The Status of STEM Education in Schools: A Case of Samtse Dzongkhag

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Abstract

This study examined the current state of STEM education in schools under Samtse Dzongkhag. Specifically, the study explored the competency of STEM teachers, the infrastructure and resources available to support STEM education, the proficiency of teachers in the use of ICT in education, and the performance of students in STEM subjects. A mixed-method approach was used, including survey questionnaires, interviews, and document analysis. The survey sample comprised 50 teachers from six schools currently teaching STEM subjects in grades IX to XII, while qualitative data was obtained from four participants, including a Lead teacher, an Academic head, a School administrator, and a District Education Officer. The study found that STEM teachers have at least a first degree from a recognised university and a majority have taught STEM subjects for more than a decade. The study also reveals that the professional development (PD) programmes attended by the STEM teachers is far below what is envisioned by the Ministry of Education and Skills Development. The study recommends revisiting the policy of professional development (PD) and providing the mandated hours of PD to teachers, upgrading laboratory equipment and apparatus, encouraging scientific research to promote innovation, and allowing students to bring mobiles to school to increase access to technology and enhance learning.

Keywords: STEM education, professional development, performance, ICT infrastructure, resources to support STEM education

Introduction

Bhutan is a small landlocked kingdom nestled deep in the Eastern Himalayas and bordered by the world's two most populous nations, India to the south and China to the north. The country is known for its unique developmental philosophy – Gross National Happiness (GNH) – that guides its development. As Bhutan's developmental philosophy is GNH, this study investigated the factors responsible for the development of Science Technology Engineering and Mathematics (STEM) subjects in the schools of Samtse Dzongkhag (District) in Bhutan. STEM Education is vital to the realisation of this philosophy, as the quality of Mathematics and Science education is central in building human capital, especially in the case of Bhutan, where science and technology are still in the developing stage. The way STEM subjects are currently taught in the schools and colleges of Bhutan needs to be revisited.

STEM subjects have gained more attention with rapid advancements in Information and Communication Technologies (ICT). It has become necessary for people of all ages to attain and apply scientific knowledge effectively and efficiently to be successful citizens. In particular, students need to be well equipped with higher-order STEM knowledge, as the lack of understanding of basic STEM principles can result in an inability to solve numerous scientific problems.

In the 21st century, scientific and technological innovation has become increasingly important in our daily lives. STEM education is vital for technological advancement and economic growth of the nation. As a developing country, it is essential for Bhutan to have human resources that can contribute to the social and economic development of the nation in the field of science and technology. The paradox for Bhutan is that despite the relatively high levels of unemployed youth in the country, the need for specialised human resources such as doctors, engineers, technocrats and health workers are high.

Although the increasing need for STEM education was felt by the nation, the development of the STEM education curriculum is in its nascent stage. Teaching and learning takes place in the absence of technology in Bhutanese classes even though students are exposed to numerous technologies in this digital age outside the classroom. Moreover, resources are notably limited in the field of STEM education. These limitations have resulted in the adopting of traditional methods of teaching and learning, which continues to perpetrate rote learning wherein the students are not able to apply their knowledge in real-life situations (Utha et al., 2021). Further, it has also been reported that Bhutanese students were unable to understand the core concepts and apply knowledge to real-life situations across grades and subjects (Rai, 2019). Moreover, the students' performance in Mathematics and Science in the class X Bhutan Certificate of Secondary Education (BCSE) in 2021 was below expectations. For instance, the mean marks of Mathematics (52.72) and science (62.12) were the lowest compared to other subjects as reflected in Table 1 (BCSE, 2022). Students' performance in STEM subjects in class XII exam (BHSCE, 2022) were also not very encouraging though 93.09 percent of Science students passed their exams.

Table 1

Subject-wise Performance Class X students in Bhutan Certificate of Secondary Education (Class X) Examination, 2021

Sl #	Subject	Pass%	Mean
1	English	95.84%	64.88
2	Dzongkha	90.27	62.94
3	Economics	85.39	67.07
4	Mathematics	48.17	52.72
5	History Civics & Geography	84.15	65.13
6	Science (Chemistry, Biology, & Physics)	75.07	62.12
7	Computer Hardware	100	86.82

The decline in the performance of Mathematics and Science by students has deeply concerned parents, Ministry of Education and Skills Development (MoESD), policy makers and other stakeholders. This concern is also held by His Majesty the King who considers the education of the citizens of Bhutan as a strength for a small nation and often shares his apprehension on the deteriorating performance of students' in Mathematics and Science with the education fraternity. Such apprehension was shared during numerous Royal audiences.

His Majesty, The King of Bhutan, issued a Royal Decree (Royal Kasho) on 17th December 2020, echoing the nation's vision to accelerate its technological advancement and globalisation in the field of education. His Majesty also stated that STEM should be prioritised in education and available technologies should be used optimally. His Majesty commanded Bhutanese teachers to adopt global best practices by using information and media literacy as well as technological skills to promote learning that involves self-discovery, exploration, and the creation of new knowledge. STEM education is necessary to achieve this. Considering the importance of ICT in education, the MoESD has introduced ICT in schools for all class levels since 2017. The need to enhance ICT capacity of teachers is also featured in Bhutan Education Blueprint (2014-2024). According to Bhutan Education Blueprint, teachers need to use ICT vigorously in their teaching to improve the quality of education.

Yet in the face of all these problems, students' performance in Mathematics and Science must now be a problem of national concern, and the onus of addressing this issue falls on the Samtse College of Education (SCE) as we train secondary Mathematics and Science teachers in the country. SCE plays a strategic role in building quality STEM teachers including ICT-enabled approaches that are

academically sound and professionally competent to prepare the younger generation of Bhutanese children to brace for the challenges of the 21st century.

This study was carried out by a team of Science faculty from SCE with the funding support from the Connected Learning for STEM (CL4STEM) project. This study is part of a bigger project supported by the International Development Research Centre (IDRC) research grant.

The study aimed to:

i. ascertain teacher's competency in Science and Mathematics education;
ii. identify Science and Mathematics education learning infrastructure and resources in the schools;
iii. determine ICT infrastructure and resources and teacher's proficiency in the use of ICT in education;
iv. find out the service conditions of teachers in the school; and
v. assess the performance of students in STEM subjects.

Therefore, the participation of Bhutanese STEM teachers in the CL4STEM project is relevant and timely. This study is a fragment of a bigger project aimed to provide teachers' capacity building programmes and ensure robust STEM education in the nation. Further, the project is intended at developing Open Educational Resources (OER) for STEM education, thereby addressing the need for STEM teachers in the nation.

Research Methodology

This study employed an exploratory mixed method which was concurrent in nature as both qualitative data and quantitative data were collected simultaneously. A mixed methodology is often considered while studying a topic that cannot be addressed by one single method and when very little is known about the topic. For the current study, since no similar study has been done in Bhutan, a mixed methodology was seen as appropriate to understand the topic at hand. Quantitative data were collected through surveys while qualitative data were garnered through interviews and documents analysis. A mixed methods approach benefits the research design in numerous ways, especially the data from one approach can be corroborated or contrasted from the other method (Creswell, 2019). Qualitative design is very valuable in theory-building (Patton, 2006) due to the critical and interpretive nature of qualitative data.

Research Setting

This study was situated in Samtse Dzongkhag in southern Bhutan. Samtse is one of the four Dzongkhags located in the south of Bhutan. It has a population of 63,000 (National Statistical Bureau, 2020). Although Lhotshampkha is the dominant language spoken by the heterogeneous Lhotshampa community, Dzongkha, English and other languages are also spoken. Samtse experiences hot and humid summer with an average temperature of 17°C in winter and 35°C in summer. It receives moderate to heavy rainfall of about 1500-4000 mm annually. It is connected with roads and shares an international border with the Indian states of Sikkim to the west and West Bengal to the south.

Both heat and monsoon have an impact on education. In the southern plains, classes are often cancelled, as students are not able to travel to schools when the river is swollen or when bridges are washed away by incessant rain. Majority of the students have to walk long distances crossing rivers and mountains to reach schools. They are often exposed to the challenges of landslides, floods, swollen rivers, and other hazards. This concern raises the issue of equal access to education, as schools in Bhutan follow a common curriculum and practice. Students are also required to follow the same board

examination both at the Dzongkhag and at the national level. However, school infrastructure and facilities have not been adapted to the climatic condition of the country. For example, while schools in southern plains have fans installed to overcome the summer heat, the fans can barely keep the classroom temperature conducive for learning.

Participants

All Middle Secondary Schools (n=1), Higher Secondary Schools (n=3) and Central Schools (n=3) of Samtse Dzongkhag participated in the study. During the study period a total of 89 teachers were teaching STEM subjects in these seven schools; however, the survey participants included only 50 teachers teaching STEM subjects in grades IX to XII in the above schools. In addition to the survey, the study also involved interviews with several key individuals, including a Principal, a Lead Teacher, a District Education Officer, and an Academic Head of the school. The interview was conducted online and was semi-structured in nature. Furthermore, the study relied on secondary data sources, such as policy-related documents and research articles, to supplement the primary data collected through the survey and interviews.

Both the survey and interview questions were developed by STEM faculty at Samtse College of Education, and the questions were validated and confirmed by experts from Tata Institute of Social Sciences, Mumbai, India who had conducted similar research earlier in a different context. This was done to ensure the reliability and validity of the data collected through the survey and interview, which can help enhance the credibility and usefulness of the study's findings.

Data Analysis

Data obtained from surveys were construed through numbers and percentage and presented in the form of Tables for easy reference and interpretation. For the interview data, the researchers interpreted the opinions of the participants with the narrative description of the meaning the researchers attributed. Findings from the survey were triangulated with qualitative findings such as interviews and documents analysis of office orders, Teaching timetable, teachers workload, inventory of library and science laboratories. In the sections that follow, themes generated to answer the five research objectives are presented.

Findings and Discussions

Findings are presented under the following themes namely Teacher education and service conditions; Quantitative indicators of schooling under Samtse Dzongkhag; Assessments performance of students in STEM subjects; Teacher proficiency in Science and Mathematics education; Science and Mathematics education learning infrastructure and resources; and ICT in education. Demographic information is presented first. For easy reference and to maintain anonymity, the schools are represented as School 1, School 2… and the interview participants are represented as Principal, Lead Teacher, District Education Officer and Academic Head.

Demography

Data revealed that the majority of STEM teachers (N=50) who participated in the survey have Bachelors in Education (B.Ed) qualification (n=24) followed by Postgraduate Certificate or Postgraduate Diploma in Education (PgDE/PgCE) (n=16) and Master in Education (MEd) (n=8). There are only two teachers with MSc as reflected in Table 2. In the Bhutanese context, teachers with B.Ed do not have first degree as they enrol into B.Ed programme after class XII. However, other teachers have a first degree. In terms of teaching experience, the majority of teachers have teaching

experience of ten years and above while a few teachers (n=14) are quite new to the system. Majority of the teachers are above thirty years of age.

Table 2

STEM Teacher Qualification, Teaching Experience and Age Category (N=89)

	Qualification				Teaching experience			Age category		
School	BEd	PgDE/ PgCE	MEd	MSc	< 5 yrs	5-10 yrs	>10 yrs	<30 yrs	30-39 yrs	>40 yrs
School 1	4	2	1	-	2		5	1	5	1
School 2	5	3	1		3	2	4	3	1	4
School 3	6	3		1	2	2	6		2	6
School 4	5	-	1	-	3	2	1	2	2	1
School 5	2	4	2		4	3	1	5	3	
School 6	2	4	3	1		1	9		3	7
Total	24	16	8	2	14	10	26	11	16	19

All the participating schools are located in semi-urban areas, connected by motor roads and have internet connectivity. Some of the schools are located closer to the district capital. All the teachers own smartphones while accessibility of phones in case of students vary from 10% to 80%. Three of the six participating schools have boarding facilities as reflected in Table 3.

Table 3

Socio-economic Profile of students, STEM teachers and Status of ICT in Samtse District

Name of the school	No. of full-time teachers	No. of teachers teaching STEM subjects	School Status	School Location	% of teachers who owns a smart phone (approx.)	% of students who have access to martphone (approx.)	Type of Internet connection	Data Speed (mbps)
School 1	30	7	DS	Semi-urban	100	10	Fiber Optic	7
School 2	66	12	BS	Semi-urban	100	80	Fiber Optic	7
School 3	68	30	DS	Semi-urban	100	60	Fiber Optic	6
School 4	81	19	BS	Semi-urban	100	30	Fiber Optic	11
School 5	33	11	BS	Semi-urban	100	50	Wifi	
School 6	32	10	DS	Semi-urban	100	80	Fiber Optic	10

Teacher Education and Service Conditions

The government has accorded highest priority to education since the inception of modern education in the early 1960s. In Bhutan, secondary teachers are trained at SCE, while primary teachers and national language teachers (Dzongkha) are trained at Paro College of Education (PCE), Paro. Bhutan considers teachers as the cornerstone of the education system, and they need to be constantly updated with the latest knowledge and instructional strategies. Teachers are also given scholarships to pursue studies - both short and long term - in Bhutan as well as third countries. In terms of monetary remuneration,

teachers are one of the highest-paid civil servants in the country. Further, their promotion to the next higher level is ensured after serving for a certain number of years at a particular level.

To provide continuous professional development (PD) to result in effective classroom delivery, Human Resource Policy (THRP) 2014 and In-Service Education of Teachers (INSET) Master Plan mandated that every teacher receive a minimum of 80 hours of need-based PD programme in a year. The Ministry of Education and Skills Development (MoESD) has established the Teacher Professional Support Division (TPSD) under the Department of School Education in 2016 to oversee the PD process and monitor its effectiveness. However, the analysis of survey data revealed that the PD attended by STEM teachers are bare minimum and does not meet the mandates of attending 80 hours of PD in a year. For instance, the average hours of PD attended by STEM teachers of Samtse in the last three years (2018-2020) are between 22.3 - 28.3 hours, which is significantly lower than the required number of 80 hours, as evident from Table 4.

Table 4

Information on PD Attended by STEM Teachers between 2018-2020

PD	2018		2019		2020	
	Average no. of PD	Average no of hours of PD	Average no. of PD	Average no of hours of PD	Average no. of PD	Average no of hours of PD
Focused on STEM content	0.3	5.9	0.4	6.7	0.4	6.6
Focused on ICT-enabled teaching	0.5	1.4	0.5	2.3	0.9	5
Area others than STEM	1.1	15.2	1.4	19.3	1.5	10.7
Total	1.9	22.5	2.3	28.3	2.8	22.3

Further, as per MoE (2014), teachers are required to teach a maximum of 18-22 hours per week, which approximately calculates to 5 periods of 50 minutes every day. Moreover, Bhutan Education Blueprint 2014-2024 recognises the need to ensure a conducive classroom environment by equipping classrooms with dynamic teaching-learning resources, maintaining an ideal class size of 24 students for primary schools and 30 for secondary schools. In contrast, the teacher survey data revealed that most teachers in the schools have more than 30 hours of teaching workload per week. This is further confirmed by Kaka's (2017) study in Bhutanese schools which stated that , in reality, most schools in the urban areas are overcrowded and schools located in remote areas have few students in the class.

Quantitative Indicators of Schooling under Samtse Dzongkhag

In the context of this study, the quantitative indicators of schools include the number of STEM students, the number of teachers teaching STEM subjects, ICT facilities, and students who own smartphones in the participating schools of Samtse district as detailed below.

The survey findings reveal that there are more students taking STEM subjects in class IX and X compared to class XI and XII as reflected in Table 5. This difference in number is attributed to STEM subjects being compulsory till class X, but once the students' progress to class XI, they have the option to choose STEM subjects or humanities based on their performance in class X examination. School 1 does not have class XI and XII as it is a Middle Secondary school.

Table 5

Total Number of Students Taking STEM Subjects

Name of the school	Class IX			Class X			Class XI			Class XII		
	M	F	T	M	F	T	M	F	T	M	F	T
School 1 *	35	35	70	31	40	71	-	-	-	-	-	-
School 2	123	129	252	86	109	195	20	15	35	17	10	27
School 3	73	78	151	43	51	94	12	19	31	8	8	16
School 4	126	125	251	118	118	236	18	16	34	19	12	31
School 5	123	139	262	111	130	241	0	0	0	0	0	0
School 6	74	52	126	66	71	137	38	18	56	21	17	38

School 1 * does not have class XI & XII

The data also shows that the number of teachers teaching STEM subjects in these schools are not proportionate to the number of students taking STEM subjects. For instance, School 4 has more STEM students compared to School 3; however, the number of STEM teachers are fairly low compared to School 3 as reflected in Table 5 and Table 6. This may be attributed to teacher shortages especially in STEM areas as a result of superannuation of senior teachers or other teachers leaving the teaching profession for good.

Table 6

Number of Teachers Teaching STEM Subjects

Name of the school	Class range	Number of full-time teachers	Number of teachers teaching STEM subjects
School 1	PP – X	30	7 (23%)
School 2	PP – XII	66	12 (18%)
School 3	PP – XII	68	30 (44%)
School 4	PP – XII	81	19 (24%)
School 5	IX – XII	33	11 (33%)
School 6	IX – XII	32	10 (31%)

ICT facilities in the participating schools are barely minimum except for desktops and few basic devices such as printers, sound system and projectors as reflected in Table 7. School 5 does not have a single projector.

Table 7

ICT Facilities Available in the Schools of Samtse Dzongkhag

No. of devices/ School	School 1	School 2	School 3	School 4	School 5	School 6
Laptops	0	1	1	4	4	0
Desktops	22	18	35	85	40	40
Projectors	7	1	3	5	0	2
Printers	2	4	5	5	1	2
Photocopiers	0	2	1	2	0	1
Generator/	0	0	0	0	0	0

Inverter/UPS						
Tablets	0	0	0		0	0
Smart boards	0	0	0	0	0	0
Smart TVs	0	0	3	0	0	17
Scanners	0	1	1	1	1	2
Web cameras	0	0	0	1	0	0
Sound system	1	1	3	2	1	2

In terms of the number of STEM students possessing smartphones of their own, findings revealed that 80% of the students from two schools namely School 2 and School 6 have smartphones with School 4 at 30% and the lowest is School 1 with only 10% of the students possessing smartphones of their own as reflected in Table 8. The high percentage of students without smartphones may be attributed to the fact that many of these students come from rural pockets and parents may not be able to afford one. Further, students are not allowed to carry phones into the schools and classrooms as per MoESD's policy.

Table 8

Total % of Students who own Smartphones in Classes IX-XII

Name of school	Students who own a smartphone (%)	Total No. of students in school											
		Class IX			Class X			Class XI			Class XII		
		M	F	T	M	F	T	M	F	T	M	F	T
School 1	10	35	35	70	31	40	71						
School 2	80	123	129	252	86	109	195	57	55	112	44	49	93
School 3	60	73	78	151	43	51	94	21	55	76	20	28	48
School 4	30	126	125	251	143	118	261	57	51	108	42	61	103
School 5	50	123	139	262	111	130	241	42	32	74	40	33	73
School 6	80	126	52	178	137	71	208	134	68	202	145	77	222

Performance of Students in STEM Subjects

The analysis of BCSEA results of class X and XII students from the four participating schools in Samtse for the last three years (2018-2020) revealed that the performance of class X students in the STEM subjects were not encouraging. For instance, the pass percentage of class X students in STEM subjects is just above 70% in 2018 and 2020 as reflected in Table 9 while, the average pass percentage of class XII students in STEM subjects for the 2018-2020 is 90%.

Table 9

Pass Percentage in STEM for classes X and XII in Samtse

Name of school	Class X pass % in STEM			Class XII pass % in STEM		
	2018	2019	2020	2018	2019	2020
School 3	94.60	88.00	70.80			87.50
School 4	15.00	13.00	8.00	80.00	90.00	90.00
School 5		85.00	92.00			
School 6	70.65	83.34	82.00	94.00	96.00	97.00
Total	180.25	269.34	252.8	174	186	274.5
Average %	60.08	89.78	63.20	87.00	93.00	91.50

Similarly, the Programme for International Student Assessment for Development (PISA-D) study carried out by the Organisation for Economic Cooperation and Development (OECD) in 2017 to find the status of Bhutanese students aged between 15 and 16 years in three areas namely numeracy, literacy and scientific literacy revealed that Bhutanese students found it difficult to formulate situations mathematically, and tasks related to the content area (BCSEA, 2019). Likewise, although Bhutan performed better than most PISA-D countries, a huge performance gap was found between Bhutan and PISA countries. Bhutan's performance is about 23 to 35 points (% points) below OECD averages. Moreover, Bhutanese students' weaknesses were identified primarily in items that required interpretation of data.

Teacher Proficiency in Science and Mathematics Education

Teacher proficiency in the context of this study refers to teacher competencies, teacher training and ongoing support as discussed below.

Teacher Competencies

Teacher competencies here refers to teaching experience and qualification of the teachers. The survey data on the experience of STEM teachers in Samtse Dzongkhag revealed that more than 50% of the teachers have taught STEM subjects for more than ten years, followed by 20% with a teaching experience between 5 and 10 years, and 28% with less than 5 years.

Table 10

Number of years of Teaching STEM Subjects

Number of years	Number of Teachers	% of Teachers
Less than 5 years	14	28.0
5 to 10 years	10	20.0
More than 10 years	26	52.0
	50	100

All STEM teachers at least have a University degree. The split-up of STEM teachers' qualifications is reflected in Table 11.

Table 11

Number of Teachers with Different Professional Qualifications

Qualification	Number of Teachers	% of Teachers
B.Ed	24	48.0
PgDE/PgCE	16	32.0
MEd	08	16.0
MSc	02	04.0
Total	**50**	**100**

Newly Qualified Teachers (NQT) [less than 5 years] were fewer in schools located in Urban districts compared to Samtse. For instance, Thimphu and Paro Dzongkhags have zero NQT while Samtse has 16 NQTs (Utha et al., 2022).

Teacher Training and Ongoing Support

In the context of this study, teacher training and support refers to Professional Development (PD) provided to teachers to enhance their content and pedagogical knowledge. The survey data from the teachers indicated that the status of PDs attended by teachers from 2018-2020 is very limited, as reflected in Table 12. Teachers across Bhutan did not attend even close to 50% of the mandated 80 hours of PD (Utha et al., 2022). The case is worse in remote Districts. For instance, for the last three years, teachers from urban Dzongkhags, namely, Thimphu and Paro, attended an average of 15 hours and 10 hours of PD respectively, while teachers of Samtse Dzongkhag attended only 6 hours of PD on average as evidenced from Table 12.

Table 12

Number of PD and hours of PD Attended by STEM Teachers (2018-2020)

Dzongkhag	2018		2019		2020		The average number of PD	Average hours of PD
	No. of PD	Hours of PD	No.of PD	Hours of PD	No. of PD	Hours of PD		
Thimphu	0.38	5.63	1.00	13.38	1.31	26.00	0.90	15.20
Paro	0.58	10.67	0.50	6.67	0.83	12.17	0.64	10.00
Samtse	0.36	6.85	0.38	8.49	0.17	2.17	0.3	5.84

Infrastructure and Resources to Support Science and Mathematics Education

It is imperative for all schools to have adequate infrastructure and resources, especially well-equipped Science and Mathematics laboratories as effective teaching and learning of STEM involve observing, handling, and manipulating real objects and materials. Theories learnt in classrooms may not be easily understood unless students observe and execute the process practically. Therefore, schools must have adequate infrastructure to make STEM interesting and effective for students and to encourage them to contribute significantly in the related field.

Survey data revealed that of the 6 schools that participated in the study, one school did not have a chemistry laboratory and one did not have a physics laboratory while no participating schools had a Mathematics laboratory. However, all participating schools have well-furnished libraries. Since library facilities are considered a requisite across many disciplines, libraries are prioritised over Science Labs.

Interview participants opined that despite the availability of science laboratories, budget provision was required to replenish laboratory chemicals, equipment, and consumables on a timely basis, which was lacking. For instance, one of the interviewees expressed that "budget provision is required to replenish the consumables and restock chemicals and other equipment from time to time in the science laboratory. Quite often the lab runs out of chemicals or the chemicals get expired and not able to perform science practicals" (Academic Head). Similarly, one of the school Principal's that participated in the interview articulated that "they are not able to replenish laboratory resources owing to lack of funds" (Principal). Besides laboratory and library resources, textbooks are used in the school for the teaching of STEM subjects. They also use guidebooks, reference books, past question papers, and instructional guidelines (Academic Head). The participants also reported that they use online resources to support teaching and learning (Lead Teacher).

Science and Mathematics Education Initiatives

In pursuit of developing STEM education, MoESD of Bhutan initiated a number of activities, such as overhauling the Science and Mathematics curriculum, upgrading the qualification of Science and Mathematics teachers to the masters' level, organising STEM Olympiad among many others. The STEM Olympiad is aimed to improve the quality of STEM education by sparking students' interest in STEM-related areas, instill positive attitude and values, and provide recognition for outstanding achievement in STEM education (REC, 2019). The importance of STEM education is also echoed in Education Blueprint 2014-2024 which underlines that students with deep knowledge and understanding of STEM will succeed in higher education or function effectively in a competitive economy (MoE, 2014). Besides, the Royal Society for STEM, under His Majesty's Secretariat, is set up to strengthen Bhutan's participation in scientific and technological innovations.

ICT in Education

In the context of this study, ICT in education is discussed under the following sub themes such as Attitudes and practices concerning ICT in education, Teacher proficiency in ICT in education, ICT in education infrastructure and resources, and ICT in education initiatives as discussed below.

Attitudes and Practice Concerning ICT in Education

All interview participants (n=4) in this study expressed that ICT played a vital role in continuing teaching and learning in schools during COVID-19 pandemic. Since teachers were teaching online for the first time, the Chief District Education Officer expressed that, in order to help teachers cope with online teaching, they were trained to use online teaching strategies. However, slow internet speed, lack of proper infrastructure, minimal exposure of students, teachers' minimal knowledge on the use of ICT in teaching, and additional expenses the teachers and parents had to bear on data packages, are challenges faced by all concerned (Principal & Lead Teacher).

Other concerns associated with ICT in education is large class size in the schools. For instance, access to ICT could not be provided to every student owing to a large number of students in the class (Principal). Hence, access to ICT was prioritised for students preparing for high stake examinations (Lead Teacher). Further, to add to the problems, teachers' ICT knowledge varied. According to one

Principal, some teachers in his school had very good ICT skills, while few teachers were least bothered to enhance their ICT knowledge (Principal).

Considering the importance of ICT in education, MoESD has been initiating the introduction of ICT in schools for all class levels since 2017. By 2021, it was envisioned that ICT subjects will be taught across classes PP-XII. However, in practice, ICT subjects are yet to be introduced in some classes and schools. This delay was caused mainly because of COVID-19 pandemic, in addition to schools' readiness in terms of infrastructure and equipment, and teachers' capabilities.

Teacher Proficiency in ICT in Education

Survey data (n=50) revealed that the average number of PD in ICT attended by the teachers in Samtse in the last three years (2018-2020) is very low as reflected in Table 13. The same was echoed by interview participants that teachers' had minimal knowledge on the use of ICT to support teaching (Lead Teacher) as many teachers did not attend any PD in the last three years. It is mostly newly qualified teachers that did not attend any PD. Survey data also revealed that the average number of PD increased slightly in 2020. This increased in the number of PD was necessitated to facilitate online lessons in the schools. This is echoed from the interview findings as expressed by the Lead Teacher:

> Compared to previous years, PD at both cluster and school levels reduced due to frequent closing of schools. Despite all the challenges posed by COVID-19, PD requirements of needy schools were addressed by having face-to-face and online PDs.

Table 13

Number of PD attended by the Teachers (2018-2020)

Dzongkhag	No. of STEM teachers	The average number of PD attended in the year (focused in ICT enabled)		
		2018	2019	2020
Samtse	50	0.13	0.32	0.79

The need to enhance the ICT capacity of teachers is considered a key intervention to ensure the successful integration of ICT into teaching. Bhutan Education Blueprint (2014-2024) states that teachers need to use ICT pervasively in their teaching to improve the quality of education. Since most of the teachers have not studied ICT subjects in their school/college/teacher training period, they need to undertake PD programmes focused on ICT-enabled teaching.

Chiphen Rigpel Project was started in 2010 to transition Bhutan into a modern IT-enabled and knowledge-based society. The Chiphen Rigpel Project (2010-2015) was instrumental in providing basic ICT skills training to all teachers in Bhutan. During the 11th five year plan (FYP), MoESD developed and implemented its first-ever Education ICT Masterplan, iSherig-1 to provide digital pedagogy training to teachers.

Based on the emerging priority and progress made in iSherig-1, MoESD developed its second Education ICT Masterplan, iSherig-2, to act as a road map while implementing Education in ICT in the 12th FYP. The iSheri-2 Education ICT Master Plan (2019-2023) prioritises implementing programmes through concerted efforts to update the curriculum and upgrade infrastructure as per changing ICT landscape. Equal priority is accorded to the capacity development of professionals delivering the curriculum and managing ICT facilities and services.

ICT in Education Infrastructure and Resources

Access to infrastructure and internet are prerequisites for the successful integration of ICT in teaching and learning. Recognising the importance of the internet and computers in enhancing the quality of education, SDG indicator 4.a.1(MoE, 2020) emphasises the need to have good access to internet and computers in schools. Although the majority of secondary schools and a few primary schools in Bhutan are connected to the internet, iSherig-II Review Report (MoE, 2019a) indicates that most of these schools are still challenged with inadequate bandwidth.

Infrastructure - Survey data reveals that schools in Samtse have a functional ICT laboratory to support ICT aided teaching and learning. For instance, there are functional laptops and desktops supported with associated devices such as printer, projector, photocopier and smart TV as reflected in Table 14 though the number is less compared to schools in the capital city Thimphu (Utha et al., 2022).

Table 14

ICT Infrastructure Available in the School

Dzongkhag	Number of functional ICT infrastructure											
	L	D	P	Pr	Ph	G	T	SB	ST	S	WC	SS
Samtse	10	240	18	19	6	0	0	0	20	6	1	10
Thimphu	62	214	67	24	7	5	36	1	15	5	26	5

L=Laptop; D=Desktop; P=Projector; Pr=Printer; Ph=Photocopier; G=Generator/Inverter/UPS; T=Tablet; SB=Smartboard; ST=Smart TV; S=Scanner; WC=Web Camera, SS=Sound System

Survey data also reveals that all schools in Samtse have fiber optic broadband connections though the speed varies between 7-11mbps. All schools have access to electricity and internet connection most of the time.

ICT devices owned and used by teachers as learning resources -The information on ICT devices owned and used to support teaching by teachers in the Samtse Dzongkhag schools is reflected in Table 15.

Table 15

Device Owned and used by Teachers for Teaching and Learning

Dzongkhag	No. of STEM teachers	ICT devices owned by the teacher (%)		ICT devices teachers frequently used in teaching (%)			
		Laptop	Smart phone	Laptop	Smartphone	Projector	Smart TV
Samtse	50	94.34	81.13	94.34	81.13	62.26	33.96

Table 15 shows that a majority of the teachers that participated in the survey (N=50) own a laptop (94.34%) while most of them have smartphones (81.13%). They use these devices to support their teaching and learning. A small section of schools in Samtse use smart televisions (33.96%). Besides, projectors are also used in classrooms during teaching. For example, 62.26% of teachers in Samtse Dzongkhag use a projector as reflected in Table 15. Teacher survey data also reveals that the percentage of students with access to smartphones varied between 10-80% implying that some students do not have access to smartphones. This may be because some schools do not allow students to carry

smartphones to the classroom, and some students cannot procure smartphones owing to financial constraints.

This study also looked at the various means of communication, the use of digital multimedia, and engagement in online teaching. The information generated from the survey reveals that most of the teachers use email to communicate (77.36%), while all teachers use social media apps to communicate and update news (100%). Among digital applications, all teachers favour videos as the commonly used application to support their teaching. This was supported by a Lead Teacher in the interview. Further, all teachers indicated that they use Google docs, PowerPoint, simulation, and Mentimeter as reflected in Table 16.

Table 16

Communication Tools used by Teachers

Dzongkhag	Communication through email (%)	Communication through other social media (Wechat, Telegram, WhatsApp, Facebook …) (%)	Internet and social media use to update news (%)	Digital application (video, simulation PowerPoint, Mentimeter, Google doc …) use in teaching-learning (%)
Samtse	77.36	100	100	100

Conclusion and Recommendations

All STEM teachers have at least a first degree from recognised Universities. Majority of the teacher (59%) respondents have postgraduate degrees while 41% have first degree. The experience of teachers teaching STEM subjects in Samtse Dzongkhag is quite positive, as evident from more than 50% of the respondents having taught STEM subjects for more than ten years, 29% taught between 5 and 10 years, and 19% with less than 5 years.

However, it is discouraging to note that the Professional Development (PD) received by STEM teachers is minimal. The PDs received by teachers from Samtse amounts to less than 20% of the mandated hours prescribed by MoESD that stipulates that all teachers should attend 80 hours of PD annually. For instance, the findings reveal that between 2018-2020, only 6 hours of PD on average was attended by teachers of Samtse Dzongkhag. The situation is no different in urban centres. For the same period, STEM teachers in Thimphu and Paro attended an average of 15 hours and 10 hours of PD, respectively (Utha et al., 2022). The case would be worse in schools located in remote places.

The findings reveal that the performance of students in STEM subjects from the participating schools in the class X and XII STEM subjects is good in the national examination with a pass percentage for (2018-2020) at 90%. However, the high pass percentage may be attributed to the fact that students merely have to score 35% in a subject to pass. Bhutanese students' performance in the PISA-D 2017 suggests there are rooms for improvement (BCSEA, 2019). The report reveals that students face difficulty in formulating situations mathematically, and solving tasks related to content areas while in Science, they struggle in interpretation of data.

STEM teachers involved in this study were very positive of the potential of ICT in making teaching and learning meaningful and impactful. Most of the teachers had their first experience of teaching online when the pandemic struck the country in 2020 causing the closure of schools. Despite limitations such as an absence of ICT infrastructure and resources, lack of ICT knowledge both for teachers and students, slow connectivity and heavy data packages consumed for online classes, students progressed to next grade during the pandemic though there may have been compromises on the depth of learning.

Considering the importance of ICT in education, MoESD has introduced ICT in schools for all class levels since 2017. The need to enhance the ICT capacity of teachers is also featured in Bhutan Education Blueprint (2014-2024). According to Bhutan Education Blueprint, teachers need to use ICT vigorously in their teaching to improve the quality of education. Based on the emerging priority and progress made in iSherig-1, MoESD developed its second Education ICT Masterplan, iSherig-2, to update the curriculum and upgrade infrastructure as per the changing ICT landscape. Equal priority is granted to the capacity development of teachers delivering the curriculum and in managing ICT resources and services.

In pursuit of enhancing STEM subjects, MoESD in Bhutan initiated a number of activities, such as reviewing the Science and Mathematics curriculum, upgrading the qualification of Science and Mathematics teachers to the masters' level, and organising the STEM Olympiad among many others. Besides, the Royal Society for STEM, under His Majesty's Secretariat, is set up to strengthen Bhutan's participation in scientific and technological innovations (Utha et al., 2022).

Through the Connected Learning Initiative (CLIx) project, Samtse College of Education with support from TISS, Mumbai is providing professional support to STEM teachers in schools under Samtse Dzongkhag. This exercise aligns well with the Royal Decree for Reform in Education which emphasises STEM subjects. Hence, the Connected Learning Initiative (CLIx) as an innovative STEM teaching practice in Bhutanese schools is seen as a worthwhile initiative to cascade to other schools to enhance STEM learning across schools in Bhutan.

Based on the findings, the following recommendations are made in order to enhance and strengthen teaching and learning of STEM subjects;

(i) The study reported that teachers who attended PD expressed that the training broadened their understanding about the teaching learning process though some of the training was not specifically for STEM subjects. Further, the training on online teaching organised by MoESD has helped them in making their lessons effective. However, the Professional Development acquired by the majority of STEM teachers in Samtse is far below what is envisioned by the Ministry of Education and Skills Development. Moreover, it is reported that the number of available PDs has reduced from the previous years (Lead Teacher). The concerned officials will need to revisit the policy and provide the required hours of PD as mandated.

(ii). STEM teachers have more than 30 hours of teaching per week as opposed to 18-22 hours per week as per the existing education policy (MoE, 2014). This extra workload has impacted teachers from preparing quality lessons to attending to students' work and giving constructive feedback. The school authority should ensure that the standing MoESD policy is respected and enforced.

(iii).The participants in the study opined that due to lack of equipment, it is challenging for teachers to practically show and analyse samples in STEM subjects. The introduction of the New Normal Curriculum by REC also demands more practical aspects in teaching and learning. It is recommended to the concerned schools to facelift specific laboratory equipment and apparatus required to make learning of Science practical and meaningful to carry out some scientific research that can result in innovation.

(iv).The PISA-D 2017 reported about the weaknesses of STEM students (BCSEA, 2019). In Mathematics, students had difficulty in formulating situations Mathematically, and solving tasks related to the content area. In Science, they faced challenges in interpretation of data. Further, in the participating schools, students' performance in STEM disciplines from 2018 to 2020 is just above average (Table 9). Hence, in the designing and implementation of OERs, additional support especially in the areas identified may have to be considered.

(v).Many schools have policies in place that prohibit students from bringing mobile phones to school. However, given the increasing importance of technology in education, students ICT knowledge and access to ICT equipment may need to be considered as computer laboratories in many schools are not well resourced. As suggested by some experts, schools should consider allowing students to bring their own devices in particular (mobile phones) as a way to increase access to technology and enhance learning.

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