International Journal of Education and Development using Information and Communication Technology (IJEDICT), 2024, Vol. 20, pp. 40-54

The Impact of Physics Open Educational Resources (OER) on the Professional Development of Bhutanese Secondary School Physics Teachers

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ABSTRACT

This study investigated the impact of Open Educational Resources (OER) on the professional development of Bhutanese Physics teachers. Collaborating with partner institutions in Tanzania, Nigeria and India, Samtse College of Education developed and implemented three physics modules: Force and Motion; Work, Power and Energy; and Electromagnetism. These OER incorporate activity-based learning, technology integration, Universal Design for Learning (UDL) and design thinking principles. A mixed-methods approach, including pre-test and post-test scores, lesson plans, reflections, and interviews were used to assess the impact of OER on teacher's Subject Matter Knowledge (SMK), Pedagogical Content Knowledge (PCK) and General Pedagogy Knowledge (GPK). Additionally, the study examined a Community of Practice (CoP) on Telegram to understand knowledge sharing within the community. The findings revealed that most teachers demonstrated improved proficiency level after using OER, thus positively impacting their professional development by enhancing content knowledge, technological skills, and pedagogical practices. However, some teachers require further enhancement in SMK and PCK especially in Work, Energy and Power and Electromagnetism modules. The use of CoP proved valuable for knowledge sharing and collaboration. The study recommends educational institutions support the Continuous Professional Development (CPD) of Physics teachers by providing access to OER for their use and additional resources to enhance their SMK and PCK.

Keywords: *Physics; Open Educational Resources; Community of Practice; Pedagogy; Technology; Teaching and Learning.*

ACKNOWLEDGEMENT

This work was supported by the Global Partnership for Education Knowledge and Innovation Exchange, a joint endeavour with the International Research Centre, Canada. The views expressed herein do not necessary represent those of IDRC or its Board of Governors.

INTRODUCTION

The Bhutanese Education System (BES) introduces the study of science from class IV to VI, offering an introduction to the subject. In classes VII and VIII, students delve into General Science, where they explore Biology, Physics, and Chemistry as distinct chapters within a single subject. As they progress to classes IX and XII, science is presented as three separate disciplines: Biology, Physics, and Chemistry. Class XI represents a pivotal juncture where students must make a crucial decision that will significantly impact their future STEM career paths. They are presented with a trio of options as follows: (1) Biology, Physics, and Chemistry as one combination; (2) Mathematics, Physics, and Chemistry as another; and (3) Biology, Physics, Chemistry, and Mathematics as the third combination. Notably, option (3) grants students the flexibility to later opt out of either Biology or Mathematics, offering a wider array of choices.

Option (3) requires additional effort and is often considered more challenging, and it stands as a less frequently chosen option compared to options (1) and (2). Nevertheless, this combination provides students with a broader spectrum of opportunities for pursuing STEM related careers, making it a valuable choice for those with ambitious aspirations in the scientific arena.

In this study, the focus is only on the Physics module implementation in seven Bhutanese secondary schools. The Physics teacher educators of Samtse College of Education (SCE) along with partner countries curated high quality, locally relevant, interactive OER in the form of three modules - Force and Motion, Work, Power and Energy, and Electromagnetism. The modules were developed in consultation with secondary school physics teachers' needs and difficulty level in teaching these modules. Each module consists of four units to be implemented to grade X to XII. The modules are designed to enhance teachers' SMK, PCK and GPK that would support student learning. The modules include activity-based learning with the framework of technology integration and UDL principles and design thinking. Techniques such as independent reading, hands-on activities, online discussion forums, story-based learning, making supplementary videos on certain topics, animated videos, simulation, interactive videos, illustrations, and virtual labs are contextually embedded. From the inception till the implementation, a rigorous vetting was carried out during weekly project meetings.

All participating teachers were enrolled in the Telegram mobile app-based Community of Practice (CoP) where Physics teacher educators and the research fellow were also members. The learning and experience from the OER were expected to empower the participants in subject content, emerging pedagogy, and technology knowledge and skills. This research focused on examining the impact of OER and CoP on pre- and in-service (including newly qualified) Physics teachers' SMK, PCK and GPK focusing on the following research question:

- How did the Physics teachers practice' evolve by participating in OER and CoP based Professional Development?

BACKGROUND

To understand the underlying problems inherent in learning STEM subjects across countries, a global South-South collaboration between the Samtse College of Education, Bhutan, the Open University of Tanzania, the Ibrahim Badamasi Babangida University-Lapai, Nigeria and the Tata Institute of Social Sciences, India, carried out a joint project. The project, *Connected Learning Initiative for Teacher Education in Mathematics and Science* (CL4STEM), funded by the International Development Research Centre (IDRC) was aimed at developing the capacity of secondary teachers, including Newly Qualified Teachers (NQT) in mathematics and science using Open Educational Resources (OER) and Community of Practice (CoP).

LITERATURE REVIEW

Dorji, et al (2023) highlighted a prevalent issue within Bhutanese schools, where a majority of students encounter challenges when it comes to learning science subjects, particularly Physics. In support of this observation, in an earlier study Zangmo (2015) revealed generally positive attitudes toward science among students but identified Physics as the subject most commonly perceived as difficult and least interesting. Tamang (2004) had earlier elaborated on this issue, pointing out that Physics remains a difficult subject for Bhutanese students due to its complex derivations and definitions; numerous formulas and laws, and the often-daunting task of tackling endless calculations. Aligning with these findings, Utha, et al (2023) established a direct correlation between students' proficiency in Mathematics and their performance in Physics, as the subject demands a considerable amount of mathematical problem-solving. Their study indicated that students proficient in Mathematics tended to excel in Physics as well, a conclusion consistent with the findings in other earlier research studies by Hamelo (2016) and Oon & Subramaniam (2013).

As for the prevailing negative attitude towards Physics, research studies have attributed this phenomenon to the inherently abstract nature of Physics content. For example, Dendup, et al (2021) found that Bhutanese students and teachers developed negative perceptions of astrophysics primarily due to its abstract content, which are further reinforced by the lack of opportunities to visualize the processes through the use of Information and Communication Technology (ICT) tools. Similarly, Tenzin, et al (2023) highlighted the challenge presented by abstract concepts in electric circuitry and emphasized that students often have difficulty understanding these concepts because they are difficult to visualize. These difficulties are not confined to Bhutan; they have also been reported in other countries (Angell et al., 2004). To address such challenges, there is a growing consensus that ICT tools, such as video lessons and simulations, can play a crucial role in facilitating the understanding of abstract concepts (Dorji et al., 2023; Penjor et al., 2022; Finkelstein et al., 2005).

OER are digitised materials offered freely and openly for educators, students and self-learners to use and re-use for teaching, learning and research (Hylen 2006, p.1). According to Das (2011) OER was a recent innovation that was especially relevant for achieving equitable access to quality education and stressed that resources created by educators and researchers should subsequently be open for anyone to use and reuse with an intent that the OER would be available to lifelong learners across the professions and occupations.

CoPs are a well-established concept of social, situated and professional learning through the regular interaction of the community members (Wenger, 1998). They draw on the idea of situated learning (Lave & Wenger, 1991) that states that learning happens by participation in social processes that are situated within specific socio-cultural contexts. Research has shown that the application of teacher professional knowledge is contextual and value-based, where teacher learning is social and situated in nature (Sarangapani. 2011; Winch, 2004; Cochran-Smith & Lytle, 1999). Studies have also shown a strong influence of teacher social networks on teacher participation, attitudes towards the professional development opportunity, and ability to understand and implement these ideas (Baker-Doyle & Yoon, 2010). Research has also shown that professional development for teachers can happen through the two-pronged nature of CoPs participating in the Telegram CoPs' "activities, discussions, conversations, and reflections" and secondly through sharing of artifacts, such as student work, teaching resources, and strategies (Thirumalai et al, 2019). Secondary teachers can use this forum to ask questions, seek clarifications and share their doubts with the teacher educators about the content of the OER, their implementation in the classroom and general teacher practice.

METHODOLOGY

The study required implementation of OER by the teacher participants in the respective schools. Aligning with the requirement, a mixed method approach was employed. The data were collected administering a pre-test and post-test, lesson plan and reflection analysis and conducting structured interviews. The structured interview was used as several researchers and schools were engaged in data collection.

The data collection aimed to evaluate teachers' Knowledge, Attitudes, and Practices in three broad themes: Subject Matter Knowledge, Pedagogical Content Knowledge, and General Pedagogical Knowledge. Each of these themes are further broken down into the following sections:

Subject Matter Knowledge (SMK):

- Knowledge of Science and Mathematics

- Nature of Science/ Mathematics

Pedagogical Content Knowledge (PCK)

- Instructional Strategies
- Students Misconceptions
- Representation of content
- Context of Learning
- Curriculum Knowledge

General Pedagogical Knowledge (GPK)

- Equity and Inclusion
- Classroom Management
- Assessment

Teacher participation was measured using module-based scores, their activities on the Moodle interface, number of messages sent and nature of interactions in the online Telegram CoP. The target population for this intervention was pre-service teachers of SCE on field practicum and Physics teachers teaching in middle and higher secondary schools of Samtse Dzongkhag in Bhutan. Samtse Dzongkhag was selected as the study implementation happened during the COVID-19 pandemic which posed certain restrictions on travel. The study used criterion purposive sampling, a type of non-probability sampling technique as the target population was Physics teachers teaching in middle and higher secondary schools of Samtse Dzongkhag. A total of 20 teachers was selected - five teachers with less than five years of teaching experience labeled as Newly Qualified Teachers (NQT); five of them with five or more years of teaching experience labeled as in-service teachers; and 10 pre-service teachers who were engaged in the OER modules for a period of 6 weeks per module. The pretest and posttest were administered to all 20 teachers but only the NQTs were interviewed at three phases (baseline, midline and endline) of intervention implementation with interview questions structured around SMK, PCK, GPK, and CoP.

RESULTS AND DISCUSSION

Module Completion

The data in Table 1 below shows that the module completion rate for all three modules was 100%, which is supported by Hilton et al. (2016), who reported that students are slightly more likely to complete online courses or OER than face-to-face courses.

All interview participants in the present study saw their participation as a positive opportunity to improve their professional practice and knowledge. The CoP data also revealed that teacher educators' constant support and gentle reminders helped improve the completion rate. Arhin & Laryea (2020) reported that tutoring support improved student retention by 1.42 times and that the probability of a student who had a positive perception of tutoring support staying on the program was 0.83.

However, the module on Electromagnetism was found to challenging for some participants because it was the last module offered and happened towards the end of the academic term. The in-service teachers and NQTs were busy with the year-end activities and the pre-service teachers were busy with completing the field practicum in the schools. They also had to carry out examination related work.

While OER provides participants with an opportunity to improve their professional practice and knowledge, it is important to give participants enough time or flexi time to complete the OER courses.

Table 1: *Module completion rate by teachers in all the three modules*

Course completion rate	**NQTs**	**Preservice**	**Inservice**	Total
1 - 20%				
21 - 40%				
41 - 60%				
61 - 80%				
81 - 100%	100%	100%	100%	100%
Total	100%	100%	100%	100%

Performance Analysis

Teachers' subject content knowledge of the three modules was assessed through pre- and post-tests, each of which consisted of 15 questions. In the Force and Motion module, the average score of the 20 teachers was 8.20 out of 15 in the pre-test and 11.23 in the post-test, indicating an improvement in learning after enrolling in the module.

The performance matrix in Table 2 below shows that in the pre-test, the majority of teachers were in the emerging (N=9) and proficient (N=8) levels, with a few (N=3) in the accomplished level. However, the performance analysis of the pre-test shows that of the nine teachers in the emerging level, six progressed to the proficient level and two to the accomplished level. Additionally, out of eight teachers in the proficient level, four progressed to the accomplished level. Initially, there were only three teachers in the accomplished level, but after enrolling in the module, the number of teachers in the accomplished level doubled.

Therefore, the data indicates a significant improvement in teachers' performance in the Force and Motion module after enrolling in the module.

The pre-test for the module was administered during the school break so that teachers could start implementing the module as soon as the school session began. Some teachers reported problems with Internet access or time constraints, such as being in villages with limited Internet access or having to attend to family responsibilities. However, the teacher educators extended the pre-test deadline for these participants, ensuring that all teachers were able to complete it.

Table 2: *Performance of participants in pre-test and post-test in Force and motion module*

Number of teachers		Post Test			
		Novice	Emerging	Proficient	Accomplished
Pre test	0-25% Novice	0	0	0	0
	26-50% Emerging	0	1	6	2
	51-75% Proficient	0	0	4	4
	76-100% Accomplished	0	0	0	3

In the module Work, Power, and Energy, the average score of 20 teachers was 10.22 out of 15 in the pre-test and 9.55 in the post-test, indicating that the teachers' performance in the pre-test was slightly better than in the post-test. The decrease in performance in the post-test was mainly due to the performance of three pre-service teachers, whose scores were less than 7. However, analysis of the individual teachers' performance matrix in Table 3 shows that the number of teachers in the proficient level was 15 in the pre-test, out of which five progressed to the accomplished level but one dropped to the emerging level in the post-test. Despite the drop in the average score from 10.22 to 9.55 in the post-test, the pre-test and post-test performance matrix indicates that the teachers' performance improved in the post-test. For example, out of 15 teachers in the proficient level in the pre-test, five improved to the accomplished level in the post-test.

Table 3: *Performance of participants in pre-test and post-test in Work Energy and Power module*

Number of teachers		Post Test			
		Novice	Emerging	Proficient	Accomplished
Pre-test	0 - 25% (Novice)	0	0	0	0
	26-50% Emerging	0	1	2	1
	51-75% Proficient	0	1	9	5
	76-100% Accomplished	0	0	0	1

The average pre-test score of the teachers in the Electromagnetism module was 9.6 out of 15, and the average post-test score was 9.98 as shown in Table 4, indicating a slight improvement in module learning. Of the 20 teachers who took the pre-test, 14 were rated as proficient and three as accomplished. Of the 14 teachers at the proficient level, three progressed to the accomplished level in the post-test, but two dropped to the emerging level.

Table 4: *Performance of participants in pre-test and post-test in Electromagnetism module*

Number of teachers		**Post-test**			
		Novice	**Emerging**	**Proficient**	**Accomplished**
Pre-test	0-25.9% Novice		1		
	26-50.9% Emerging		1		1
	51-75.9% Proficient		2	9	3
	76-100% Accomplished			2	1

The data does not exhibit significant change in the content enhancement of the teachers, nevertheless, the small progression provides a positive tone to the intervention indicating that the OER did to some extent, result in enrichment of the content. The small progression could also be due to the fact that OER is being introduced for the first time to the teachers who are used to a teacher centered approach and have limited knowledge of the advantages and possibilities of OER. In a study carried out by Kurelovic (2016), it was noted that in order to reap the full benefits of OER, it is important to create awareness and educate teachers and researchers about the advantages and possibilities that OER offers.

Lesson Plans and Reflections

Each participant had to plan three lessons in each module and implement them in the classroom. They were also required to write a reflection on the implemented lesson. All the lesson plans and reflection had to be uploaded in the OER platform. The Physics educators at SCE assessed the lesson plans and the reflections out of 100 on three themes: Subject Matter Knowledge (SMK), Pedagogical Content Knowledge (PCK) and General Pedagogical Knowledge (GPK) with each theme consisting of specific requirements. The performance of the participants was categorized into Novice (N), Emerging (E), Proficient (P), and Accomplished (A) based on their ability to demonstrate elements of SMK, PCK and GPK in their lesson plans and their ability to articulate it in the reflection writing. The following tables and figures present the categorization of the participants into N, E, P and A based on their lesson plan and reflection scores for the three modules.

SMK Performance

Figure 1 shows the SMK performance categorization in all three modules. A total of 75% of pre service and in-service teachers are at the Proficient level in the module *Force and Motion*. This suggests that most participants have a good understanding of the subject matter related to *Force and Motion*. A relatively smaller percentage (7.5%) are in the Accomplished level indicating that few participants have an exceptional level of Subject Matter Knowledge on this module.

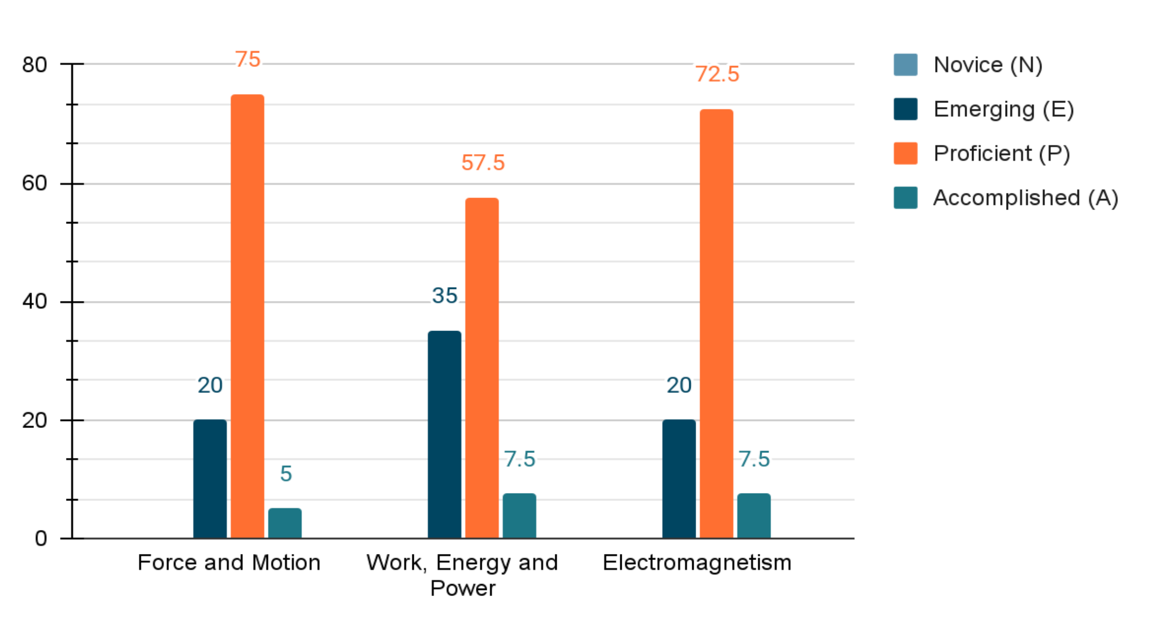

Figure 1: Bar graph illustrating SMK categorization of participant's lesson plans and reflection scores for the three modules

In the *Work, Power and Energy* module, the distribution of participants' knowledge levels is relatively spread out. A total of 57.7% are in the Proficient level and 7.5% in the Accomplished level. A significant number of participants (35%) are at the Emerging level, suggesting that some teachers require Subject Matter Knowledge enhancement.

The data for the *Electromagnetism* module shows that a majority of participants are at the Proficient level (72.5%). A small percentage (7.5%) are at the Accomplished level. This indicates a good understanding of the subject matter on the module. However, there are participants at the Emerging level (20%), indicating a need for improvement.

Overall, a mean of 68.33% of the participants are at least at the Proficient level of Subject Matter Knowledge in all three modules. This is likely due to the fact that the module is designed for pre-service and in-service teachers who are expected to have a strong understanding of the subject matter. However, there is room for improvement, as the number of participants at the Accomplished level (6.67%) is limited in all three topics.

PCK Performance

Figure 2 shows the categorization of participants based on their pedagogical content knowledge (PCK). The distribution of proficiency levels is consistent across the three modules, with the majority of participants at the proficient level, followed by the emerging level and the accomplished level. A small number of participants are at a novice level of knowledge in all the modules.

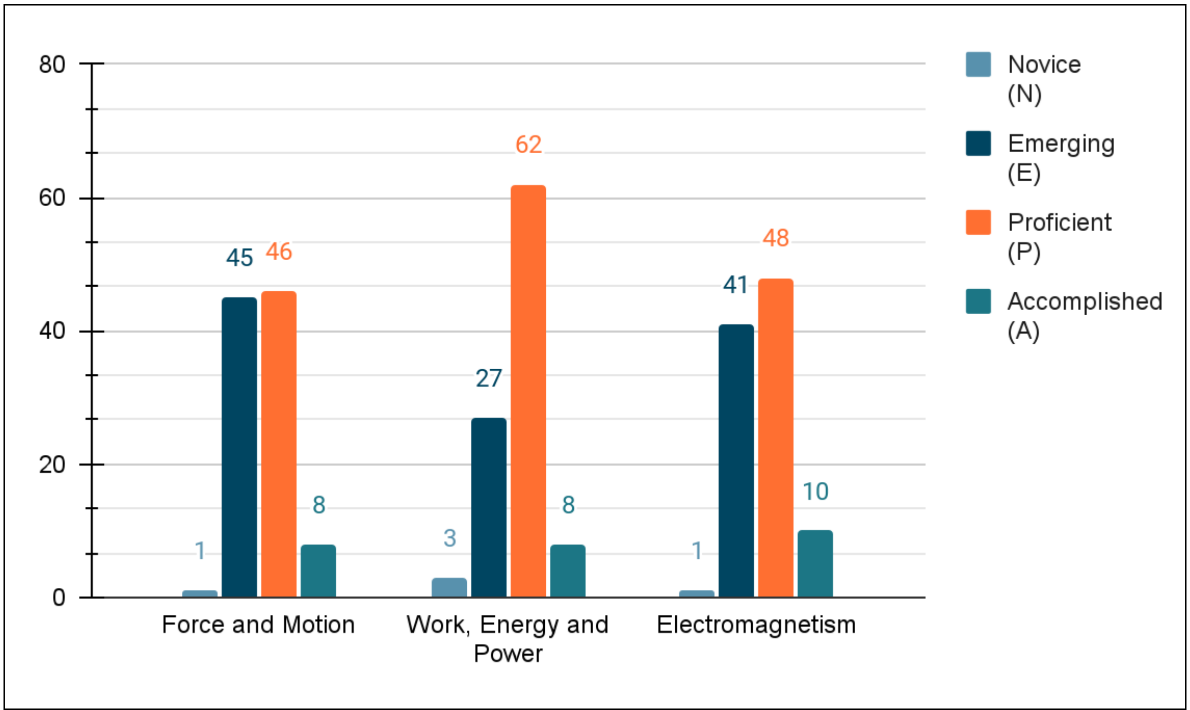

Figure 2: Bar graph illustrating PCK categorization of participant's lesson plans and reflection scores for the three modules

The module *Work, Energy and Power* has the highest percentage (62%) of the participants in proficient level compared to *Electromagnetism* (48%) and the F*orce and Motion* module (46%). It also has the smallest percentage of participants in Emerging level (27%) compared to *Electromagnetism* (41%) and Force *and Motion* (45%) modules. This suggests that the participants have a better understanding of how to effectively teach Work, Energy and Power to the students compared to the *Electromagnetism*, and Force *and Motion* modules. There is room for improvement in PCK in the Electromagnetism and Force *and Motion* modules as there are a large percentage of participants in emerging levels in the Force and Motion (45%) and Electromagnetism (41%) modules respectively. It was found that the teachers used the activity designed in the modules as they found it relevant to topics they were teaching.

Participant 1301 mentioned teaching speed and velocity to Class 8 students in a way that was designed in the CL4STEM module. Participant 1301 noted:

> *"I tried to teach in that way by showing the simulation and videos and all so I think my students enjoyed it and they learned well."*

General Pedagogical Knowledge (GPK) Performance

Figure 3 shows the general pedagogical knowledge (GPK) performance in all three modules. The data shows that a significant portion of teachers, that is, more than 50%, have reached the proficient level in each module, demonstrating a solid foundation in their understanding and teaching skills. However, there are also a notable number of teachers at the emerging level, indicating they are still learning and developing their pedagogical knowledge. This is not surprising, as the participants include pre-service teachers and newly qualified teachers (NQTs). There are more teachers in the emerging level and fewer proficient teachers in electromagnetism compared to the other two modules. This suggests that the electromagnetism module is more difficult and more teachers need additional support to learn and teach this module effectively. A smaller proportion of teachers (less than 10%) are categorized as accomplished, signifying a high level of mastery in both subject matter and teaching strategies. These teachers are a valuable asset for any school, and they can be used as mentors to help other teachers develop their pedagogical knowledge.

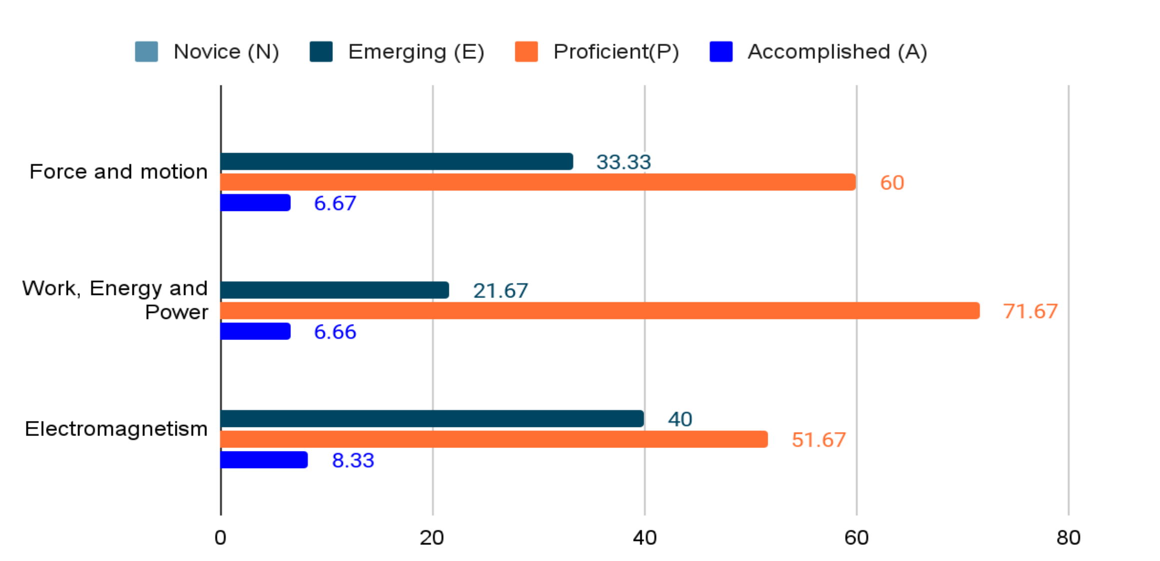

Figure 3: Bar graph illustrating GPK categorization of participant's lesson plans and reflection scores for the three modules

The data shows that a significant portion of teachers, that is, more than 50%, have reached the proficient level in each module, demonstrating a solid foundation in their understanding and teaching skills. However, there are also a notable number of teachers at the emerging level, indicating they are still learning and developing their pedagogical knowledge. This is obvious as the participants include pre-service and NQT. There are more teachers in the emerging level and fewer proficient teachers in electromagnetism compared to the other two modules. This suggests that the electromagnetism module is more difficult and more teachers need additional support to learn and teach this module effectively. A smaller proportion of teachers (less than 10%) are categorized as accomplished, signifying a high level of mastery in both subject matter and teaching strategies. This is a valuable asset for any school. These teachers can be used as mentors to help other teachers develop their pedagogical knowledge.

The difficult nature of the electromagnetism module is confirmed by participant 1301. Participant 1301 noted:

> "*When it comes to the last module that is electromagnetism, I found it difficult to learn. Still frankly I'm not that clear about the module. So many laws and rules. Maybe I'm not in touch with that topic especially as I have been teaching class 8 till last year. Recently I have started teaching Class 9. Maybe because of that I have forgotten the concept now and I faced difficulties while doing that module.*"

Community of Practice (CoP)

The CoP in the Telegram allowed Physics pre-service and in-service teachers, teacher educators, and TISS research fellows to come together virtually to share practices, ask questions, clarify doubts or discuss concerns on any topic within the OER modules. The CoP offered a space for participants to share their practice without any evaluation or judgment. The CoP participation analysis of all modules is reflected in Table 5.

Table 5: *Frequency of posts by participants*

Role	Number of posts In Force and Motion module	Number of posts In Work, Power and Energy module	Number of posts In Electromagnetism module
NQTs	24	31	15
Pre-service Teachers	27	10	5
In-service Teachers	36	42	20
Teacher Educators	107	122	90
Research fellow	0	8	3
Total	194	213	133

Overall, the data in Table 5 shows that participation in CoP in the module Electromagnetism is lowest. This could be due to the teachers' engagement in completing the syllabus and exam related work as this module implementation happened towards the end of the academic session. The analysis also shows that the pre-service teachers were not very active compared to the other teachers. The pre-service teachers cited their engagement in the field practicum and having to juggle between teaching and the tasks they had to complete in this module.

The frequency of the posts by content was analysed and the results are shown in Table 6. It shows that posts on communication and administrative matters dominated in all three modules. The posts on the UDL were the lowest.

Table 6: *Frequency of posts by content*

Type of Posts	Number of posts in Force and Motion module	Number of posts in Work, Power and Energy module	Number of posts in Magnetism and Electromagnetism module
PCK	40	43	21
UDL	8	4	0
Technical	26	17	14
Communication/ Administrative	120	21	79
Total	194	85	114

Although the data in Table 6 and Table 7 shows there was maximum correspondence and sharing of posts during the implementation of all the modules, the participants were hesitant to open up in the beginning and preferred to be silent observers. Especially for the first module. Force and Motion, the teacher educators had experiences of participants communicating to teacher educators outside of the CoP. It was found that the teachers hesitated to ask or clarify questions, should their questions be found to be irrelevant by teacher educators and other teachers. The teacher educators encouraged the teachers to use the CoP for communication so that other members also benefit. They also acknowledged anyone asking questions or seeking clarification and provided immediate responses. This helped as the teachers' participation improved over time and participants expressed the view that this kind of CoP is useful as they can clarify their doubts or learn about best practices. For example, teacher 1301 posted a question seeking support from others to answer the activity questions as shown in Figure 4 below.

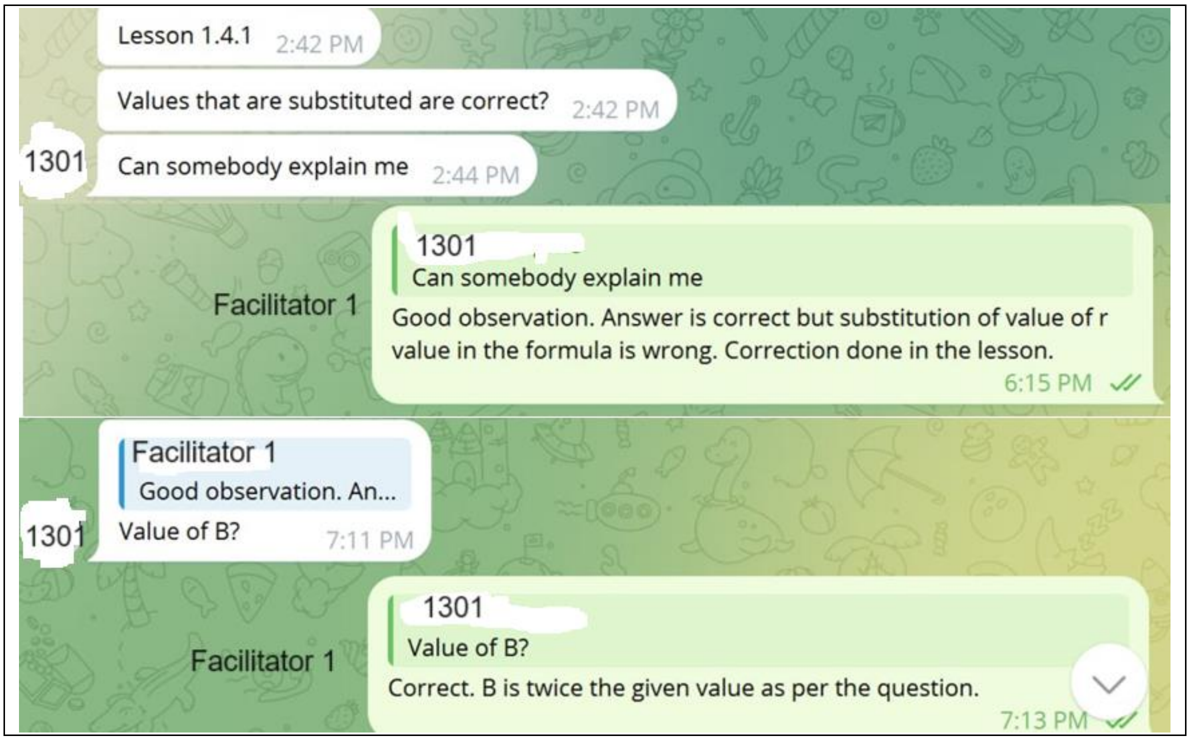

Figure 4: Screenshot communication on CoP

Similar incidents are present in the CoP forum. This shows that the participants are feeling more comfortable letting others know that they do not know the answer and can use the CoP as a learning platform where no judgment is made. This is in line with research findings by researchers where teacher learning is social and situated in nature (Sarangapani, 2011; Winch, 2004; Cochran-Smith & Lytle, 1999).

Some other good practices are sharing students' engagement in learning. For example, Teacher 1305 highlighted a picture of students using the material to build electromagnets, which indicated that that the students were fully involved in the activity. Further, another teacher (# 1306) posted an image of a numerical problem seeking support from the members of the group as shown below in Figure 5.

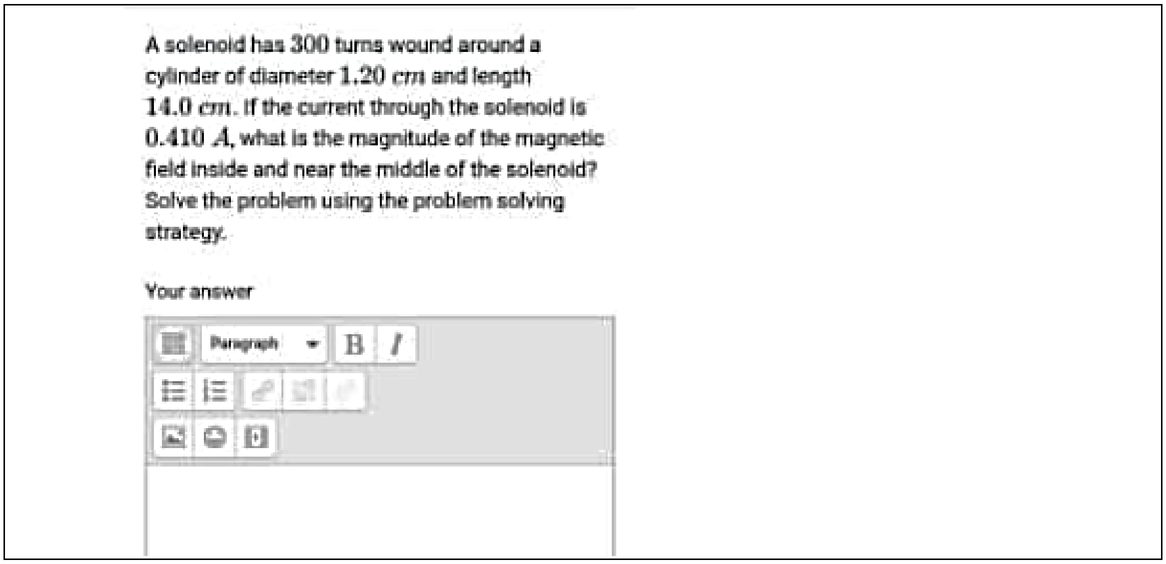

Figure 5: Screenshot communication on a Numerical Problem Seeking Support

LIMITATIONS

It is important to note that the study may have limitations or biases that could impact the generalizability of the findings. For example, the study included teachers from only Samtse Dzongkhag; implementation of the modules especially the Electromagnetism module happened towards the end of the academic session; and teacher participants included pre-service teachers on field practicum. However, the use of OER has led to looking at teaching, learning and assessment through a different lens. As such, the study recommends further research by extending the use of OER beyond Samtse Dzongkhag. It also recommends that the relevant stakeholders carry out continuous professional development for Physics teachers to enhance their SMK and PCK knowledge.

CONCLUSIONS

Overall, the findings of this study suggest that the participants have developed a range of knowledge and experience related to pedagogy and technology for teaching, and there are also some levels of instances with some participants having achieved a higher level of expertise than the rest. This indicates that the participants in the study have developed varied levels of SMK, PCK and GPK which could have a positive influence on their ability to effectively teach the subject matter. The CoP is a great way to share knowledge and practices. However, it has to be noted that there are teachers who required support in SMK and PCK, especially in the Work Energy and Power and Electromagnetism module.

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