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Impact of ICT integration in Science Classrooms at One of the Middle Secondary Schools

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Abstract

The purpose of this study is to explore the impact of ICT integration in science classrooms at one of the middle secondary schools of Bhutan. This study adopted a mixed-method approach with a pretest-posttest control group design. Tools used for the data collection were semi-structured interviews, survey questionnaires, class observation, and test questions. Qualitative data were analysed thematically, while quantitative data were analysed using descriptive statistics such as mean and standard deviation. The finding of the study revealed that the integration of ICT in the science classroom enhances students' engagement and academic achievement in the test. Further, online science resources such as websites and YouTube videos were found to be more effective in learning science. In addition, 3 prominent challenges in integrating ICT in the science classroom were found to be; insufficient gadgets, inadequate network facilities, and misuse of the gadgets by students.

***Keywords*— ICT, Classrooms, Middle Secondary Schools, YouTube**

I. INTRODUCTION

1.1 Background

Information and Communication Technology (ICT) has become increasingly popular in the educational landscape worldwide. The use of ICT in the classroom has become prevalent in recent years, and the benefits of its integration are well-documented in the literature. For instance, Ghavifekr et al. (2014) proposed that ICT integration can improve student engagement, motivation, and achievement through collaborative learning, critical thinking, problem-solving, and creativity skills.

ICT can provide students with access to a wealth of educational resources, such as online databases, educational videos, and simulations, which can enrich their learning experiences.

In Bhutan, the Chiphen Rigphel Project was launched in 2010 with financial assistance from the Government of India (Dorji, 2020). Since then, ICT remained one of the subjects in Bhutanese schools.

Further, with the advancement of digital technologies, teachers and students have access to ICT tools, which enhances student engagement and learning outcomes in the classroom. Hence, ICT integration is given priority in schools, even in teaching and learning science. Science for class 10 in Bhutanese schools comprises 3 disciplines which include chemistry, biology, and physics. Thus, in the context of this study, science refers to the combination of these 3 disciplines, regarded as a single subject.

1.2 Aim of the Study

This study aims to study the impact of ICT integration on classroom engagement and academic achievement in science, for class 10 students.

1.3 The Objectives of the Study

1) To study the effect of ICT integration on students' engagement in science classrooms.

2) To find out the impact of ICT integration on students' academic achievement.

3) To Evaluate ICT tools that enhance student learning of science.

4) To find out the challenges in integrating ICT in the classroom.

1.4 Research Questions:

How can the integration of ICT in classroom instruction enhance students' engagement and academic achievement in a middle school science classroom?

1.5 Sub question

1. How does the integration of ICT impact students' engagement in the classroom?
2. What is the impact of ICT integration on students' academic achievement?

3. What ICT tools enhance student learning of science?
4. Identify the challenges in integrating ICT in science class.

II. LITERATURE REVIEW

Findings from various studies indicate a positive correlation between ICT use and student engagement. The study conducted by Aylzhanova et al. (2022) found that students exposed to ICT-enhanced science lessons exhibited higher levels of emotional, behavioral, and cognitive engagement compared to those in traditional classrooms. Similarly, Hamed & Aljanazrah (2020) reported that the integration of interactive simulations and virtual labs in science lessons significantly increased students' interest and motivation to participate in scientific inquiries and experiments. Additionally, Adhami and Taghizadeh (2020) discovered that students engaged in collaborative learning activities using ICT tools demonstrated higher levels of engagement, peer interaction, and active participation during science lessons.

ICT integration in science lessons has also shown a positive impact on students' academic achievement and learning outcomes. A study by Haleem et al. (2022) revealed that students exposed to ICT-based science instruction exhibited higher gains in scientific knowledge and conceptual understanding compared to their peers in traditional classrooms. Martin and Bolliger (2018), reported that the use of online resources significantly improved students' retention of scientific information and their ability to apply knowledge to real-world scenarios. A meta-analysis by Ghavifekr et al. (2014) indicated that ICT integration positively influenced students' test scores and academic performance in science subjects across various grade levels.

Simulations provide students with immersive, risk-free environments to explore scientific phenomena (Smetana & Bell, 2012). Similarly, Kang and Hong (2020) found that virtual simulations enhance conceptual understanding and critical thinking skills. Moreover, ICT tools help in creating collaborative learning environments. For instance, Ghavifekr et al. (2014) suggested that promoting collaborative learning experiences using online platforms fosters teamwork and communication skills.

Despite the potential benefits, the integration of ICT tools in science education faces several challenges and barriers. Unequal access to technology and the internet can create a digital divide, limiting students' access to ICT resources (Warschauer, 2003). This inequality may exacerbate existing educational disparities. As per the study conducted by Ertmer and Leftwich (2010) teachers' limited ICT skills and familiarity with educational technologies may hinder effective integration in the classroom. Further, the successful integration of ICT tools requires alignment with existing curriculum goals and assessment methods (Levin & Wadmany, 2006). Failure to integrate seamlessly may lead to a fragmented learning experience. Moreover, Onyenanu (2015) emphasizes the multifaceted nature of integrating ICT into education. Notably, it has the potential to interrupt valuable learning time, encourage excessive usage, dilute pedagogical focus through computer games, and inadvertently subject students to diversions such as inappropriate content.

Similarly, in Bhutan, the challenge of integrating ICT in the classrooms as proposed by Wangdi and Rai (2022) is the students' inability to access gadgets in remote places. This issue predominantly arises due to the geographical location of the schools, coupled with parents' limited economic background and the delayed advancement of technology. Furthermore, the study conducted by Wangdi et al. (2021) underscored the issue of high internet costs, which poses a significant barrier for students seeking to engage in online teaching and learning.

III. METHODOLOGY

This study employed a mixed-methods approach, a combination of both quantitative and qualitative methods, to comprehensively investigate the impact of integrating ICT in science lessons on student engagement and academic achievement. A pretest-posttest control group design was adopted to assess changes in student engagement and academic achievement.

3.1 Sampling

The study involved 36 students from class 10 and 3 science teachers including a teacher each for biology, chemistry, and physics who teach science subjects in class 10, at one of the middle secondary schools. The sampling technique adopted was purposive. Purposive sampling is a non-probability sampling technique where participants are deliberately selected based on specific criteria relevant to the objectives of the study.

3.2 Data collection tools

The qualitative data collection tools adopted for this study include semi-structured interview questions and class observation, while the quantitative tools used were a 5-point Likert scale, and class test, as detailed in the following sections.

3.2.1 Class Observation

Class observations were done, to collect information on classroom dynamics and teacher-student interactions during science lessons. The observations were done 3 times each,

before and after the intervention programme. The observation form was developed that included the following aspects:

i. Student Engagement and Participation**:** Observing students' participation, involvement in ICT-based tasks, and their level of attentiveness during the lesson.

ii. Use of ICT Tools: Document the specific ICT tools utilized by the teacher and students during the lesson and their impact on engagement.

3.2.2 Class test

The pre-test and post-test were administered to evaluate students' knowledge and understanding of science concepts before and after the intervention programme. The test consisted of:

Subject-Specific Questions: Multiple-choice questions and short-answer questions to assess the students' baseline understanding of science concepts before the intervention, and their progress after the intervention programme.

3.2.3 Survey Questionnaire

The pre-survey and post-survey questionnaires were administered that measured students', engagement, the impact of ICT integration on test achievement, the effectiveness of ICT tools, and challenges faced by students and teachers in the integration of ICT in science classes.

3.2.4 Semi-structured Interview

Pre and post semi-structured interviews were conducted with science teachers to gain insights into their experiences, and perceptions on challenges in integrating ICT in science lessons. All science teachers (3 teachers teaching biology, chemistry, and physics) of class 10 were interviewed and their responses were recorded.

3.3 Data analysis

Quantitative data from surveys and class tests were analyzed using Statistical Package for Social Science (SPSS). The Descriptive features of SPSS such as mean and standard deviation were employed to analysed quantitative data. Similarly, qualitative data from observations and interviews were analyzed thematically using verbatims, categories, and themes.

3.4 Intervention Programme

During the intervention phase, specific ICT tools were integrated into the science lessons. The integration was carried out over a predetermined period, allowing sufficient time for students to experience and engage with the ICT-enhanced science lessons.

Some of the notable interventions were:

1. Phet Simulations: Phet simulations use visual representations of concepts in science that are hard to understand. It is easy to access and free to use by anyone with a device and an internet connection. A total of 9 science lessons were taken, including 3 chemistry lessons, 3 biology lessons, and 3 physics that involved the use of Phet simulation
2. Online Science Resources: Online science resources in this study refer to various websites, and YouTube videos, that are easily available and freely accessible online. A total of 9 lessons including 3 lessons each for biology, chemistry, and physics were taken using the Online Science Resources. This involves the use of both YouTube videos and a website in a particular science lesson.
3. Online platform: The online platform in the context of this study refers specifically to 3 online platforms such as Slido, Ed Puzzle, and Near Pod.

IV. RESULTS: A COMPARISON OF PRETEST AND POST-TEST DATA

This section presents the findings of the study and is presented in four major themes. They are; Integration of ICT and Students' Engagement in Science Classroom, Integration of ICT and Students' Academic Achievement, ICT Tools that Enhance Science Learning, and Challenges of Integrating ICT Science in the Science Classroom, as detailed below.

4.1 Integration of ICT and Students' Engagement in Science Classroom

The integration of ICT in the teaching of science enhanced the students' engagement in the class. This is evident from the 6 rounds of class observation., which were done 3 times before administering the intervention and 3 more times after the intervention programme. Out of 36 students, 7 students voluntarily took part in responding to questions and sought clarification in the class, during the pretest and the number significantly rose to 28 students after the integration of ICT in the science classroom, as presented in Table 1

Table 1 Students' Voluntary Participation in the Science Class

Pre-test			Post-test		
Rounds	**Male**	**Female**	**Rounds**	**Male**	**Female**
Round 1	2	0	Rounds 4	5	4
Round 2	1	1	Rounds 5	6	5
Round 3	2	1	Rounds 6	4	4
Total	**5**	**2**	**Total**	**15**	**13**

Data obtained from semi-structured interviews with teachers also supported that students' engagement in classroom lessons is enhanced after the use of ICT in classroom teaching. For example, an interview with teacher 2(Tr2), before the administration of the intervention programme expressed that:

> It is frustrating to see that only a handful of students are interactive and engaging in the class. I am trying my level best but most of the students seem to be feeling bored. That's why, I often go to the class with some jokes and short stories.

Similarly, teacher 1(Tr1) reported that:

> Some students neither contribute to the team activity in the class nor are attentive and responsive in the class. I always see a few students dozing off.

However, the teacher noticed an improvement in the students' engagement in the class after the intervention programme. For instance, Tr3 expressed that:

> I think the use of ICT tools ignites the interest of the students in learning science. I see them more interactive and engaging when I teach them using ICT tools like YouTube videos, and PowerPoint presentations. I have seen students enjoying the quiz activity in Ed puzzle too.

Further, the mean comparison of data from the survey questionnaire also aligns with the above finding. With the composite mean of (M=4.1; SD=1.3) in the post-test, and the composite mean of (M=2.1; SD=1.8) in the pretest, the data indicated improvement in the engagement of students in the science class as detailed in Table 2.

Table 2 Comparison of Pretest and Posttest Survey Response on Students' Engagement in the Classroom

Statements	Pretest			Post-test		
	Mean	Standard Deviation	Level of opinion	Mean	Standard Deviation	Level of opinion
I love to participate in the classroom activity.	2.6	0.6	Moderate	4.1	0.4	High
I don't feel sleepy in the science class.	1.4	0.5	Very low	3.9	1.2	High
I enjoy doing the class activity.	2.2	1.3	Low	4.4	1.9	High
I understand all the concepts clearly in the class.	1.7	1.1	Low	4.1	1.7	High
Composite mean and standard deviation	2.1	1.8	Low	4.1	1.3	High

[1.0-1.50=Very low, 1.51-2.50=Low, 2.51-3.50=Moderate, 3.51-4.50=High, 4.51-5.00=Very High (Zangmo, 2016).

4.2 Integration of ICT and Students' Academic Achievement

The findings from the test result revealed that the students' academic achievement in science is enhanced while integrating ICT into classroom teaching. The mean score has increased from 42.5 in the pretest to 61.2 in the posttest with a mean difference of 18.7 as shown in Table 3.

Table 3 Comparison of Students' Score in the Pretest and Posttest

Test	Gender	Mean	Total Mean	Mean Difference
Pretest	Boys	40.6	42.5	18.7
	Girls	44.4		
Post-test	Boys	59.1	61.2	
	Girls	63.3		

Similarly, the data obtained from the interview with the science teacher agreed that integration of ICT in the science classroom enhances students' performances in the test and examination. For instance, Tr2 said that:

> I firmly believe that the use of ICT tools to teach science will help students to learn better, which would result in better performance in tests and examinations. This is because ICT tools such as simulations, animations, and videos help in visualizing concepts that are not practically visible.

In addition, Tr3 mentioned that:

> The use of ICT to teach science can ignite students' interest in learning science. This definitely will lead to better performance in the tests and examinations.

4.3 ICT Tools that Enhance Science Learning

The data obtained from the students' survey shows that the ICT tools enhance the learning of science with the composite mean (M=3.8; SD=1.1) as indicated in Table 4. As per the survey data, an effective ICT tool that enhances the learning of science is online science resources that include websites and YouTube videos, with a mean of (M=4.2; SD=0.8).

Table 4 ICT Tools Which Enhance Science Learning

Statements	Mean	Standard Deviation	Level of opinion
My learning of science is enhanced when the teacher uses Phet simulations	3.7	1.3	High
My learning of science is enhanced when the teacher uses online science resources such as websites and YouTube videos)	4.2	0.8	High
My learning of science is enhanced when the teacher uses online platforms such as Slido, Ed Puzzle, and Near pod	3.4	1.1	Moderate
Composite Mean and Standard Deviation	3.8	1.1	High

[1.0-1.50=Very low, 1.51-2.50=Low, 2.51-3.50=Moderate, 3.51-4.50=High, 4.51-5.00=Very High (Zangmo, 2016).

Data from the science teachers' interviews also revealed that YouTube videos and information from websites and web pages enhance science learning. For instance, Tr1 spoke that:

> Information on a particular concept is accessible and available on YouTube and websites. I use them to teach students in the class. The concepts which are often difficult to teach students are better done while using the videos, and supplementary information from the websites.

Similarly, Tr3 mentioned that:

> I often resort to using YouTube videos because I see many YouTubers who can explain and illustrate science concepts much better and clearer.

Further, the data from the classroom observation support that YouTube videos are more effective in making students understand concepts better in science. This is evident from the smaller number of students seeking clarification in the class while using YouTube videos as indicated in Figure 1

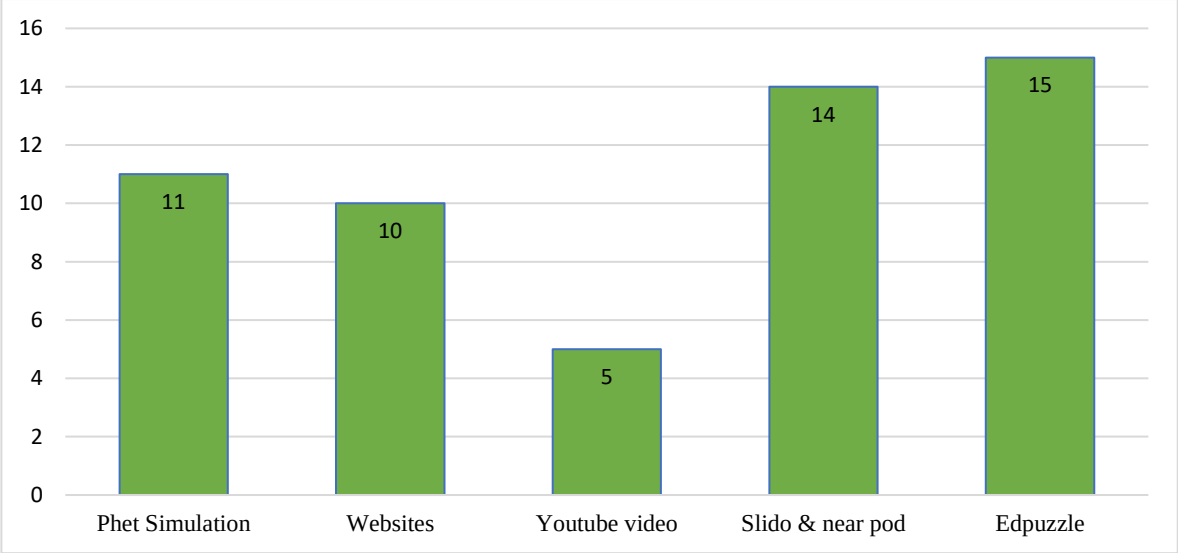

Fig.1: *Number of Students Who Sought Clarification while Using Different ICT Tools in the Class*

4.4 Challenges of Integrating ICT Science in the Science Classroom

As per the data obtained from the Semi-structured interview, numerous challenges faced by the science teachers in integrating ICT in the class include insufficient gadgets in the school, inadequate network coverage, and improper use of the internet facility by students. For instance, Tr2 mentioned that:

> Integrating ICT in the classroom is a challenge. To point a few, I believe that the insufficient computers or gadgets in the school lower my motivation to use some ICT tools I am familiar with. The dream of having sufficient computers in the school is still a dream. This issue is fueled by inadequate network connections. We have internet connections only in Staffrooms, offices, and IT lab.

Similarly, Tr1 pointed out that:

> We don't have enough gadgets in the school. That's not the only issue. Even if we can manage gadgets, there is no network connection in the classrooms. Using personal data and sharing it with students costs us huge. The cost shoots up when students misuse the facility we try to provide. Often, I see students playing games or engaged in other websites and platforms.

In addition, Tr3 said:

> There can be a list of challenges in using ICT for teaching and learning science. I would like to specifically mention that, lack of internet connection in the class, insufficient computers/gadgets in the school, and improper use of the ICT facilities by students are the top challenges I encounter.

The findings from the class observation also indicated that the school has inadequate computers or gadgets. For instance, in the classes observed during the activity that used Ed puzzle, and Slido during the intervention programme, 8 students were seen waiting for their turn to complete the activity after their colleagues. On the other hand, 3 male students were observed playing a game, and 1 female student watched a drama on YouTube.

V. DISCUSSION

In this section, the main findings of the study are discussed concerning 4 themes. They are Integration of ICT and Students' Engagement in Science Classroom, Integration of ICT and Students' Academic Achievement, ICT Tools that Enhance Science Learning, and Challenges of Integrating ICT Science in the Science Classroom as detailed below.

5.1 Integration of ICT and Students' Engagement in Science Classroom

This study revealed that the integration of ICT in the teaching of science enhanced the students' engagement in the science class (See Section 4.1). It is consistent with the study conducted by Aylzhanova et al. (2022) who found that students exposed to ICT-enhanced science lessons exhibited higher levels of emotional, behavioral, and cognitive engagement compared to traditional classrooms. A similar conclusion was made by Hamed & Aljanazrah (2020) who reported that the integration of interactive simulations in science lessons significantly increases students' interest and motivation to participate in scientific

inquiries. Additionally, Adhami and Taghizadeh (2020) discovered that students engaged in collaborative learning activities using ICT tools demonstrated higher levels of engagement, peer interaction, and active participation during science lessons

5.2 Integration of ICT and Students' Academic Achievement

This study revealed that the students' academic achievement in science is enhanced by integrating ICT into classroom teaching (See Section 4.2). A study by Haleem et al. (2022) agreed with this finding when they proposed that students exposed to ICT-based science instruction exhibited higher gains in scientific knowledge and conceptual understanding compared to their peers in traditional classrooms. Further, Bolliger (2018), reported that the use of online resources significantly improved students' retention of scientific information and their ability to apply knowledge to real-world scenarios. Additionally, Ghavifekr et al. (2014) also pointed out that ICT integration positively influenced students' test scores and academic performance in science subjects across various grade levels.

5.3 ICT Tools that Enhance Science Learning

This study also revealed that an ICT tool that enhances maximum learning of science is online science resources that include websites and YouTube videos (See Section 4.3). This finding is consistent with a study by Wong (2013) who found out positive relationship between student engagement in class with online resources, which resulted in better overall academic results. Further, Otchie et al. (2020) also proposed that teachers' use of YouTube videos to teach STEM makes teaching more realistic, interactive, and relevant to the needs of the learners, potentially motivating students to take up an interest in learning science. Similarly, a study done by Bohloko et al. (2019) found that the percentage of experimental group students who passed the post-test doubled as a result of using YouTube videos (from 12 to 27%), while the percentage of control group students who passed the exams stayed the same at 5% for both the pre-test and the post-test.

5.4 Challenges of Integrating ICT Science in the Science Classroom

Findings from this study pointed out 3 challenges in integrating ICT in the class which include, insufficient gadgets in the school, inadequate network coverage, and improper use of the facility (gadget and internet) by students (See Section 4.4). This finding is consistent with a study done by Wangdi and Rai (2022) who revealed that one of the most significant challenges in using ICT in the classroom is the students' inability to access gadgets in remote places. This issue predominantly arises due to the geographical location of the schools, coupled with parents' limited economic background and the delayed advancement of technology in Bhutan. Furthermore, the research conducted by Wangdi et al. (2021) underscored the issue of high internet costs in Bhutan, which poses a significant barrier for students seeking to engage in online classes. This adds to the issue of inadequate network coverage in the school. Moreover, Onyenanu (2015) emphasizes the multifaceted nature of integrating ICT into education. Notably, it has the potential to interrupt valuable learning time, encourage excessive usage, dilute pedagogical focus through computer games, and inadvertently subject students to diversions such as inappropriate content.

VI. CONCLUSION

In conclusion, the integration of ICT in the science classroom enhances the students' engagement in the science classroom as presented in Section 4.1. Further, the ICT integration in the science classroom impacts students' academic achievement positively as indicated in Section 4.2. This study also found out that the effective ICT tools for teaching and learning science are online science resources that include YouTube videos and websites or webpages, followed by Phet Simulations, and online platforms like Slido, Ed Puzzle, and Nearpod as detailed in Section 4.3. Challenges in the integration of ICT in the science classrooms were found associated with insufficient gadgets in the school, inadequate internet connections in the school, and misuse of internet facilities such as gadgets and internet connections by students as presented in Section 4.4.

RECOMMENDATION

This study found that the integration of ICT in the science classroom enhances the students' engagement and academic achievement in tests. Further, the study pointed out that the school faces challenges with inadequate gadgets and network connections. Therefore, this study recommends the Ministry of Education and Skills Development (MoESD), to support schools across the country with adequate gadgets and network connections and work towards improving ICT facilities for schools through the formulation of plans and policies.

This study also apprises the school administration on the positive impact of integrating ICT in science classrooms. Therefore, the study recommends the school administration to take proactive roles in framing policies and gathering resources that help the school enhance ICT uses and practices. The school administration is also recommended to work on apprising higher relevant authorities and seeking

donors for the supply of gadgets for the students in the school. Further, the school authority shall frame policies and guidelines for allowing the students to bring their personal gadgets to school for learning purposes.

Further, owing to their technical nature, science concepts demand multiple representations such as the use of animations and simulations. The use of ICT tools and features, specifically the science online resources that include YouTube videos and websites were found to be more effective ICT tools in teaching science to the students. Hence, this study recommends the science teachers of class 10, to use YouTube videos and websites in the science lesson.

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