:

Participant 5023 “I made efforts to cater to different types of learners by covering the content through various resources and activities. I focussed on refining my approach to better address the diverse needs of all learners, ensuring that each student feels valued, supported, and able to thrive in the learning environment. It's positive to note that boys and girls participated equally during the lesson. This balanced participation suggests that there were no apparent gender differences in engagement or involvement in the activities. Additionally, the absence of marginalised groups in the classroom context indicates a homogeneous demographic composition, where all learners had similar socio-economic, linguistic, and religious backgrounds. I offered encouragement and remained flexible to ensure inclusivity and engagement in class".

Participant 5021 "The lesson was inclusive in in terms of materials, activities and method that could cater to the different needs of the varied learners. Provided various ways to participate other than speech communication. Taking in consideration all the learners with varied learning abilities is time consuming and challenging"

Participant 5022 "Conducive environment was maintained in the classroom whereby all students were able to take part in class discussion. Some members in the groups seem to slow learners and were to encounter difficulty in understanding the concepts. Need to re-engage children in making them understand the concepts".

Participant 5024 "I made every student to take part in the activity actively and equally. Class was organised group wise. Every learner tried to participate equally. I tried to help to the children who are shy and introvert".

Participant 5026 "As the lesson was designed with UDL having varieties of activities, needs of all the learners are meet".

Participant 5027 "The activity was designed in such a way that the choices were given to children to do the activity as per their convenience and understanding of the topic".

Participant 5028 Mixed gender and students with visual problems were seated in the front"

Participant 5030 "it was observed that educated parents' children were more forthcoming and confident".

Participant 5029 "Furniture were arranged in teams for students to work in team".

Participant 5033 "Though both boys and girls participated equally, but there were some differences in participation among students from different socio-economic backgrounds".

Participant 5036 "learners from lower socio-economic backgrounds required more support. I addressed the emotional aspect of learning by providing encouragement and support to learners who were struggling".

In conclusion, the participants demonstrated a strong commitment to fostering inclusion and equity within their classrooms by actively creating engaging and supportive environments for all learners, regardless of gender, socio-economic background, or ability level. Participants used a range of strategies to cater to diverse needs, including differentiated instruction, Universal Design for Learning (UDL), and varied methods of participation. These approaches helped ensure that all students felt included and valued.

Some of the equal opportunities that several of the respondents mentioned referred to those relating to boys and girls participating in all activities. Some, however, indicated that they did not observe any difference in the way girls or boys participated. They did note differences in participation and lack of confidence because of socio-economic problems. Extra attention was given to the learners who needed special support either because of learning difficulties or economic problems, which consequently obliged continuous adaptation of teaching methodology by the teachers in view of such students' needs. The efforts of the participants to encourage the shy or introverted students, the use of varied resources, and adjustments in classroom arrangements, as for example seating by team and visual adjustments, do indeed point toward the interest of participants in making a classroom a more inclusive learning environment. In contrast, some participants at the same time also mentioned difficulties and that the adjustments within the large scale of learner abilities required a lot of effort and consumed lots of time, which reveals that in practice it is still open to further fine-tuning.

b. Build on students’ prior conceptions

In regard to building on students’ prior conceptions generally teachers have used questions to test student’s prior knowledge. Several lessons began by asking questions designed to connect with students' existing knowledge and experiences, thereby tapping into their prior conceptions. This approach not only helped in engaging students from the start but also made the learning process more relevant to their everyday lives. The following are selected evidences that illustrates usage by teacher participants:

Participant 5020 “Use popcorns to test their understanding of food chain. Did you see any animals eating other animals? Give some examples of these animals being eaten or who eats the other”.

Participant 5022 “Recapitulate the previous lesson by summarising the previous lesson on ecological interaction”.

Participant 5023 “Show a short video clip or images depicting various ecosystems and ask students to identify different organisms within them. Encourage students to think about how these organisms might be connected”.

Participant 5026 “Pre-test was administered”.

Participant 5030 “Let students write freely whatever they know about ecosystem”.

Participant 5037 “make students reflect on their personal observation and experience”.

Consequently, probing questions and activities linking new content to prior knowledge and experiences of students were employed by the teachers. In this way, students were engaged from the beginning but also made relevant and relatable to everyday experiences. By using recapitulation, reflection, and pre-assessment, participants brought about the activation of students' prior knowledge in such a way that the bridge into new topics became less jolting. Throughout the module, techniques such as video prompts, free writing, and personal reflections tended to be more thoughtfully created to build upon students' prior knowledge and deepen their understanding of the lesson at hand.

c. Address misconceptions and areas of difficulties

Some lessons effectively addressed common misconceptions by actively exploring students' preconceptions. This was achieved through the use of multimedia resources, such as videos, and real-life examples that provided concrete contexts for understanding abstract concepts. These strategies helped clarify misunderstandings and reinforced accurate knowledge, further supporting an inclusive and equitable learning environment. The following are some of the examples illustrating how participants addressed misconceptions and area of difficulties:

Participant 5022 “Recapitulate the previous lesson by summarising the previous lesson on ecological interaction”.
Participant 5023 “Used Padlet allowing students to jot down their thoughts”.
Participant 5024 “Used videos to make students understand clearly”.
Participant 5027 “At the end of the session, I asked them to do exit ticket, giving feedback about the session. This helped me to get to the points they were confused about and needed my assistance further in the next session. This helped them to compare and clarify their misconceptions”.

Participant 5036 “An interesting example of misconception was when a learner thought that plants were the primary consumers in a food chain. I addressed this misconception by explaining the role of plants as producers”.

In summary, some lessons addressed the students' misconceptions through active investigation of their prior knowledge and were able to use some techniques to sort out the misunderstandings. To set contexts that would make the concepts concrete, teachers used electronic media such as videos, digital platforms, and even real-life examples. This not only ironed out confusion but also laid solid knowledge, leading to a more inclusive and equitable learning environment. For example, Participant 5023 used Padlet for sharing thoughts among students, whereas Participant 5027 used exit tickets to determine where students were confused. Participant 5036 also clarified a misconception that plants are primary consumers, but actually, plants are producers in the food chain because they produce food through photosynthesis. Such an approach developed deeper understanding and solved common areas of difficulty.

6.1.2 Content

a. Use processes on science

The implementation of processes in science and build students’ competences to meet the goals of teaching science was exhibited through the activities designed in the lesson and to some extent the implication was indicated through the reflections. The following selected examples illustrates how students were provided to hypothesise or draw conjures:

Participant 5001 “Explorative study by visiting the school surrounding to identify the both biotic and non-biotic components in the environment”.

Participant 5023 “Conduct a guided exploration of food chains and food webs using a hands-on approach. Learners enjoyed the Gizmos simulation the most. They found the hands-on experience engaging and effective in understanding complex concepts. The interactive nature of the simulation allowed them to apply theoretical knowledge in a practical setting, fostering deeper comprehension and enjoyment”.

Participant 5021 “Process oriented teaching with progressive series of activities “Each group will be asked to discuss at least one threat to ecosystem from human activities (What are some threats to ecosystems from human activities?). Students were asked to explain their points to the whole class. Teacher will comment and add point when deemed necessary. Students will be asked to come up with point each on the ways to minimise the impacts of anthropogenic activities on ecosystem. In a pair, students will be given a task to discuss and list down some lifestyle that has impacted our ecosystem”.

Participant 5022 “When students are made to observe the phenomenon by themselves learning becomes more interesting. For example, in my lesson I made them to observe phenomenon from nature which made learning more interesting”.

Participant 5028 “Observation is more interesting for the kids to learn because they can easily relate with their lives or daily lives”.

Participant 5030 “The learner designs a model (conceptual, theoretical, physical or simulation) of a local ecosystem that represents its biotic and abiotic components. The learner may use relevant software and programming languages to develop a model of a local ecosystem”.

Participant 5031 “Learners were briefed to visit the identified ecosystem, observe ad study biotic components, abiotic components and their interactions in the ecosystem and finally designing the respective ecosystems which enhances scientific skills”.

Participant 5035 “Field trips within the campus and nearby forest will be organised to provide hands-on learning experiences”.

Participant 5036 “learners were encouraged to think critically about the role of each organism in a food chain, which is an essential aspect of scientific inquiry”.

Participant 5037 “Students will be asked to come up with point each on the ways to minimise the impacts of anthropogenic activities on ecosystem”.

The infusion of science processes and the development of students' competencies in the lessons were quite effectively shown by including several hands-on, exploratory, and inquiry activities. These activities allowed the students to make hypotheses, carry out observations, and conduct simple scientific investigations that could allow them to develop a better understanding of scientific concepts. For instance, **Participant 5001** engaged students in an exploratory study of the biotic and abiotic components surrounding them”, while **Participant 5023** used simulations and hands-on explorations to explain the complex issues of food chains. Again, **Participant 5021** motivated process-oriented learning through the analysis of the impact on ecosystems caused by human activities. On the other hand, **Participants 5030 and 5031** laid emphases on ecosystem modelling and field studies as a method to enhance scientific skills. These approaches built up the students' scientific knowledge as well as developed their critical thinking, observation, and problem-solving skills in developing scientific inquiry.

b. Facilitate higher order thinking

Several teacher participants' lessons effectively promoted higher-order thinking by incorporating critical and thought-provoking questions throughout the instruction. These questions encouraged students to go beyond mere memorisation and engage in deeper analysis, synthesis, and evaluation of the material. By challenging students to think critically, the lessons fostered an environment where learners could explore complex ideas, consider diverse perspectives, and develop well-reasoned arguments. In addition to open-ended questions, participants also utilised multiple-choice questions to assess students' understanding and promote active engagement with the content. These questions were strategically integrated into activities and discussions, providing opportunities for students to apply their knowledge, analyse different options, and justify their choices. This combination of questioning techniques helped to create a dynamic learning environment where students could develop critical thinking skills and deepen their comprehension of the subject matter.

The following examples outlines processes that were carried to facilitate higher order thinking:

Participant 5006 “Delivered the lesson through design thinking approach”.

Participant 5021 “Process oriented teaching with progressive series of activities “Each group will be asked to discuss at least one threat to ecosystem from human activities (What are some threats to ecosystems from human activities?). Students were asked to explain their points to the whole class. Teacher will comment and add point when deemed necessary. Students will be asked to come up with point each on the ways to minimize the impacts of anthropogenic activities on ecosystem. In a pair, students will be given a task to discuss and list down some lifestyle that has impacted our ecosystem”.

Participant 5022 “Process oriented teaching with progressive series of activities “Each group will be asked to discuss at least one threat to ecosystem from human activities (What are some threats to ecosystems from human activities?). Students were asked to explain their points to the whole class. Teacher will comment and add point when deemed necessary. Students will be asked to come up with point each on the ways to minimize the impacts of anthropogenic activities on ecosystem**.** In a pair, students will be given a task to discuss and list down some lifestyle that has impacted our ecosystem".

Participant 5023 "Throughout the lesson, I provided clear explanations and examples to help students understand the fundamental concepts of Ecology, including, interaction (positive and negative), food web and food chain. Additionally, I facilitated activities and discussions to reinforce these concepts and assess students' understanding. Further, encouraged them to think critically about the relationships between different organisms and their roles as producers, consumers, or decomposers. Some provoking questions were asked such as "What happens if one species in the food chain disappears?" or "How do energy and nutrients flow through the ecosystem?"

Participant 5035 "learners were encouraged to think critically about the role of each organism in a food chain, which is an essential aspect of scientific inquiry".

The lessons were effective in promoting higher-order thinking because several teacher participants incorporated critical and thought-provoking questions that elevated the students beyond mere rote memorisation to the levels of significant analysis, synthesis, and evaluation. Such lessons offered an opportunity for critical thinking and thereby an opportunity for complex ideas to be developed and provided ample time for reasoned argumentation and consideration of views. The participants used questioning techniques that ranged from open-ended to strategically placed multiple-choice questions, allowing active engagement and applied knowledge. For example, **Participants 5021 and 5022** ran discussions on the human impact in ecosystems, allowing students to think through threats and solutions. **Participant 5023** provided questions that engaged critical thinking in terms of food chains and interactions among organisms in an ecosystem. **Participant 5035** probed thinking about the role an organism plays in respect to a food chain. Such process-oriented activities combined with reflective questioning opened dynamic learning environments for enhanced critical thinking and deeper understanding by students.

c. Plan to build students' competences to meet the goals of teaching science

With regards to plans to build students' competences to meet the goals of teaching science. The lesson activities exemplified the iterative nature of scientific inquiry, where experimentation, observation, and argumentation are integral to advancing our understanding of natural phenomena. By actively engaging in these practices, students not only gained a deeper appreciation for the food chains and food webs and how it relates to ecosystem dynamics but also developed essential skills in critical thinking, data analysis, and evidence-based reasoning. The following are some of the examples that demonstrated plans to build students' competences to meet the goals of teaching science: Participant 5023 "the session exemplified the iterative nature of scientific inquiry, where experimentation, observation, and argumentation are integral to advancing our understanding of natural phenomena. By actively engaging in these practices, students not only gained a deeper appreciation for the food chains and food webs and how it relates to ecosystem dynamics but also developed essential skills in critical thinking, data analysis, and evidence-based reasoning".

Participant 5026 "The learner obtains information on interactions, such as food chains, food web and interactions amongst living organisms from relevant materials (e.g., books, online pieces, articles, etc.) or web links".

Participant 5029 "they were interacting while discussing on the examples for different interactions and also while going through other teams' work and especially while providing feedback on other's work".

Participant 5031 “understanding biotic components, abiotic components and then evaluating how these two components interact in the ecosystem. Students were able to respond to all teacher questions”.

Participant 5032 “I enjoyed teaching the lesson and found the group activities particularly effective in engaging students. This session was different as it involved more interactive and student-led activities than my usual approach. I felt positive about this change and noticed a higher level of student engagement and interaction as a result. Time constrain was major hindrance to complete on time”.

Participant 5036 “The class was organised into group discussions and role-playing activities. Learners interacted with each other by sharing their ideas and participating in discussions”.

Some of the activities planned for the lessons were appropriate to build the students' competence to realise goals in science teaching, especially the process of inquiry iteratively. In that case, by experimentation, observation, and argumentation, the way students understood food chains, food webs, and ecosystem dynamics was honed by developing critical thinking, data analysis, and evidence-based reasoning.
For instance, **Participant 5023** has emphasised the engagement of students in these scientific practices, whereas Participant 5026 explained how to let learners get information from several sources. Equally, **Participants 5029** and **5036** encouraged collaboration and interaction through engaging in group discussions and feedback which furthers students' analytical and communicational competencies. Similarly, **Participant 5031** focused on measuring biotic and abiotic interactions, while **Participant 5032** explained that interactive activities led by the students themselves are more motivating for the participants. Such a strategy conveys an engagement in scientific competence by the active participation of the students during their learning process, despite limitations mentioned by them, regarding time constraints.

2.6.3 Teaching and Learning

a. Use instructional strategies for active learning

In terms of the use of instructional strategies for active learning. The classes were primarily organised into small groups for collaborative activities and discussions. Each group worked together to complete tasks, such as analysing data, solving problems, or discussing concepts. However, there was also an element of individual work within the group setting, where each member contributed their ideas and insights to the group's overall understanding. Group, pair activities, and individual task was popularly used by majority. Few even considered roleplay in their lessons. The following selected examples display specific usage examples and patterns in their lessons:

Participant 5001" used group work and independent study. Used activity sheet to recall student learning. Exit ticket strategy was used and was relevant".
Participant 5023 "Row-wise activity organised in the class due inconveniences to give greater opportunity".

Participant 5023 "The class was primarily organised into small groups for collaborative activities and discussions. Each group worked together to complete tasks, such as analysing data, solving problems, or discussing concepts. However, there was also an element of individual work within the group setting, where each member contributed their ideas and insights to the group's overall understanding".

Participant 5026 "Divide students into groups and assign each group a specific ecosystem. Students investigate the ecosystem and were encouraged to record their findings in a data table based on the interaction in the ecosystem".

Participant 5030 “In five groups of maximum six students each facing each other (mixed grouping)”.

Participant 5031 “teacher organised the first task to be done in groups of five members. Then individual tasks and followed by the group tasks again”.
Participant 5032 “Used individual and group work. Weak students were paired with performing students”.

Participant 5035 “Collaborative tasks will be assigned to encourage peer-to-peer learning and foster creative and critical thinking skills”.

Participant 5037 **“**because it consisted of heterogenous mixed gender group that help students of different learning ability exchange their idea. In a pair, students will be given a task to discuss and list down some lifestyle that has impacted our ecosystem”.
The lessons were characterised by instructional strategies for active learning, especially collaborative group work, paired activities, and individual tasks. Most teacher participants used such an approach in actively involving the students in problem-solving, data analysis, and discussions. This style allowed for peer-to-peer learning whereby students exchanged ideas and elaborated on one another's understanding.

For example, **Participant 5001** used group work and individual study, activity sheets, and exit tickets to assess learning. **Participant 5023** structured group projects but allowed individual inputs within groups; **Participant 5026** assigned different ecosystems to different groups and had them promote hands-on explorations and the recording of observations. **Participant 5031** combined group and individual activities, ensuring that students worked some with others and some on their own. **Participant 5032** paired weaker students with stronger ones in support of peers. **Participant 5037** adopted mixed-gender, heterogeneous grouping strategies so ideas could be exchanged amongst students at different levels of ability. Generally, these strategies encouraged active learning and helped develop students' critical thinking and teamwork skills.

b. Use of multiple representations

Generally, majority have used smart TV, YouTube videos, interactive videos, chart, text book, worksheet, board were listed in the resource or teaching materials used. By integrating these different resources, the lessons catered to various learning styles, allowing students to engage with the content in a manner that best suited their preferences and needs. For instance, technology was often employed to create interactive and multimedia-rich experiences, while worksheets and textbooks provided structured, text-based learning opportunities. Visual aids, such as pictures, further supported learning by offering visual representations of key concepts.

The following is an illustration of the pattern and types of resources teachers have used in their lessons:
Participant 5023 “Provide students with materials such as pictures of organisms, index cards, and string to construct food chains and food webs. Provide students with materials such as pictures of organisms, index cards, and string to construct food chains and food webs. Mobile, smart TV, projector, chalk, ppt slides, videos, animation, Gizmos simulation, chart papers, and marker”.
Participant 5027 “The resources that I used for my lessons were topic related images, PPT, worksheets for students to do hands-on practice, assessment criteria set for the activity done in class”.
Participant 5027 “PPT presentations on Auxin, Video lessons on plant growth regulators”.
Participant 5030 “Google Lens, Smart TV, Videos, Projector”.

Participant 5036 “Diagrams of food chains, printed examples of different ecosystems, and worksheets for guided practice”.

All in all, most of the teacher participants were able to embed a gamut of resources, including smart TVs, YouTube videos, interactive media, charts, textbooks, worksheets, and even traditional tools such as boards and chalk, in pursuit of creating diverse and engaging learning experiences. These varied teaching materials were dedicated to serving different learning styles of students wherein they could engage with their chosen content.

Participant 5023 used videos, simulations, hands-on materials such as pictures, and index cards for building food chains. **Participant 5027** combined images that were related to the topic at hand, PPTs, and worksheets that allowed hands-on practice along with assessments. **Participant 5030** used tools like Google Lens and Smart TV to make it more interactive. **Participant 5036** used diagrams and printed material for guided practice in ecosystem concepts. This method satisfied all learning styles because students had the ability to see, hear, and touch the material in order to promote learning and retention.

c. Create opportunities for multiple modes of expression

Most of the lessons showcased diverse opportunities for students to express their understanding through various modes of expression, including the use of technology, worksheets, textbooks, and visual aids like pictures. By integrating these different resources, the lessons catered to various learning styles, allowing students to engage with the content in a manner that best suited their preferences and needs. For instance, technology was often employed to create interactive and multimedia-rich experiences, while worksheets and textbooks provided structured, text-based learning opportunities. Visual aids, such as pictures, further supported learning by offering visual representations of key concepts. Though all participants seem to use question and answer all through the lessons to check the understanding of the students. The lesson plans and reflections detailed out specific use of a variety of opportunities provides for students to express their learning. The following is an outline of the examples extracted from the analysis:

Participant 5004 “Reading, watching, expression opinion and drawing”.

Participant 5014 “Simple games used to keep class active. Opportunity to interact in the class using quiz and question”.

Participant 5021 “YouTube videos and pictures of the plants and animals. Handout on the impacts of human activities on the ecosystem”.

Participant 5023 “Conclude the lesson with a brief written reflection or discussion where students describe one new thing, they learned about food chains and food webs and how it relates to ecosystem dynamics. Assess students' responses based on their understanding of the concepts and their ability to apply higher-order thinking skills to analyse ecological relationships. Overall, the combination of group work and individual sharing facilitated active participation, collaboration, and knowledge sharing among students. It encouraged students to work together, exchange ideas, and learn from one another while also providing opportunities for individual contribution and accountability within the group setting”.

Participant 5025 “In their team, let the students discuss and come up with one example each for different interactions and make a presentation either on chart or board or in laptop depending on their choice”.

Participant 5026 “Each group will share their collected data with the class. The learner constructs a model (e.g., theoretical, conceptual, physical, or simulation) that explains interactions amongst organisms. Students completed the quiz in google form to check their progress”.

Participant 5027 “The choices were given to children to either design the food chain or food web as per their convenience and used it as exit ticket”.
Participant 5029 “Used gallery walk to review student work displayed and let others team assess and provide feedback”.

Participant 5035 “The session will culminate in the creation of ecosystem models by student teams, using locally available materials to deepen their understanding of the ecosystem's significance”.

Participant 5030 “develop a model that represents/explains the relationship between biotic and abiotic components of a local ecosystem, communication skills, and ability to critique. Provide necessary feedback and intervention to the learner”.

Participant 5031 “The group will be exploring, observing and identifying their respective ecosystem and list the biotic and abiotic components for 20 minutes individually. Then, they will be instructed to gather in the class. Once gathered, each group must share biotic and abiotic components observed in their ecosystem by one of the group representative for 10 minutes. After each group has shared or reported the two components, teacher will further ask the following questions”.

Participant 5032 “After the group activity, each group presents their findings to the class. This reinforces their learning and provides an opportunity for peer teaching. The lesson concludes with a short reflection activity where students summarise what they learned about interactions in ecosystems”.

Participant 5035 “Learners will first share their responses with their shoulder partners, and then selected pairs will share their answers with the entire class”.
Participant 5036. “Assign students to create a simple food chain diagram for a given ecosystem and demonstrated through role play”.

In summary, the lessons were able to demonstrate a wide range of opportunities for pupils to express their understanding in diversities of ways using technology, worksheets, textbooks, and even visual aids such as pictures. These different resources facilitate many learning styles, thereby allowing students to grasp the content in ways best suited for them. The use of technology allowed multimedia interactive learning, whereas through worksheets and textbooks, learning could be more structured. These were further enhanced by appropriate use of visuals that presented clear models of the abstract concepts being learned.

In addition to the foregoing tools, question-and-answer methods employed throughout the lesson constantly checked on student comprehension. Many participants included creative activities that allowed students to show their learning. For instance, **Participant 5004** allowed the students to read, watch, give an opinion, and draw, while **Participant 5025** gave the student an option for presenting their understanding using charts, boards, or laptops. Similarly, **Participant 5029** used gallery walks for giving peer feedback, while **Participant 5035** asked students to model the ecosystems with materials available in the local area.

Some prompted high-level thinking by having the students share their results or think about a particular activity. Participant 5032 supported learning by having the students do group presentations and reflections; Participant 5027 allowed the students to choose and design any food chains or food webs they wished. In combination, these various teaching approaches and learning tools facilitated the students to be able to actively engage, think critically, and work in teams while still addressing the various learning preferences of students.

d. Use locally available materials

The content and the activities in the module allowed much room for teachers to use the local ecosystem as a resource for learning to the fullest. Although only a limited number of respondents actually reported on the use of particular resources that are accessible, it was evident from the other responses that full use was made of the natural and local ecosystem where the lessons were set. With the use of immediate surroundings, teachers created rich learning experiences that linked students to their surroundings.

Other more creative teachers used the locally available materials for model construction, turning those abstract concepts of science into real tangible things their students could easily learn about. Indeed, instead of doing it with textbooks or digital pictures, the motivation came from using environmental materials like leaves, stones, or even small animals to make models of food chains or ecosystems. This also makes lessons more interesting, as it allows the students to develop a sense of ownership in research and interaction with their immediate surroundings.

Furthermore, contextualising the content by using real-life examples and locally available resources enhanced relevance for the student's life. Curiosity comes with relevance, and students begin to question their ecosystems on aspects that would further their exploration and understanding. Moreover, the use of local materials allowed students to engage their imagination and creativity in devising innovative ways of representing complex concepts.

This, in turn, means that experiential learning had the benefits of making these students develop critical thinking skills through analysing their findings and reflecting upon their observations. It fostered collaboration in as much as students very often would work in groups to gather materials, share ideas, and discuss models. Students would, therefore, not only grasp scientific principles through experiences but also have a deeper appreciation for the things around them.

e. Link conceptual content to students’ everyday life experiences and prior knowledge

Participants indicated an attempt made on making students to connect conceptual content to everyday life experience and prior knowledge especially at the end of the lesson. Unfortunately, not many concrete evidences were available, nevertheless the following is are a collection for few evidences gathered that to some extent highlight in the lesson plans and reflections:

Participant 5020 “Highlighted the interconnectedness of food chains and the importance of biodiversity”.

Participant 5022 “Students were able to share the examples of mutualism more as they might have witnessed in their daily life”.

Participant 5023 “The activities, discussions, reflections, and questions enabled students to recognize and describe the interconnections within food chains and food webs and their significance in maintaining ecosystem balance”.

Participant 5026 question posed "Provide scientific explanations on how is the stability of the ecosystem maintained by interactions amongst organisms?". Administered post-test".

Participant 5030 "I went to each group and asked simple questions to develop curiosity and even taught them few names of plants and insects".

Participant 5031 "Ask the group to design and construct their respective ecosystem using locally available resources and bring to the class in the next day".

Participant 5032 "Teaching different types of interactions and their impact on the ecosystem balance enable students to use reflect".

Participant 5037 "making students to link from their observation and experience".

In sum, participants showed very good attempt to link conceptual content to students' everyday life experiences and prior experiences especially towards the end of the lessons. Though there were not concrete pieces of evidence showing this connection, the examples that had been collected expose the strategies used by participants to facilitate such links.

Participant 5020 was pointing out that the examples of food chains and biodiversity are linked together and should be in real life valued. **Participant 5022** was pointing out the mutualism examples can be provided by students through experiences in everyday life, and that proved students learned to apply scientific ideas to scenarios familiar to them. Besides, Participant 5023 mentioned that activities, discussions, reflections, and questions enabled students to identify and describe the relationships in both food chains and food webs and thus appreciate their roles in maintaining the balance of ecosystems. Questions such as "Provide scientific explanations on how is the stability of the ecosystem maintained by interactions amongst organisms?" by **Participant 5026** reinforced further depth-of-inquiry scaffolding, followed by the administration of a post-test. Furthermore, the strategy of **Participant 5030** to make both groups participants in the process through simple questions was such that it raised curiosity and also made the students aware of the names of various plants and insects, adding to the knowledge. **Participant 5031** asked students to design and build their respective ecosystems using available resources, which helped in calling on hands-on learning and reinforced practical applications of theoretical concepts. **Participant 5032** teaches the types of interaction and how they influence the balance of the ecosystem, and this fact has allowed the students to make a reflection; **Participant 5037** makes a relation between observation-experience to make relevant connections to learning.

While these efforts are laudable, indicating that there is still some way to go in providing clear evidence on a consistent basis of linking conceptual content to life experiences, such initiative taken by teachers creates a firm base for students to lay the knowledge learned at school into their daily life. Further emphasis on such linkage will enlarge the vistas of students' comprehension and appreciation of scientific concepts as related to the world around them.

This report is a thematic analysis of lesson plans and reflective reports from the ecology module, under the three main themes: Learners, Content, and Teaching and Learning. Indeed, findings indicate the positive impact of OER on the teacher participants' PCK.

The analysis evidences a commitment by participants in promoting inclusive and equitable learning environments. With well-planned, interactive, and supportive strategies, teachers planned activities that met the needs of all learners regardless of gender, socio-economic status, or ability. The most used methods of addressing learners' needs include differentiated instruction, Universal Design for Learning, and different ways of participation. While some of the respondents indicated equal participation of boys and girls, others reported that the level of participation was determined by socio-economic status; most especially, learners with special needs required special attention, along with modified teaching methodologies.

The probing questions and activities used by the teachers helped connect new learning to prior knowledge and experiences. Techniques such as recapitulation, reflection, and pre-assessment were considered quite helpful in the activation of prior knowledge, thus allowing smoother transitions toward new concepts. Videos and real-life examples created a better understanding of the concept; therefore, an inclusive learning environment with reduced misconceptions was created.

Inquiry-based learning activities of an exploratory and practical nature helped in developing scientific processes and competencies among students. Such experiences allowed learners to formulate hypotheses, make observations, and conduct scientific inquiry that enhanced their critical thinking and problem-solving skills.

Lesson designs supported higher-order thinking by incorporating critical and probing questions that took students further in analysis, synthesis, and evaluation. Differentiated strategies of questioning included both open-ended and multiple-choice questions to ensure activity and use of knowledge. Embedded reflective questioning in process-oriented learning activities enabled interactive experiences that fostered the development of critical thinking and a more profound level of understanding.

The instructional strategies employed facilitated active learning through cooperative groups, paired activities, and individual tasks that enhanced problem-solving and learning from peers. Most participants used a range of resources, including but not limited to smart TVs, YouTube videos, interactive media, charts, textbooks, and worksheets, to cater for different learning styles and increase student engagement.

The content and activities of the module also emphasised using the local ecosystem appropriately as a learning resource. Although only a few of the responding students were able to point out some of the resources that were available, there was evidence to indicate that the natural environment was aptly integrated into lesson plans in order to provide relevant and robust learning experiences which obliged students to be curious about and explore their natural environment.

Also, there were commendable efforts by participants to link conceptual content to students' present and real-life experiences, especially in the latter part of the lessons. Though concrete examples were few, the instances that were gathered showed strategies employed to create such links. Emphasis on integrating academic content with real-life experiences should be pursued relentlessly to further promote understanding and appreciation of scientific concepts by students in relation to their own environment.

In a nutshell, this analysis deems that while there is certainly more that can be done, the teachers have laid a broad foundation for an inclusive and intellectually stimulating learning environment. These findings point to continuous adjustment and reflexivity in teaching practices as needed to effectively align academic content with the experiences students have lived through.

2.7 Social learning in CoPs

2.7.1 Frequency of posts by participants

Table 2.5: *Frequency of posts by participants*

Role	**Number of posts**
Teacher participants	93
Teacher Educators	61
Total	154

2.7.2 Frequency of posts by contents and types

Table 2.6: *Frequency of posts by contents and types*

Posts by content	**Number of posts**
PCK	6
UDL	4
Technical	8
Communication/ Administrative	136
Total	**154**
Type of post	**Number of posts**
Text only	143
Images	10
External Links to other resources	0
Others (webinar zoom link)	1
Total	**154**

2.7.3 Qualitative dialogues/ discussion threads

The content of the chat primarily consists of reminders, requests for technical clarifications, and participants' feedback on the video lessons. There has been minimal discussion regarding the actual content of the module. Most interactions have focused on logistical matters and resolving technical issues, rather than engaging in deeper conversations about the subject matter. Below are a few examples of these interactions:

SM

09:15

Shekhar Mishra

Greetings to all esteemed professors and member teachers, a small suggestion on the condition set for completing each activity in the second module. As we are supposed to complete the activity at one go, it giving us some problem. 1. Firstly the activities are quite long and at times difficult to complete as we hav other obligation to attend. 2. Secondly, there is no way at present to re do the half done activity. This ma hamper the results later. 3. Frequent power fluctuation may also pose challenge in completing the activit one go. As such, we would be grateful if the condition to complete the activity at one go be lifted so that be able to fulfill the need la. Sorry for the inconvenience caused la

TP

18:00

Tshering Pem

In reply to this message

I have been doing all the activities sincerely but I do not think this is possible with students because it is totally aloof from our class action plan and does not align with our classes. It's one thing to arrange one class for the lesson but another to engage our student daily with these activities. I have never complained about this module being burdensome because I vouched to do it on my own. However, this here, engages students on daily basis, which is impossible atleast for me. I do not know about others. This is totally alienated from our normal schedule and literally diverts us from our course.

DW

18:21

DS(06)13-591 Yeshi Wangdi

In reply to this message

Laas la Dr

DD

22:14

Dr Kinzang Dorji

In reply to this message

Thank you for sharing your perspective. It's evident you've been putting in sincere effort into all the activities. Your dedication is truly commendable. I understand your concern about the alignment with your class action plan and the daily engagement of students with these activities. It's important for us to ensure that our approach remains cohesive with our course objectives. Your willingness to take on challenges independently is admirable. Let's explore how we can strike a balance between engaging students and staying aligned with your class objectives. Your input is invaluable in shaping our learning journey. I am indeed inspired by your commitment to maintaining the integrity of your class action plan while still being open to new challenges. Your proactive attitude is exactly what makes your learning environment so vibrant and dynamic. Embracing these opportunities for growth, even when they diverge from your usual routine, is a testament to your resilience and dedication to excellence. Let's harness this energy to find creative solutions madam. Together, we can turn every challenge into an opportunity for growth and innovation. Your positive mindset is a driving force in our collective success!

TP

:16

hering Pem

nce a lot of teachers raised the questions and were promised that they will put up with the committee, we ere not shared the follow up. So was just wanted to confirm. However, I hope the final module will not collide ith our vacation. Video recording will not be possible.

ST

:23

nerab Gonpawoong Tenzin

ST

nerab Gonpawoong Tenzin 07.05.2024 15:35:06

i have suggested before, video lesson recording consumes time and inconvenience for teacher, students and corder.

One topic are not covered

second those teacher who are not teaching respective class

Need of another teacher or friend to record

uploading video lesson

ST

:26

nerab Gonpawoong Tenzin

nd we are also busy with questions preparation for midterm la

:28

e would like to request, at least do away with video recording, rest we can adjust our time for you all even in ght la

K

:31

arma Rinzin

stead of reviewing other teachers lessons, we can do lesson reflection on ones own lesson la.

deo recording and exchanging is a huge inconvenient for us.

KC

13:39

Kelzqng Chodup

::10

sson Reviewer please do it at earliest please so that we move forward quickly.

KC

:58

lzqng Chodup

, uploading of video lesson is too much head ache. We have to record whole lesson. That's great but to
load it is really challenging la. The lesson recprding excess/go beyond more than 1 GB but for uploading its
na accept/ will be able to upload only 100gb. Upon exploring so much I could not even find any apps to
nvert 1GB to 100mb. The limits set to upload recorded video is only 100mb. With it what can we do it. Plz

2.8 Teacher Educator's reflection on the overall implementation (Moodle and CoP)

2.8.1 Participation of teachers

For example, from the outset, these teachers were already teaching in schools, in addition to many other tasks; hence it was not easy to maintain the motivation of these teachers throughout the period of module activities. Some participants felt overwhelmed recording and submitting video lessons. They also reported that there were serious issues with network connectivity. Although most of them had succeeded in uploading their lesson plans, reflections, and pre- and post-tests without any hitch, several show delays. This often resulted in many reminders by tutors to ensure submissions were on time.

Considering these challenges, an introduction of timeline and milestones could have guided the participants as to when to do what. In addition, support issues related to recording and submission of videos may reduce these problems that revolve around connectivity. Such flexibility regarding deadlines and alternatives for submission may, therefore, increase participation as well as reduce the stress of people who try juggling many responsibilities.

2.8.2 Challenges.

First, the teacher participants were already busy with teaching and other aspects of their role in school, which made it difficult to sustain their motivation throughout the duration of the module activities. Some participants complained that recording and submitting video lessons was too much work and that serious problems existed with network connectivity. Although most succeeded in uploading their lesson plans, reflections, and pre- and post-tests without any problem, a number did suffer from delays. This was indeed the case, which needed several reminders from tutors to accomplish on time.

In this way, having a structured timeline with well-defined milestones will enable the participants to plan their time more successfully. Giving technical support about video recording and submission may also reduce problems with connectivity. Flexibility in deadlines and alternative ways of submitting work will improve participation and alleviate stress among participants who are juggling multiple responsibilities.

2.8.3 Surprises

It was expected that the scores of the post-test would increase substantially, as compared to those of the pre-test. Surprisingly, the difference was very minimal and some of the subjects even recorded the same score. This was not the expected outcome, and it created a need for further investigation into what happened and the factors affecting the assessment results.

Surprisingly, the lesson plans and reflections submitted by the participants showed significant development in their Pedagogical Content Knowledge. This means that though their test scores might have shown moderate gains, the participants were able to further their ideas regarding appropriate teaching strategies and integration of content.

As elaborated in the detailed analysis above, the learnings extracted from the OER were huge for the participants. This helped their professional development as well as made them more reflective of their teaching methodologies. In the future, the programme might place more emphasis on reinforcing better methods of assessment and finding the gaps that exist between the theory and application to ensure that once PCK improves, it would definitely be reflected in measurable improvements in student learning.

2.8.4 Any changes required in the module design

We did not have any complaints on the module's content. Thus, we may assume that there is no urgent need in changes of the module design, at least, the content coincides well with the educational goals and expectations set by participants. In general, we received quite critical feedback on some aspects of the module, namely on the number of lesson plans required, expectations about video lessons, and the timeline for submission.

The volume of lesson plans could be too great and not allow them to devote sufficient time to each lesson. One or two participants had some issues with the format and expectations of video lessons; they require more clear guidelines on this and perhaps support. Not least, the timeline for the completion of assignments is somewhat tight, without enough time to thoughtfully prepare and execute an assignment.

Given this, it may be worth reconsidering the expectations regarding the number of lesson plans and video submissions required in the future. Reducing the quantity while maintaining quality could be beneficial. Extending the timeline for submissions would allow participants more time to process their learning and produce more comprehensive work. Based on the feedback received, we will further enhance the module to better support participants in their professional development.

Module 3: Cell Structure & Organisation

3.1 Introduction

The *Cell Structure and Organisation* module was initially developed by the Nigerian team for recent teacher graduates, aiming to prepare them to teach this content to grade IX students. Later, the Bhutan Biology team adapted the module to align with Bhutanese classroom contexts for their participating Biology teachers. This foundational module aims to deepen teachers' knowledge in cell biology, enhancing their subject matter expertise, pedagogical content knowledge (PCK), and familiarity with technology and inclusive pedagogies to address the diverse learning needs of all students. The module emphasises equipping participants with skills to understand, engage with, and teach concepts in cell biology while fostering problem-solving and decision-making abilities about the natural world. In addition to PCK, the module integrates principles from Universal Design for Learning (UDL) to promote inclusivity in Biology education, ensuring accessibility for diverse learners. Technology is a core aspect, supporting teaching, learning, and assessment processes within an activity-based learning framework. The module is structured into five distinct units.

a. Timeline of implementation in the country

According to the research calendar, the module was scheduled for a six-week implementation. The module was opened to the participants on July 16 and closed on October 15, 2024.

b. Learning objectives

- Describe various types of cells from plants, animals and other living organisms;
- Differentiate unicellular and multicellular organisms;
- Trace the discovery of the cell;
- Trace the historical development of the cell theory;
- State the modern cell theory;
- Understanding of the structure of a cell which is the functional unit of a living organism;
- Demonstration of knowledge of tools and methods used in the study of cell structure;
- 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- 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;
- Explain the concept of cell differentiation;
- Describe the importance of cell differentiation;
- Describe the differences between cells, tissues, organs and body systems; and
- Draw and label tissue systems in monocots and dicots.

c. Number of units

The module has five units namely: The Cell, Types and Characteristics of Cells, Animal Cell, Plant Cell and Cell Differentiation.

d. Concepts covered

Cell theory, prokaryotic, eukaryotic, organelles, unicellular, multicellular, cell differentiation, monocot, dicot

e. Resources - activities, readings

Reading, observation, recording, self-assessment, listening to video, work sheet, practical work, discussion.

f. Nature and purpose of assessments

Formative and summative assessments were employed throughout the module to evaluate the participants' learning progress. The module began with a mandatory pre-test consisting of 45 multiple-choice questions (MCQs) focused on three key themes: learners, content, and teaching-learning. Participants were required to complete this pre-test within one hour before proceeding with the module. Each of the four units included various formative assessment activities such as quizzes, short answer writing, reflections, and practical activities with students. At the end of the module, participants were required to complete a similar 45-MCQ post-test, also within an hour. Additionally, participants had to submit two lesson plans on concepts related to the module's content and one reflection after implementing these lesson plans. Beyond tutor assessments, participants' lesson plans and recorded teaching sessions were evaluated by an assigned peer. Out of the 36 teachers involved, eight were selected as a focus group sample. Their lesson plans and teaching were evaluated by the tutor, officials from the Ministry of Education and Skills Development (MoESD), and their supervisors. All evaluations were conducted using a standardised rubric that emphasised learners, content, and teaching-learning effectiveness.

3.2 Course completion rate

3.1.1 Overall completion

All the thirty-six (36) participants completed the course successfully.

3.1.2 Assessment completion rate (Data available from Moodle platform)

Table 3.1: *Teachers' assessment completion rate*

Area of assessments	Teachers	Total
Pre-test	36	36
Session plans	36	36
Reflection	36	36
Post-tests	36	36

3.3 Time spent on the course platform

Table 3.2 below depicts 30.56% of participants spent less than 5 hours, 50% spent between 5-10 hours, and 19.44% spent between 10-20 hours to complete the module

Table 3.2: *Time spent by teachers on Moodle platform*

Hours spent	Teachers	%
Less than 5	11	30.56
5 to 10	18	50
10 to 20	7	19.44
21 to 30		
More than 30		
Total	**36**	100

3.4 Change from pre- and post-test

Figure 3.1a represents the pre-test and post-test average scores for a group of 36 teacher participants. In the pre-test, participants achieved an average score of 26.33. Following the intervention or instructional period, the average score increased to 27.58 in the post-test. This improvement of 1.25 points suggests a positive, though modest, effect of the intervention on participants' performance. The increase in post-test scores indicates some level of learning gain or skill enhancement among the participants. Further analysis may be necessary to determine the statistical significance of this change and its practical implications.

Building on the mean score analysis, Figure 3.1b illustrates the trend of individual pre-test and post-test scores, revealing a diverse range of outcomes among participants. These in-service biology teachers, balancing regular teaching duties alongside this professional development programme, showed varied responses to the intervention. While some demonstrated considerable improvement such as participants who scored in the low to mid-20s in the pre-test and improved to the high 20s or even 30s in the post-test-others exhibited minimal gains or even declines in performance (Figure 3.1b).

The mixed results may be partly attributed to external factors that affected the teachers' ability to consistently engage with the professional development. Many participants, particularly those in rural schools, faced challenges such as slow internet connectivity, which could limit access to online resources or collaborative activities. This variability in internet access and teaching responsibilities may have influenced individual performance, with some teachers benefiting more readily from the intervention than others. Overall, the data highlights both the positive impact of the intervention on average and the challenges in providing equitable learning support under varying professional and infrastructural conditions.

Figure 3.1a *Mean of Pre-test vs. Post-test Scores (n=36).*

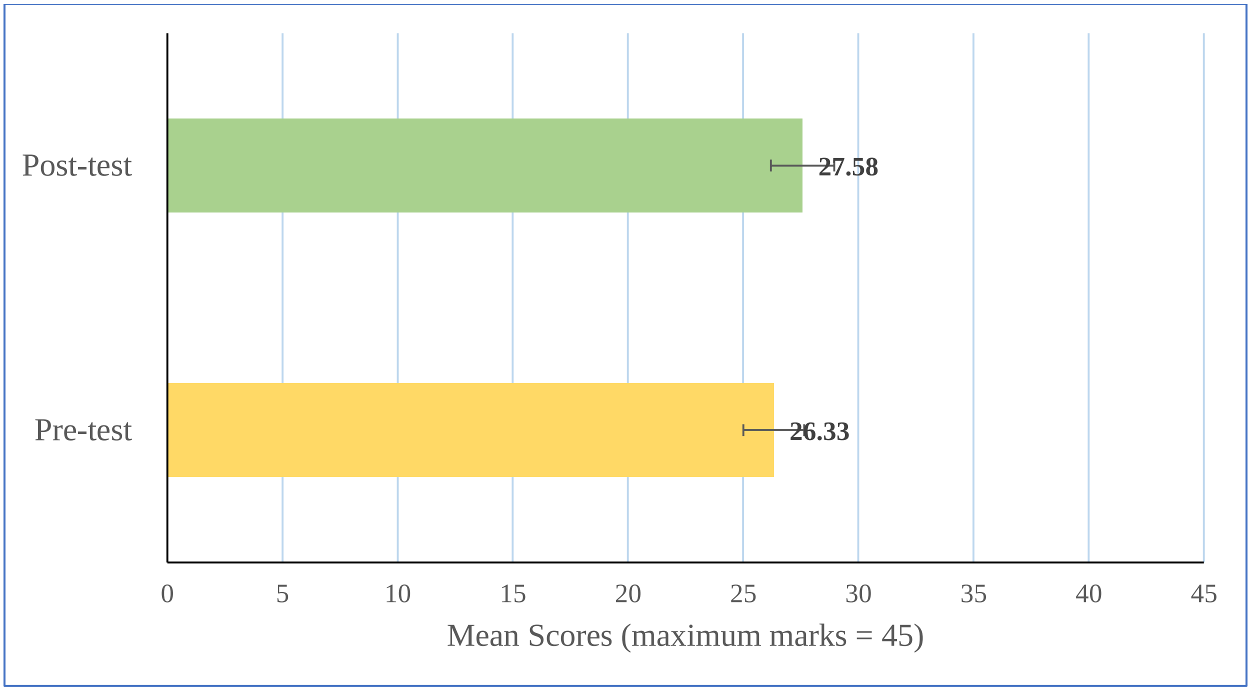
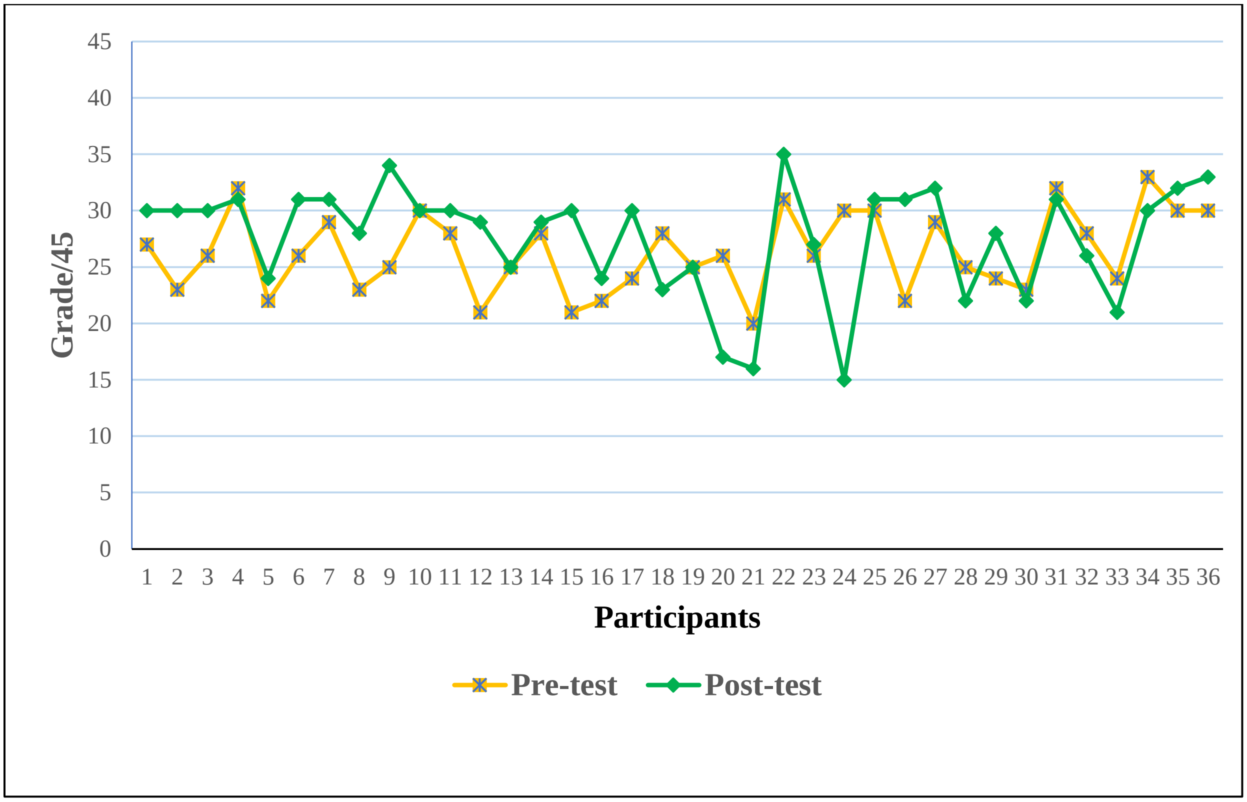


Figure 3.1b *Line graph showing the distribution of Pre-test and Post-test scores for each participants (n=36).*



The data presented in the Table 3.3 illustrates the distribution of teacher proficiency levels based on pre-test and post-test assessments. Proficiency is categorised into four levels: Novice (0-25%), Emerging (26-50%), Proficient (51-75%), and Accomplished (76-100%).

The data indicates a modest improvement in participants' proficiency between the pre-test and post-test assessments. While the number of participants in the 'Emerging' category remained unchanged, there was a slight decrease in those classified as 'Proficient,' suggesting that some participants progressed beyond this level. This is supported by the emergence of participants in the 'Accomplished' category in the post-test, with 2 individuals achieving the highest proficiency level (76-100%), a category that had no representation in the pre-test. The absence of participants in the 'Novice' category throughout both assessments suggests that all participants had at least a basic understanding of the material from the start. Overall, the data reflects a positive shift towards higher proficiency levels, though the change is not substantial across all categories.

Table 3.3. *The proficiency level of teacher participants based pre-test and post-test data*

Proficiency Level	Score Range (%)	Pre-test	Post-test
Novice	0-25	-	-
Emerging	26-50	6	6
Proficient	51-75	30	28
Accomplished	76-100	-	2

3.5 **Practice** (Session plan and reflections):

Table 3.4 presents the mean and standard deviation (SD) for key themes related to learners, content, and teaching and learning practices, based on responses from 36 participants.

In the **Learners** category, the theme "Promote inclusion and equity" has a mean of 1.53 (SD = 0.69), indicating a moderate focus on inclusive practices, although with notable variability. The themes "Build on students' prior conceptions" and "Address misconceptions and areas of difficulties" received lower means of 1.14 (SD = 0.54) and 0.73 (SD = 0.80), respectively, reflecting less emphasis on these critical teaching strategies.

For the **Content** category, the theme "Use processes on science and mathematics" scored 1.30 (SD = 0.71), while "Facilitate higher order thinking" and "Plan to build students' competences" had means of 1.11 (SD = 0.63) and 1.19 (SD = 0.70), indicating some recognition of the need for process-oriented learning and competence development, but limited implementation.

In the **Teaching and Learning** category, "Use instructional strategies for active learning" achieved a mean of 1.49 (SD = 0.57), suggesting a positive inclination toward engagement, while "Use multiple representations of content" scored the highest at 1.63 (SD = 0.48). Conversely, "Use locally available materials" had a low mean of 0.43 (SD = 0.69), indicating minimal emphasis on local resources. The theme "Link conceptual content to students' everyday life experiences" scored 1.06 (SD = 0.75), highlighting the need for stronger connections between academic content and real-life contexts. Overall, the findings reveal strengths in active learning strategies and content representation, alongside critical areas for development, particularly in addressing misconceptions and leveraging local resources.

Table 3.4: *Mean and Standard Deviation (SD) of Key Themes Related to Learners, Content, and Teaching and Learning Practices (n=36)*

Category	Theme	Mean	SD
1. Learners	P1.1 Promote inclusion and equity	1.53	0.69
	P1.2 Build on students' prior conceptions	1.14	0.54
	P 1.3 Address misconceptions and areas of difficulties	0.73	0.80
2. Content	P2.1 Use processes on science and mathematics	1.30	0.71
	P2.2 Facilitate higher order thinking	1.11	0.63
	P2.3 Plan to build students' competences to meet the goals of teaching science/ mathematics	1.19	0.70
3.Teaching and Learning	P3.1 Use instructional strategies for active learning	1.49	0.57
	P3.2 Use multiple representations of content	1.63	0.48
	P3.3 Create opportunities for multiple modes of expression	1.38	0.66
	P3.4 Use locally available materials	0.43	0.69
	P3.5 Link conceptual content to students' everyday life experiences and prior knowledge	1.06	0.75

The quantitative findings above indicate strong teacher practices in promoting inclusion and employing active learning strategies, which are corroborated by qualitative insights below:

Thematic Analysis of Lesson Plans and Reflections for Cell Structure & Organisation Module

The following report presents a thematic analysis of lesson plans and reflective reports derived from an ecology module, organised around three overarching themes: Learners, Content, and Teaching and Learning. This approach allows the nuances of how these elements interconnect and contribute to the overall teaching and learning process to be examined. By giving central focus to these themes, the study attempts to contribute to a robust evidence base concerning the impacts on PCK in these teacher participants of the module.

The **Learners theme** refers to the needs and backgrounds of students and how teachers make modifications in their strategies in order to build an inclusive and equitable learning environment for all their students. This analysis displays the level of awareness of, and response to, the distinctive differential challenges of the students' circumstances in terms of gender, socio-economic status, and differential abilities. The teachers are, through differentiated instruction and application of UDL principles, consciously creating an inclusive space conducive to active participation and engagement of all learners.

The **Content theme** probes the currency and accessibility of the content delivered in the cell and organisation module. The analysis takes into consideration how well the content aligns with the students' prior knowledge and life experiences. It does go on to emphasise, however, that incorporation of media and other resources, like videos and real-life examples, exploring the ecosystem locally, makes learning even more relevant and allows for deeper connections with the subject itself. This thematic focus also explores how teachers address misconceptions and scaffold learning in such a way that concepts are understandable and engaging for all students.

The third theme of **Teaching and Learning** considers the kind of teaching strategies utilised within the classrooms and how overall effective these are in ensuring student engagement with teaching and learning. The analysis reveals that the most striking features are active learning methodologies, such as collaborative group work, hands-on activities, and inquiry-based approaches. These techniques guarantee that students develop critical thinking and problem-solving skills, provide an avenue for peer learning, and stimulate dialogue among peers. It also points to OER integration as an important factor enhancing teachers' PCK by creating dynamic and varied learning experiences, able to accommodate different learning styles.

The result of this thematic analysis therefore suggests that the use of OER has brought very profound positive impacts on the PCK of the teacher participants. By looking at the interplay of learners, content, and teaching methodologies, this report provides an insight into a range of ways in which educators may enrich their practice toward creating an inclusive, high-achieving learning environment. This report underlines the importance of continuous professional development and reflective practice in supporting teachers to adopt approaches that will make a difference in improving the experiences and outcomes of their learners.

This section provides a thematic analysis of lesson plans and reflective reports from a module on Cell Structure and Organisation, organised around three main themes: Learners, Content, and Teaching and Learning. By focusing on these themes, the study explores how each element contributes to the overall educational experience, aiming to build a strong evidence base for the impact on teachers' pedagogical content knowledge (PCK) within this module. The "Learners" theme examines how teachers address the diverse needs and backgrounds of students, including factors like gender, socio-economic status, and varying abilities. The analysis reveals that teachers actively create an inclusive environment through differentiated instruction and the principles of Universal Design for Learning (UDL), promoting engagement and participation for all students. The "Content" theme assesses the relevance and accessibility of the material, considering how well it connects to students' prior knowledge and experiences. Teachers enhanced learning by incorporating media, local ecosystem examples, and scaffolding to address misconceptions, making complex topics engaging and relatable. The "Teaching and Learning" theme highlights strategies that foster active learning, such as group work, hands-on activities, and inquiry-based methods, which cultivate critical thinking, problem-solving, and peer collaboration. Open Educational Resources (OER) were particularly noted for enhancing teachers' PCK by diversifying learning experiences to meet varied learning styles.

In summary, the report suggests that using OER significantly enriches teachers' PCK, supporting inclusive, high-quality learning environments. It emphasises the importance of ongoing professional development and reflective practice in helping teachers adopt methods that improve learning outcomes and student engagement.

Learners

Equity and Inclusion: The participants' approaches to promoting inclusion and equity in the classroom reveal a strong commitment to creating engaging, supportive environments that cater to the diverse needs of all students. Some modified the classroom layouts for example, arranging desks into clusters (Participants 5000, 5006, and 5030)—in order to encourage collaboration and interaction. Strategies to cater to different learning styles were also often mentioned; for instance, slides and infographics supported visual learners, while discussions benefited auditory learners (Participant 5004). Many respondents also provided targeted support to low achievers and the less participatory students, creating focused groups for remedial sessions (Participant 5002) and using mixed-ability groupings to promote peer learning (Participant 5003). Emotional support was a priority, where several participants utilised encouragement, positive reinforcement, and personalised feedback to help anxious students (Participants 5008, 5009, and 5013). The use of such techniques as mindfulness and relaxation exercises (Participants 5009 and 5016) further supported students with stress in the face of complex content. Participants also insisted on creating a physical space where students can feel safe to communicate freely, checking in with the quieter ones regularly, and giving individualised feedback (Participant 5032). These put together show a balanced commitment to inclusive education that makes every student feel involved, supported, and valued.

Build on students' prior conceptions: The teacher participants demonstrated various methods for assessing students' prior knowledge, primarily through activation questions and pre-lesson quizzes to gauge familiarity with foundational concepts. Most participants began with quick, targeted questions or discussions to connect students' existing understanding to new material. For instance, Participants 5003, 5004, and 5005 used image prompts, verbal quizzes, or matching activities on cell structures to test students' knowledge. Several teachers, like Participant 5006, incorporated relatable, real-life connections—such as muscle function and injuries—to make abstract concepts more accessible. Participant 5007 conducted individualised questioning to assess students' understanding of prokaryotes and eukaryotes, while Participant 5014 combined quizzes with discussions about cell types and structures to clarify any misconceptions. Visual aids also played a role, as Participant 5025 used images of various cells to encourage identification and comparisons. Other participants, such as 5026, implemented structured tools like KWL charts, helping students articulate their current knowledge, set learning goals, and reflect on new insights. Together, these strategies reveal an intentional approach to activating prior knowledge, ensuring students are better prepared for complex topics by connecting to what they already know.

The teacher participants demonstrated various methods for assessing students' prior knowledge, primarily through activation questions and pre-lesson quizzes to gauge familiarity with foundational concepts. Most of the participants started with short, focused questions or discussions to relate students' prior knowledge to new information. For example, Participants

5003, 5004, and 5005 used visual prompts, an oral quiz, or matching activities with regards to cell structures to test students' knowledge. Many of the teachers, like Participant 5006, included relatable, real-life connections—for example, muscle function and injury—to make abstract concepts more concrete. Participants 5007 and 5014, in turn, individually questioned students' knowledge of prokaryotes and eukaryotes and combined quizzes with discussions over types and structures of cells to clarify any misconceptions. Another example is the use of visual aids, as in the case of Participant 5025, who took pictures of many types of cells, encouraging identification and comparison. Other participants, such as 5026, used structured tools like KWL charts to help students clarify their existing knowledge, set learning goals, and reflect on new insights. Taken together, these are purposeful strategies for tapping prior knowledge, ensuring students are far better prepared for complex themes through connection with what they already know.

Address misconceptions and areas of difficulties: As for correcting misconceptions, teacher participants were not consistent in their effectiveness in eliciting student preconceptions through the use of pre-tests, quizzes, discussions, and activities that specifically targeted these. Others acknowledged that misconceptions existed without indicating specific strategies to deal with them. For example, Participant 5000 pointed out that students often believe that specimens will appear exactly as they appear in books; no action was taken on this belief. Examples of these include Participant 5008, who had to discuss and clarify such misconceptions as the fact that plant cells are green because of the chloroplasts and that animal cells do not have vacuoles. Participant 5010 conducted experiments with his students to test and correct a common misconception that the rate of photosynthesis increases linearly with light intensity. Participants 5003 and 5014 recognised complex misconceptions, such as differences between prokaryotic and eukaryotic cells and functions of organelles, but suggested that more overt strategies for addressing these with explanations or 3D models would be helpful. Some teachers, like Participant 5034, used discussions to dispel the notion that cell efficiency is related to cell size while Participant 5036 related cell concepts to students' everyday lives, for example, by relating cell membranes to filters. Taken together, these strategies demonstrate an awareness of common cell biology misconceptions, although more uniform methods to address these misconceptions could further improve learning outcomes.

Content

Use processes on science: The implementation of scientific processes in lessons aimed at building student competencies in line with science teaching goals was evident in various activities, although the explicit procedures for fostering hypothesising and conjecture were often underdeveloped in lesson plans and reflections. Activities encouraged the collaborative mode of learning, where Teacher Participant 5000 pointed out that students "complete the worksheet in groups/pairs and conduct assessment for other groups/pairs" in order to interact with the diagrams representative of the topic studied in science. Tasks intended for the construction of explanations, as stressed by Teacher Participant 5002, allowed students to reflect on how "different cells have specific shapes adapted to carry out specific functions" by means of watching videos and reading notes.

Activities that allowed the students to do some observation and hypothesise included the following, when Teacher Participant 5004 shared that students used microscopes to "observe prepared slides of different cell types" and then discussed observations as evidence of cellular composition. Participant 5008 organised debates in organelle function and allowed students to work out "scientific reasoning." In the same light, Participant 5036 elaborated on how she applied microscopes to have students "form hypotheses about cell structures and discuss these in groups to justify their observations. Other activities involved hands-on modelling, as illustrated by Teacher Participant 5005, who asked students to "develop and refine models of animal cells" and engage in argumentation through presenting and justifying their models. The above examples are a starting point in building hypothesis-driven learning, but the approach will be even more effective once more explicit steps for hypothesising have been integrated to deepen the scientific thinking of the students. Even so, these activities showed several ways of interactive approaches that favoured engagement and comprehension: starting with group discussions up to the use of multimedia resources, which provided an elementary approach toward improving scientific competence.

Facilitate higher order thinking: The embedding of higher-order thinking was reflected in how teacher participants planned and incorporated leading open-ended questions into the lessons and activities. A few examples showed a more design thinking and inquiry-based learning approach to the development of students' analytical and evaluative capabilities. For example, Teacher Participant 5002 asked learners to "draw and explain with one example to justify why cells are of different shapes and sizes," coupled with constant questioning for reflection. According to Teacher Participant 5005, the hands-on activities combined with peer interaction helped students "grasp scientific concepts and develop critical thinking skills." In the approach taken by Teacher Participant 5006, "steps in design thinking" were overtly included, while Participant 5015 focused on aspects of NOS, citing observation and inquiry during cell exploration sessions as "powerful experiences that promote creativity, imagination, and critical thinking."

Other open-ended questions invoked only curiosity and deeper interest, such as Teacher Participant 5016, who asked, "Have you ever wondered how the small structures inside cells help the cell do its job and keep life going?" This led students to think about mechanisms underlying cellular processes. In developing comparison skills, Teacher Participant 5026 also led a discussion on "the similarities and differences between plant and animal tissues," which further improved the analytical powers of the students. These approaches reflect a structured effort toward instilling higher-order thinking by guiding students through thoughtful inquiry, experiential learning, and collaborative exploration.

Plan to build students' competences to meet the goals of teaching science: The activities included within this lesson where to develop science competence by illustrating scientific processes in an iterative manner, driven by inquiry; however, only a few concrete examples could be provided which explicitly outlined clear competence-building strategies. Although an inference could be drawn from several activities on scientific inquiry, experimentation and argumentation. For example, Teacher Participant 5002 had the learners "read the book and watch videos and make notes," then "draw and explain" differences in the shape and size of cells on chart paper, where both analytical and presentation skills were being employed. In another case, Teacher Participant 5003 asked students to compare diagrams of prokaryotic and eukaryotic cells, then develop "comparative charts" and debate their findings, whereby observation, analysis, and reasoning were facilitated.

More hands-on exploration was found in activities led by Teacher Participant 5004, who "provided feedback during microscope observations" and prompted students to explain what they had found. Teacher Participant 5005 focused on in-class activities that developed "critical thinking skills through hands-on experience and peer interaction." Teacher Participant 5009 extended this to ask students to create models of animal cells and label organelles, incorporating practical skills and scientific literacy. The teacher participant 5014 used concept mapping to extend knowledge about the cellular components at the "cell membrane, cytoplasm, organelles, protein synthesis, and energy production."

Other examples, such as those for Teacher Participants 5016 and 5032, involved visual modules, videos, and microscope-related activities to establish foundational knowledge. For instance, students asked why the cells looked different under different conditions of the microscope, which evoked discussion that emphasised experimental design and attention to observation. In total, these examples suggest an implicit attempt to establish scientific competencies through engaging students in the skills of observation, analysis, argumentation, and presentation that are foundational in science.

Teaching and Learning

Use instructional strategies for active learning: The classroom activities centralised instructional strategies for active learning, whereas the majority of activities organised in small groups encourage collaboration, discussion, and individual contribution. Overall, teacher participants used a combination of group, pair, and individual tasks; students could analyse data, solve problems, and deepen conceptual understanding together. For instance, it was Teacher Participant 5003 who referred to "mixed-ability groupings" that allowed for everyone's inclusion, while Teacher Participant 5004 combined "whole-class teaching, model-building in groups, and labelling diagrams individually," showing quite a well-rounded approach. Teacher Participant 5008 went further to state that group work allowed for "discussion and collaborative learning" since students actively discussed ideas, and that is the premium placed on teamwork across the board.

Pre- and post-survey data suggest that many teachers then used inquiry stations and manipulatives to engage the learners further. For example, Teacher Participant 5009 established "inquiry stations" around the classroom, one for each organelle under study, where students explored resources and then talked about the materials in small groups. In a similar activity, Teacher Participant 5010 had student groups conduct experiments whereby materials were provided, variables were discussed, and then data was collected as a whole class. In fact, in the instance of Teacher Participant 5016, students in groups observed cell slides and recorded their findings on worksheets shared between members so that learning was further reinforced by collaboration and documentation.

A few included different modes, such as role-playing and analogy explanations, to provide other ways to learn or understand the lesson. For example, Teacher Participant 5018 assigned each group posters on prokaryotes and roles in environmental health and had presentations to inspire discussion and give more relevance to the subject matter. Participants, like Teacher Participant 5035, also added field visits during which time students would work together on assignments and problem-solving activities, thus adding even more to the experiential learning mode.

The whole-class instruction and individual activities served strategic purposes, complementing the group work. For example, in the aftermath of the group activities, Teacher Participant 5034 had individual written activities, while Teacher Participant 5036 combined observations made through microscopes with group discussion of results. This was also echoed in the layout of the classroom: Teacher Participant 5037 had the furniture laid out according to mixed gender and ability mixings as specified by the Kagan method in order to ensure variety in peers as well as an encouraging learning environment. The Combined approach provides, in exquisite detail, an effective and varied instructional strategy for enabling active learning, peer interaction, and the development of critical thinking within science education.

Use of multiple representations: Teachers tended to use different teaching and learning materials, hence giving multiple representations for the different learner needs. Most technology users among the sample group include teachers who make use of YouTube videos, PowerPoint presentations, and other such digital tools to provide an interactive, multimodal experience, enabling students to participate actively with the content in formats that best suit their learning preferences. One can note from the media used in the lesson by Teacher Participant 5003, "a PowerPoint presentation on cell structures, diagrams of prokaryotic and eukaryotic cells, and worksheets" enriched engagement by making visual and text-based resources available. Another example is Teacher Participant 5037, who was using a "projector and laptop" to show a YouTube video about stem cells, combining visual and audio stimuli.

Manipulatives and other hands-on tools, like microscopes, slides, and modelling materials, were also more regularly employed. Teacher Participant 5004 used "microscopes, prepared slides of various cells, cell diagrams," adding a somewhat hands-on element so students could relate the abstract to the observed reality. Teacher Participant5026 also supported such a method by using "analogies" and "demonstrations"-a clay model analogy-to explain in an intelligible and relatable way the more difficult concept of the differentiation of cells.

Diagrams, charts, and pictures were essential in reinforcing key ideas and for catering to students who learn best visually. Teaching Participant 5008 explained that the students "liked hands-on activity of completing the worksheet the most," as it enabled them to think innovatively and make a connection with the content. Other teachers, like Participant 5015, employed short videos regarding cell theory and microscopy history to put learning into a wider scientific context.

In all, teacher participants have been resourceful in the blending of digital, tactile, and visual tools to afford differentiated learning experiences for the students. This multimodal approach ostensibly supports a diversity of learning styles in the engagement of students in scientific concepts in meaningful and memorable ways.

Create opportunities for multiple modes of expression: These lessons provided multiple opportunities for students to demonstrate their understanding through independent and collaborative work. Presentation of groups and individuals, modelling, labelling of diagrams, and drawing were used by the teacher participants, while giving feedback through peer reviews. These Activities across the board enabled the articulation of learning by students visually, verbally, and practically, while peer assessments and teacher-guided feedback supported iterative learning and self-reflection.

Most lessons continually monitored progress with question-and-answer techniques; this would be indicative of continual or formative checks throughout the lesson. For example, Teacher Participant 5001 had learners "assess other activity sheets with proper feedback and suggestion," which in themselves helped promote peer learning. Meanwhile, the Teacher Participant 5004 mixed fast quizzes and group discussions to review "key concepts about cell theory and the relationship between cell structure and function." On the other hand, the Teacher Participant 5003 also used "group presentations along with a worksheet quiz," by which she was not only able to evaluate learning but also to engage students in active learning.

Creative activities included drawing, model-making, and concept mapping-all of which allowed students to visually and kinaesthetically represent and further solidify understanding. For example, Teacher Participant 5008 requested that students complete "an in-depth diagram of an animal cell with labelled parts and their functions, “providing the student with a more extensive understanding about cellular structure. Similarly, Teacher Participant 5014 used concept mapping to relate vocabulary terms such as "cell membrane, cytoplasm, organelles, protein synthesis, and energy production, “enabling a larger conceptual understanding.

These varied methods created a three-dimensional learning process for the students that encouraged various ways of learning and allowed active participation. Teacher participants reflected on these strategies and how well-structured questioning combined with practical, visual, and verbal expressions of learning.

Use locally available materials: Only a limited number of respondents actually reported on the use of locally available materials in either building models and use of learning space within the community during some activities. Majority have not specified the use of local materials in their classroom teaching and learning process.

Link conceptual content to students' everyday life experiences and prior knowledge: Lesson plans and reflections showed attempts to relate conceptual science content to students' everyday life experiences and prior knowledge, especially towards the end of the lessons. Although Concrete evidence was a little limited, the reflections and details of lessons which were available indicated that teachers incorporate suitable applications which would enhance greater understanding and appreciation of the content for the students.

For instance, Teacher Participant 5002 mentioned that through this online laboratory simulation, students "were able to appreciate the minute structure involved in the functioning of the smallest organisms to the largest organism on the planet," thereby reaching an understanding of cellular organisation and the importance of its various organelles. This supported students in viewing how cellular structures apply to realistic biological situations. In a similar vein, Teacher Participant 5002's worksheet asked students to "explain how different cell shapes are adapted to their functions," meaning that abstract cellular concepts were embedded within functional and observable phenomena.

Hands-on activities and model-building also played an important role in relating classroom content to practical understanding. AsParticipant5005, Teacher, reflected, creating models of animal cells solidified in the students not only a stronger concept of cell structures, but also "encouraged collaboration and creativity," giving a more relatable, tangible aspect to the science of cells. According to Teacher Participant 5032, the students became very interested in using microscopes to explore the cells, an exercise that "developed their skills in handling microscopes," thereby providing hands-on practical experience in connecting scientific inquiry into day-to-day life tools and techniques.

Moreover, other teachers integrated design thinking to incorporate practical dilemmas into their lessons. Teacher Participant 5006 also mentioned that the effective employment of design thinking was because "Design Thinking was based on real-life application," which further drilled on the impact of relating science content to the familiar. In sum, an example from Teacher Participant 5013 showed how a student's observation manages to connect cell functions with "dignity of labour," a metaphor that bridges from conceptual knowledge of cell organelles to values in society and functional roles.

Although these connections were somewhat sporadic, examples indicated an effort on the part of teachers to help students connect the science concepts in ways that will help them understand that science is relevant and applies beyond the academic classroom setting.

3.6 Social learning in CoPs

3.6.1 Frequency of posts by participants

A total of 150 post were shared through the telegram group chat out of which 105 were from the teacher participants and 45 from the teacher educators (Table 3.5).

Table 3.5: *Frequency* of posts by participants

Role	**Number of posts**
Teacher participants	105
Teacher Educators	45
Total	150

3.6.2 Frequency of posts by content and types

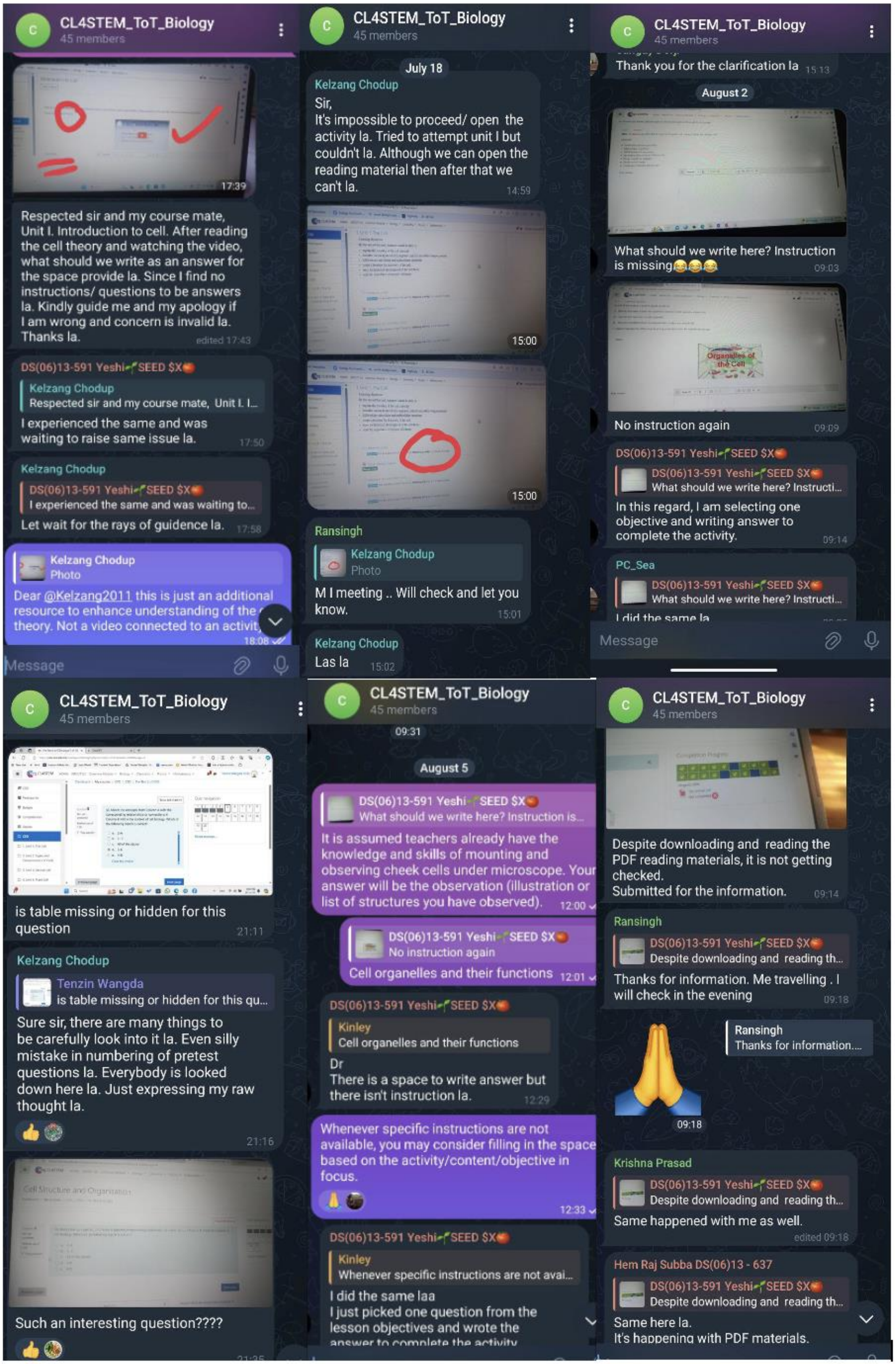
Most of the post under content were related to communication/administration (81.7%) followed by technical (15.0%) and there were none related to UDL. While based on the type of post, maximum was text (80.6%) followed by images (16.1%) (Table 3.6).

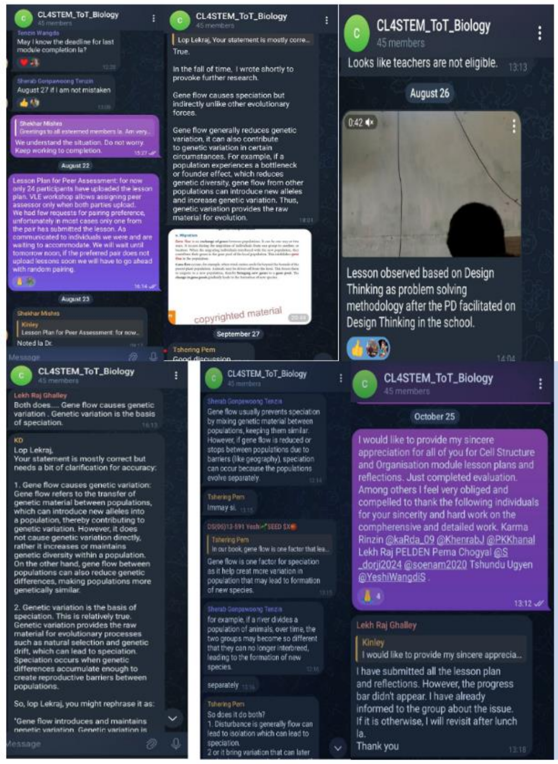
Table 3.6: *Frequency of posts by contents and types*

Frequency of posts by contents	**Number of posts**
PCK	5
UDL	
Technical	25
Communication/ Administrative	120
Total	**150**
Frequency of post by types	**Number of posts**
Text only	122
Images	25
External Links to other resources	3
Others (webinar zoom link)	
Total	**93**

3.6.3 Qualitative dialogues/ discussion threads

Beyond sharing instructions, announcements, and addressing technical issues, the chat also includes a variety of exchanges between participants and tutors. The participants have shared critical comments and posed insightful questions, while the tutors have offered clarifications and guidance. However, much of the interaction has remained logistical, focusing primarily on resolving technical or procedural issues rather than diving deeply into the module's content. Below are a few examples that illustrate these types of interactions:


CL4STEM_ToT_Biology
45 members
17:39
Respected sir and my course mate, Unit I. Introduction to cell. After reading the cell theory and watching the video, what should we write as an answer for the space provide la. Since I find no instructions/ questions to be answers la. Kindly guide me and my apology if I am wrong and concern is invalid la. Thanks la.
edited 17:43
DS(06)13-591 Yeshi SEED $X
Kelzang Chodup
Respected sir and my course mate, Unit I. I...
I experienced the same and was waiting to raise same issue la.
17:50
Kelzang Chodup
DS(06)13-591 Yeshi SEED $X
I experienced the same and was waiting to...
Let wait for the rays of guidence la.
17:58
Kelzang Chodup
Photo
Dear @Kelzang2011 this is just an additional resource to enhance understanding of the theory. Not a video connected to an activit
18:08
Message
CL4STEM_ToT_Biology
45 members
July 18
Kelzang Chodup
Sir,
It's impossible to proceed/ open the activity la. Tried to attempt unit I but couldn't la. Although we can open the reading material then after that we can't la.
14:59
15:00
15:00
Ransingh
Kelzang Chodup
Photo
M I meeting .. Will check and let you know.
15:01
Kelzang Chodup
Las la
15:02
CL4STEM_ToT_Biology
45 members
Thank you for the clarification la
15:13
August 2
What should we write here? Instruction is missing😂😂😂
09:03
Organelles of the Cell
No instruction again
09:09
DS(06)13-591 Yeshi SEED $X
DS(06)13-591 Yeshi SEED $X
What should we write here? Instructi...
In this regard, I am selecting one objective and writing answer to complete the activity.
09:14
PC_Sea
DS(06)13-591 Yeshi SEED $X
What should we write here? Instructi...
I did the same la
Message
CL4STEM_ToT_Biology
45 members
is table missing or hidden for this question
21:11
Kelzang Chodup
Tenzin Wangda
is table missing or hidden for this qu...
Sure sir, there are many things to be carefully look into it la. Even silly mistake in numbering of pretest questions la. Everybody is looked down here la. Just expressing my raw thought la.
21:16
Cell Structure and Organization
Such an interesting question????
CL4STEM_ToT_Biology
45 members
09:31
August 5
DS(06)13-591 Yeshi SEED $X
What should we write here? Instruction is...
It is assumed teachers already have the knowledge and skills of mounting and observing cheek cells under microscope. Your answer will be the observation (illustration or list of structures you have observed).
12:00
DS(06)13-591 Yeshi SEED $X
No instruction again
Cell organelles and their functions
12:01
DS(06)13-591 Yeshi SEED $X
Kinley
Cell organelles and their functions
Dr
There is a space to write answer but there isn't instruction la.
12:29
Whenever specific instructions are not available, you may consider filling in the space based on the activity/content/objective in focus.
12:33
DS(06)13-591 Yeshi SEED $X
Kinley
Whenever specific instructions are not avai...
I did the same laa
I just picked one question from the lesson objectives and wrote the answer to complete the activity
CL4STEM_ToT_Biology
45 members
Despite downloading and reading the PDF reading materials, it is not getting checked.
Submitted for the information.
09:14
Ransingh
DS(06)13-591 Yeshi SEED $X
Despite downloading and reading th...
Thanks for information. Me travelling . I will check in the evening
09:18
Ransingh
Thanks for information....
09:18
Krishna Prasad
DS(06)13-591 Yeshi SEED $X
Despite downloading and reading th...
Same happened with me as well.
edited 09:18
Hem Raj Subba DS(06)13 - 637
DS(06)13-591 Yeshi SEED $X
Despite downloading and reading th...
Same here la.
It's happening with PDF materials.



3.7 Teacher Educator's reflection on the overall implementation (Moodle and CoP)

3.7.1 Participation of teachers

For example, from the outset, these teachers were already teaching in schools, in addition to many other tasks; hence it was not easy to maintain the motivation of these teachers throughout the period of module activities. Some participants felt overwhelmed recording and submitting video lessons. They also reported that there were serious issues with network connectivity. Although most of them had succeeded in uploading their lesson plans, reflections, and pre- and post-tests without any hitch, several show delays. This often resulted in many reminders by tutors to ensure submissions were on time.

Considering these challenges, an introduction of timeline and milestones could have guided the participants as to when to do what. In addition, support issues related to recording and submission of videos may reduce these problems that revolve around connectivity. Such flexibility regarding deadlines and alternatives for submission may, therefore, increase participation as well as reduce the stress of people who try juggling many responsibilities.

3.7.2 Challenges.

First, the teacher participants were already busy with teaching and other aspects of their role in school, which made it difficult to sustain their motivation throughout the duration of the module activities. Some participants complained that recording and submitting video lessons was too much work and that serious problems existed with network connectivity. Although most succeeded in uploading their lesson plans, reflections, and pre- and post-tests without any problem, a number did suffer from delays. This was indeed the case, which needed several reminders from tutors to accomplish on time.

In this way, having a structured timeline with well-defined milestones will enable the participants to plan their time more successfully. Giving technical support about video recording and submission may also reduce problems with connectivity. Flexibility in deadlines and alternative ways of submitting work will improve participation and alleviate stress among participants who are juggling multiple responsibilities.

3.7.3 Surprises

It was expected that the scores of the post-test would increase substantially, as compared to those of the pre-test. Surprisingly, the difference was very minimal and some of the subjects even recorded the same score. This was not the expected outcome, and it created a need for further investigation into what happened and the factors affecting the assessment results.

Surprisingly, the lesson plans and reflections submitted by the participants showed significant development in their Pedagogical Content Knowledge. This means that though their test scores might have shown moderate gains, the participants were able to further their ideas regarding appropriate teaching strategies and integration of content.

As elaborated in the detailed analysis above, the learnings extracted from the OER were huge for the participants. This helped their professional development as well as made them more reflective of their teaching methodologies. In the future, the programme might place more emphasis on reinforcing better methods of assessment and finding the gaps that exist between the theory and application to ensure that once PCK improves, it would definitely be reflected in measurable improvements in student learning.

3.7.4 Any changes required in the module design

We did not receive any complaints about the module's content, suggesting that no immediate changes to its design are necessary. The content appears to align well with the educational goals and expectations of the participants. However, we received critical feedback on several aspects of the module, particularly the number of required lesson plans, expectations for video lessons, and the submission timeline. Participants also highlighted gaps in the instructions for activities, which they found confusing, indicating the need for a detailed and thorough revision of the module's embedded activities.

The volume of lesson plans may be too extensive, preventing participants from dedicating adequate time to each lesson. Additionally, one or two participants experienced challenges with the format and expectations of video lessons, pointing to the need for clearer guidelines and possibly additional support. Furthermore, the timeline for completing assignments is tight, leaving insufficient time for thoughtful preparation and execution.

In light of this feedback, it would be prudent to reconsider the expectations for the number of lesson plans and video submissions, potentially reducing the workload without compromising quality. Extending the timeline for submissions could also provide participants with the opportunity to process their learning more effectively and produce higher-quality work. Moving forward, we aim to address these concerns, further refine the module, and enhance our support for participants' professional development.