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Effectiveness of the Interactive Whiteboard in Teaching Physics

Dawa Tshering
Ministry of Education and Skills Development, Bhutan

Karma Utha
Royal University of Bhutan, Bhutan

ABSTRACT

The Interactive Whiteboard as a teaching tool, has been in use across schools and institutions in many countries. Bhutanese schools started using them for educational purposes in 2019. However, there is lack of evidence on their actual use and effectiveness in teaching physics to enhance students' learning. This study aimed to investigate the effectiveness of Interactive Whiteboard (IWBs) in teaching electromagnetic induction to 31 students using a convergent mixed method design. A Physics Achievement Test (PAT), survey, and semi-structured interviews were used to collect data. Using a purposive sampling method, 31 students participated as experimental group (EG) and 33 as the control group (CG). Six students from EG participated in semi-structured interviews, along with four Physics teachers. Independent samples t-tests on post-test results showed a significant difference ($t [62] = 4.78$, $p < 0.001$), and paired samples t-tests within the EG indicated significant improvement ($t [30] = 7.40$, $p < 0.001$) compared to traditional teaching method. Qualitative findings supported the quantitative results, demonstrating that IWBs use appeared enhance learning, save resources, and increase students' confidence in physics. However, challenges included power outages and calibration issues. The study has positive implications for educational practices and policies, recommending the use of IWBs to make learning more meaningful, realistic, and authentic.

Keywords: *Effectiveness; Interactive; Whiteboard; Investigation; Electromagnetic; Induction*.

INTRODUCTION

Technology has profoundly influenced and transformed every aspect of human life, including education. The increasing application of digital technologies has made education a global asset (Bezanilla et al., 2019). To shift from traditional teaching to 21st century practices, the Ministry of Education and Skills Development (MoESD) in Bhutan has been working to enhance the use of Information and Communication Technology (ICT) to support teaching and learning. Starting 2002, ICT was introduced as an optional subject in Class IX and was gradually expanded to higher classes (Lhendup, 2020). However, noticeable change has been limited as the teaching approach remains predominantly teacher-centred, with ICT being taught as a standalone subject rather than as an integrated tool for enhancing teaching. Today's Bhutanese students are continually exposed to technology, influencing their preferences for a technology-driven learning environment (Kinley, 2015). Hence, integrating ICT has become imperative for teachers to effectively address the learning needs of the students.

Building on the growing integration of ICT in education, tools such as computers and the internet have demonstrated their potential to drive educational change and reform (Ugwu & Nnaekwe, 2019). One such tool, the Interactive Whiteboard (IWB), has been adopted across various subjects, including mathematics, chemistry, physics, geography, science, art, and music (Dostal, 2011). As an educational resource, the IWB enhances creative teaching, fosters classroom discussions, and motivates students, thereby facilitating deeper engagement and information retention (Rizwan et al., 2018). Originally developed in the United States in the early 1990s (Canavarro & Reis, 2017), the IWB has since been widely adopted in many countries, as they increasingly recognize the advantages of interactive and technology-enhanced teaching methods (Akar, 2020; Kirbas, 2018). The growing use of IWBs in classrooms worldwide reflects the increasing emphasis on improving student engagement and learning outcomes through technology-integrated education (Canavarro & Reis, 2017).

Bhutanese students' academic performance is generally below the average of students from other countries (Gyeltshen & Zangmo, 2020). Specifically, traditional teaching methods in Science, Technology, Engineering, and Mathematics (STEM) disciplines, which often rely on rote learning, have hindered students' ability to apply their knowledge in real-life contexts (Utha et al., 2021). This is reflected in the low scores of Bhutanese students in Mathematics and Science on the Program for International Student Assessment for Development (PISA-D), when compared with top-performing countries (BCSEA, 2019). From 2016 to 2020, the average performance in Physics for Bhutanese students in the Bhutan Certificate of Secondary Education (BCSE) was 56.2, below the national average of 60% (BCSEA, 2020a). Despite a slight improvement to a mean mark of 62.95 in 2021, Physics remains one of the subjects with poorer performance (BCSEA, 2021). Researchers have attributed these challenges to the subject's abstract nature, including complex formulas, laws, and calculations (Zangmo et al., 2022; Tenzin, 2021). The study holds due importance because it is the first study of its kind in Bhutan. Moreover, it may serve as evidence-based information to relevant stakeholders like policy makers, curriculum developers, principals and teachers to upscale their teaching.

Studies suggest that students' understanding of abstract concepts can be significantly improved by integrating technology into teaching. Ahmed and Gwamna (2020) supported ICT integration in Physics education, noting that the use of IWBs improves students' learning through the inclusion of images, animations, and videos, making abstract topics more accessible (Jensen, 2017; Van et al., 2012). Additionally, the effective use of IWBs has been linked to better understanding, retention, and improved assessment results (Tsayang et al., 2020).

While IWBs have been introduced in many Bhutanese schools since 2019, and their installation expanded from 2021 onwards (Lhamo, 2021; Kipchu, 2022; Deki, 2023), there is little data on their impact specifically in teaching Physics. This study aimed to explore the effectiveness of IWBs in enhancing the learning performance of Grade X physics students. Specifically, the effectiveness of IWBs in teaching Physics refers to improvements in students' performance in test scores and conceptual understanding (Patero, 2023). Furthermore, a study by Stroud et al., (2014) suggests that the use of IWBs contributes to learning improvement across subjects. The study was guided by the following research questions:

1. Are there significant differences in pretest and posttest scores within the groups and between control and experimental group?
2. What are the teachers and students' perception towards IWBs use on teaching and students learning?
3. What are the benefits of using IWBs in students' learning?
4. What are the challenges of using IWBs?

LITERATURE REVIEW

Interactive Whiteboards (IWBs) have become popular teaching and learning tools globally over the last decade (Vainoryte & Zygaitiene, 2015). They are considered advanced teaching aids in classroom settings, equipped with touch-sensitive boards that integrate computer technology (Tan et al., 2015; Young et al., 2017). Ifeakor et al. (2020) supported the definition of IWBs as large, sensitive boards intricately connected to a projector and compute, explaining that IWBs function through the interconnection of a computer and a projector.

The effects of IWBs in teaching and learning can be measured in terms of students' test scores. A study by Ifeakor et al. (2020) found that use of IWBs in the classroom led to a notable improvement in students' performance in STEM subjects, particularly in Mathematics. Similarly, Carter and Mehta (2018) revealed that effective use of IWBs increased students' mathematical proficiency compared to those taught in a traditional classroom. A meta-analytical and thematic study by Akar (2020) found that use of IWBs has a positive, large, and significant effect on the academic achievement of students. Another study by Adel and Abdelrahman (2019) revealed a statistically significant difference in students' performance, with teachers who use technology more frequently achieving higher student pass percentage. Additionally, students are able to watch videos, engage in interactive activities, and learn academic content more effectively (Karsenti, 2016; Van Veen et al., 2012). IWBs help students visualise and better understand lesson content (Van Veen & van den Berg, 2012). Conversely, no appreciable differences were found in students' learning performance in the primary school setting where some classes were taught with IWBs and others without them and Young et al. (2017) supported earlier findings that IWBs have no statistically significant direct influence on students' learning performance.

IWBs have been identified as valuable tools for teachers, offering strong potential to support and enhance instruction. Their use has expanded globally, contributing to more collaborative and interactive classroom environments. Studies have shown that IWB can foster greater teacher-student engagement, collaboration, interaction and enrich the overall learning experience. (Donotue, 2015; Gregorcic et al., 2018; Hennessy, 2011). However, some researchers, such as Tombak & Ateskan (2019), reported that IWBs may occasionally disrupt interaction when students' attention is diverted or when prolonged use causes discomfort. Other studies have highlighted positive effects on pedagogy, noting that IWBs enhance teachers' skills, motivation, and efficiency Bidaki and Mobahseri (2013). They also enable resource sharing, lesson modification, and storage of instructional materials for later use, which can streamline lesson delivery (Lazaro & Toscus, 2013; Millar & Glovar, 2010). Similarly, Northcote (2010) observed that IWBs help teachers revisit previous lessons and connect them to new concepts, thereby reinforcing continuity in learning.

Besides, abstract concepts are made clear to the students as they are presented in the picture, animation and video form (Veen & Berg, 2012). In contrast, IWBs use in Physics has also been viewed the same as use of the regular chalkboard, mostly used as a writing surface for the teachers and as a tool to solve textbook problems (Gregorcic et al., 2017). It has been shown by Onal and Demir (2017) that it enables teachers to apply different styles of teaching by moving icons and using a menu on a toolbar to show notes and learning materials on the board. The IWB also helps teachers organize classes for visual, auditory and kinaesthetic learners, ensuring that students' learning styles are addressed and met accordingly (Toscu, 2013). In contrast, Jensen (2017) pointed out that high school physics teachers were negative towards the use of IWBs due to a lack of confidence and skill; instead, they used them as regular whiteboards. Similarly, teachers viewed as energy- and time-consuming tools, as they have to prepare two sets of lesson plans, one to be used with the IWBs and another to be used in case of malfunction, taking more time more than expected (Bas,2015). Furthermore, a study conducted in Turkey by Gregorcic, Etkina and Planinsic (2017) stated that IWBs are underutilized due to teachers' self-declared lack of technical skills, lack of pedagogical competency in integrating IWBs into their teaching and lack of appropriate materials for IWB use.

However, technical challenges related to use of IWBs still exist. According to Bidaki and Mobasheri (2012) freezing, mismatch between the whiteboard and pen, and the limitation of having only one pen are problems associated with IWB use. Power failure is another issue. Erson (2018) stated, "Electricity interruptions cause the teacher to stop and the teacher to fail." It is further noted that power failure leads to time wastage while the computer and board restart. In addition, Anaturk and Ateskan (2019) reported problems in calibration settings. International studies have consistently shown that IWBs improve students' learning performance and deepen conceptual understanding in the Physics lesson (Karsenti, 2016; Tertemiz al., 2014). However, there is limited research on the use of IWBs in Bhutanese contexts where factors such as infrastructure reliability, teachers' knowledge and skills, and classroom practices may influence their effectiveness.

METHODOLOGY

Creswell & Creswell (2018) argued that while all research methods have inherent biases and weaknesses, these could be mitigated through a mixed-methods approach. This study used a convergent parallel mixed-method design. A quasi-experimental design was employed to assess the effectiveness of IWBs in teaching electromagnetic induction in a real classroom setting. Based on the pre-test results, students were assigned to the EG and CG non-randomly. The EG received IWB-based lessons, during which students were taught electromagnetic induction using features like the pen, eraser, whiteboard for drawing figures, PowerPoint presentations, and videos, while the CG was taught using traditional lecture methods with chalk and chalkboard.

The study was conducted in one of the schools under the Mongar District. Research participants were already familiar with the researchers. After formal approval from the school administration and consent from the participants, the data were collected using a Physics Achievement Test (PAT), a survey and semi-structured interviews. The PAT was piloted with 10 students using mid-term exam results, and an item analysis was conducted to evaluate conceptual understanding (CUT), difficulty index, and item discriminability. As shown in Table 1, and following Panjantan et al. (2018), the mean difficulty index was 0.71, and the discrimination index was 0.27, indicating that some items were too easy and required revision. Three easy items were discarded, and others were modified to improve content validity in alignment with the curriculum standards. The final PAT, consisting of 20 multiple-choice questions (MCQs), was administered to both the experimental group (N=31) and the control group (N=33) totalling 64 students. The reliability of the PAT items was ensured through expert consultation with physics teachers, and the test items were developed according to the current physics curriculum, to confirm the validity of the items.

Table 1: *Indices of Difficulty and Discriminability Level of Test Items*

Index	Difficulty level	Discriminability
0.86 above	very easy	To be discarded
0.71 -0.85	easy	To be revised
0.30 -0.70	moderate	Very good items
0.15-0.29	difficult	To be revised
0.14 below	very difficult	To be discarded

Note: Adopted from Panjaitan et al., (2018) p.2

To further support the PAT findings, a 5-point Likert scale survey (Yapici & Karakoyun,2016; Karsenti,2016; Mokoena et al., 2022) was conducted to the EG to assess their perceptions of IWBs in teaching and learning. The 40-item questionnaire was also piloted at a school in Bhutan to achieve reliability. The data were then merged, triangulated, and analysed for comprehensive results.

The Cronbach's alpha coefficient was 0.9, indicating high internal consistency and reliability (Creswell, 2012, p.25), as shown in Table 2. The survey items were validated through aligning survey items with the aims and objectives, research questions and themes.

Table 2: *Reliability Categories*

Cronbach's Alpha	Category
> 0.90	Very highly reliable
0.80 -0.90	Highly reliable
0.70- 0.79	Reliable
0.6-0.69	Marginal/minimum reliable
< 0.6	Not reliable

Note: Creswell, 2012, p.25

The qualitative data were collected through face-to-face semi-structured interviews with four physics teachers from participating schools and six students from the EG, based on convenient purposive sampling, for about eight hours. The credibility of the semi-structured interview questions was ensured through data triangulation by converging information from expert teachers and the supervisor. Furthermore, to determine the accuracy and trustworthiness of the responses, member checking was carried out. The PAT data were analysed using inferential and descriptive statistics. T-tests, including paired and independent sample t-tests, were used to compare group mean scores for significant differences, while survey data were analysed using the Mean (M) and Standard Deviation (SD). Tables 3 and 4 present the Likert scale measurements and their interpretations.

Table 3: *Measurement Scale of Likert Items*

Level of agreement	Score
Strongly Disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly Agree	5

Note: Adopted from Zangmo et al., 2016, p. 52

Table 4: *Interpretation Scale of the Overall Means Scores*

Means score	Levels of interpretation
1.00-1.50	Very low
1.51-2.50	Low
2.51-3.50	Moderate
3.51-4.50	High
4.51-5.00	Very high

Note: Adapted from Zangmo et al., 2016, p. 52

Creswell & Creswell (2018) asserted that researchers should respect the informants' rights, needs, values and preferences. The researchers fully abided by research ethics by seeking formal approval from the Office of the Dean of Research and Industrial Linkages (DRIL) of Samtse College of Education, Bhutan. Consent was obtained from the school principal and all participants. The confidentiality and anonymity of both quantitative and qualitative data were assured to the participants by using pseudonyms - S1, S2, S3, S4, S5 and S6 for students and T1, T2, T3, T4 and

T5 for teacher participants. It was assured that the data would be preserved in Google Drive for at least five years, with access limited to the researchers.

In the quantitative phase, the pre-test and post-test were conducted to assess students' conceptual understanding of electromagnetic induction. In addition, students' perceptions of IWB use in their learning, as well as the benefits and challenges of using IWBs, were examined using a five-point Likert scale survey. In the qualitative phase, in-person semi-structured interviews were conducted with six students from the EG and four Physics teachers. The findings from the two methods were triangulated and integrated to enhance clarity and comprehension. Qualitative data were analysed thematically in five steps (Creswell & Creswell, 2018). The qualitative findings further substantiated the quantitative results, suggesting that IWB use may have enhanced learning performance and benefitted both teachers and students despite its limitations.

RESULTS

Normality Test for the Pre-Test and Post-Test Score of the Groups

According to Mishra et al. (2019), the Kolmogorov-Smirnov and Shapiro-Wilk tests are commonly used to assess data normality and determine whether to use parametric or non-parametric tests. Given the small sample sizes of the Experimental Group (EG, N=31) and Control Group (CG, N=33), based on the actual number of students in each class, the Shapiro-Wilk test was used to evaluate the normality of the PAT scores. The null hypothesis was rejected if the p-value was less than 0.05, indicating a non-normal distribution, which would require non-parametric tests. If the p-value was greater than 0.05, the null hypothesis was not rejected, suggesting a normal distribution and allowing for the use of parametric tests. The results showed that both the pre-test and post-test scores followed a normal distribution, as the p-values were greater than 0.05. Consequently, parametric tests were conducted. Table 5 presents the normality test results for the pre-test and post-test scores of both the EG and CG.

Table 5: *Shapiro–Wilk test of Normality for pre-test and post-test scores*

Tests	Groups	No. of participants	P-values
Pre-test	CG	33	0.186
	EG	31	0.348
Post-test	CG	33	0.199
	EG	31	0.051

Note: (p >.05) CG: Control Group EG: Experimental Group

Tests for Equality of Means of the Pre-Test Score

The Shapiro-Wilk test, Levene's test, and t-test were carried to assess variance and mean equality between groups, ensuring comparable performance and avoiding researcher bias in assigning the EG and CG, selecting tests and increasing the reliability of the research findings. Table 6 shows the results of the equality of means between two groups based on their pre-test scores. Both assumption of homogeneity of variance and the equality of means of the groups were tested at the confidence level of 95% (i.e., p = .05). Table 6 presents the assumption of homogeneity of variance satisfied via Levene's F test, F (62) = 5.01, p =.02. Similarly, independent samples t-test demonstrated no significant difference in their mean score, t (62) = .71, p = .48 because p-value is greater than .05. Groups approximately with equal variances and means in their pre-test concluded two groups had an equal knowledge and level of understanding about Electromagnetic induction

Table 6: *Independent Sample T-tests for Equality of Means (Pre-Test)*

		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	**Sig.**	**T**	**df**	**Sig. (2-tailed)**	**Mean Diff.**
Pre-Test	Equal variances assumed	5.01	.02	.71	62	.48	.40
	Equal variances not assumed			.70	50.47	.48	.40

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Pre-Test Score Between the Groups

An independent sample t-test at a 95% confidence interval examined statistically not much differences in mean scores between the EG and CG. The EG had a pre-test score of M = 9.74 (SD = 2.75), while the CG scored M = 9.33 (SD = 1.76), showing minimal difference. Table 7 compares the groups' pre-test mean scores.

Table 7: *Pre-test Descriptive Statistics by Group* **(***EG vs. CG)*

	Groups	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Pre-test scores	Experimental Group	31	9.74	2.75	.49
	Control Group	33	9.33	1.76	.30

Test of Equality of Mean and Variance of the Post-Test Score

Levene's test assessed variance and mean equality, confirming learning performance based on significance and mean differences in post-test scores between the EG and CG using an independent sample t-test, as shown in Table 8.

Table 8: *Independent Sample T-tests for Equality of Means Based (Post-test)*

		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Diff.**
Post-test score	Equal variances assumed	3.52	.06	4.78	62	<.001	2.79
	Equal variances not assumed			4.74	54.16	<.001	2.79

The assumption of homogeneity of variances was tested and satisfied using Levene's F test, F (62) = 3.52, p = .06. With equal variances assumed, the independent samples t-test revealed a statistically significant effect, t (62) = 4.78, p < .001. The p-value (p < .001) and mean difference M = 2.79 indicate a significant difference in post-test scores between groups.

Post-Test Score Between the EG and CG

An independent sample t-test at a 95% confidence interval was conducted to assess statistically significant mean differences in post-test score between the EG and CG. The EG achieved a mean post-test score of M = 15.58 (SD = 2.86), while the CG obtained M = 12.78 (SD = 1.89). Table 9 shows a significant mean difference (p = 2.80) between the groups. The finding indicates IWB is significantly effective in teaching electromagnetic induction.

Table 9: *Post-Test Descriptive Statistics by Group (EG Vs. CG)*

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Post-test scores	Experimental Group	31	15.58	2.82	.48
	Control Group	33	12.78	1.93	.33

Comparison of Pre-Test and Post-Test Score Within the EG

A paired sample t-test at a 95% confidence interval revealed a statistically significant difference in students' mean scores within the EG, with a mean difference of M = 5.83, t(30) = 7.40, p < .001 (Table 10). The p-value (< .001) indicates a significant and effective intervention in teaching electromagnetic induction.

Table 10: *Paired Samples T-test Within EG (Pre-test vs. Post-test)*

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair	Post-test score Pre-test score	5.83	4.15	.74	4.31	7.36	7.82	30	.000

Table 11: *Pre-Test and Post-Test Descriptive Statistics Within EG*

	Mean	N	Std. Deviation	Std. Error Mean
Post-test score	15.51	31	2.82	.50
Pre-test score	9.74	31	2.75	.49

As shown in Table 11, the group had a pre-test score (M = 9.74, SD = 2.75) and a post-test score (M = 15.51, SD = 2.82), showing a significant increase in mean score (M = 5.77). This indicates that IWB had a significant effect on students' learning. The Cohen's d effect size, expressed by point estimate value was 1.34 which suggests a large effect of using IWB on the students in understanding the concept, as represented in Table 12.

Table 12: *Effect Size for EG*

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
Post-test score	Cohen's d	4.27	1.34	.85	1.83

Note: Cohen’s d use pooled standard deviation (Very Small<0.2; Medium <0.5, Large >0.8) (Adopted from Gulkesen et al., 2022)

Teachers and Students’ Perception Towards IWB In Their Learning

To gauge students’ perceptions of the use of IWBs in their learning experiences, data were collected based on three specific variables: students’ learning, perceived benefits, and potential challenges encountered during its use. The mean, standard deviation and level of perception were computed and analysed to examine the perception of students from EG toward the use of IWBs. Table 13 shows the average score (M=3.83, SD= 0.73), indicating that IWBs are highly effective in enhancing students’ learning.

Table 13: *Perception of the Students Towards IWB in Their Learning*

Sl. No	Items	Mean (M)	Standard Deviation (SD)	Perception Level
1	I learn more when teachers use IWB in learning	3.96	0.65	High
2	I learn faster when teachers use IWB	4.06	0.85	High
3	I perform better in the Physics test.	4.35	0.81	High
4	It is easier to understand when the teacher uses IWB.	3.93	0.72	High
5	The use of IWB makes the abstract concept clear.	4.00	0.79	High
6	The use of IWB makes my learning effective.	3.51	0.51	High
7	IWB helps me retain information better.	4.00	0.77	High
8	IWB use keeps me active in the class.	4.00	0.72	High
9	The use of IWB makes it easier to connect physics to real life.	3.93	0.68	High
10	I become excited when my teacher uses IWB.	3.48	0.77	High
11	IWB use make lesson interesting.	3.96	0.55	High
12	The use of IWB engage me during the activity.	4.06	0.67	High
13	The use of IWB make lesson enjoyable.	3.87	0.62	High
14	IWB use make me concentrate in lessons.	3.64	0.87	High
15	The use of IWB makes me work harder.	3.45	0.80	High
16	I prefer teacher teaching with IWB.	4.00	0.85	High

17	I feel more confident in learning physics with IWB.	4.00	0.68	High
18	The use of IWB increases my interaction.	3.51	0.96	High
19	IWB enhances my knowledge.	4.06	0.51	High
20	I participate more when the teacher uses IWB	2.83	1.00	Moderate
Overall		**3.83**	**0.73**	**High**

The interview data reinforced the survey findings, confirming that IWB use enhanced student learning and performance. For instance, student S3 said, "It offers various tools that make topics more specific, simplifies teaching and learning, and helps students achieve better scores while saving resources for future lessons." Similarly, teacher T2 noted, "Students perform better in exams. I've seen significant improvements in both understanding and academic scores." Both teachers and students preferred using IWBs, appreciating their ability to save resources for future use. Teachers also found IWBs convenient; T2 stated, "I prefer teaching with the IWB because it's easy to use. If we're absent, we can download video lessons on specific topics for students." Students also noted that the IWB helped them understand concepts more clearly, with S1 commenting on its effectiveness. Consistent with the survey results, all teachers and students agreed that the IWB boosted their confidence in teaching and learning Physics, thanks to its interactive and visual features.

Teachers and Students' Perception on Benefits of IWB

The data in Table 14 indicates high perception level with the overall mean score value (M=4.10, SD=0.73) regarding benefits of IWB.

Table 14: *Students' Perception on benefits of IWB*

Sl.No	Items	Mean (M)	Standard Deviation (SD)	Perception level
1	IWB replaces Chalkboard	4.29	1.10	High
2	IWB helps me revisit earlier lessons	4.16	0. 96	High
3	Teacher can teach lesson faster	4.25	0.72	High
4	IWB help me perform well in Physics	3.54	0.67	High
5	I get motivated more in learning physics	4.00	0.57	High
6	The use of IWB helps me watch educational videos	4.35	0.83	High
7	The use of IWB helps me present our work to the class	4.38	0.49	High
8	IWB allows me to save learning resources for future use	4.51	0.56	Very High
9	IWB gives me new opportunities to gain new knowledge	4.22	0.71	High
10	IWB use help control behaviour problems-sleeping during class hours	3.32	0.94	High
Overall		**4.0**	**0.41**	**High**

The survey results indicated that the use of IWBs allowed learning resources to be saved for future use. Likewise, teachers and students in the interviews shared similar views. For example, T2 said, “We can save everything that is done in the classroom to reuse it in the next time while taking revision classes”. The student participants (S3) also said, “It can save learning resources for the next lesson.” Further, the interview findings highlighted that the use of IWB assists the conceptual understanding and learning through subject related videos and animations (S2).

Teachers and Students’ Perception On Challenges of Using IWB

Table 15 shows the findings on potential challenges encountered while using IWBs. The data revealed a high level of perception of IWBs with an overall mean score and standard deviation (M= 4.00, SD=0.79).

Table 15: *Students’ Perception on Challenges of Using IWBs*

Sl.No	Items	Mean (M)	Standard Deviation (SD)	Perception level
1	IWB and its Pen are compatible with each other	3.74	0.77	High
2	The use of IWB saves time	4.45	0.67	High
3	Electricity is necessary for IWB to function	4.70	0.78	Very High
4	Teachers are confident to use IWB	4.29	0.69	High
5	The use of IWB requires frequent technical support	4.22	0.61	High
6	The use of IWB saves energy	3.35	1.19	High
7	IWB helps me learn new concept	4.25	0.57	High
8	I can look at IWB for a longer duration	3.32	1.10	High
9	I can write notes fast from the IWB	3.64	1.08	High
10	I can focus more in the lesson	4.03	0.48	High
Overall		**4.00**	**0.36**	**High**

Consistent with the survey results, both teachers and students identified power failure as a major challenge. S1 shared, “We cannot use it when there's a power cut. We have to wait until the electricity comes back.” The teachers have expressed similar concern. For instance, T1 said:

> *“One of the problems with the use of IWB is power disruption. We prepare the lessons to present through the IWB. Sometimes, when there are power disruptions, it usually affects our lesson. Therefore, we also need to have backup lessons.”*

Calibration issues were another challenge reported by participants. S2 shared:

> *“Sometimes the IWB freezes during lessons, causing time loss. Calibration works intermittently, and eventually, the teacher resorts to the lecture method.”*

Similarly, S3 noted:

> *"The board needs frequent calibration. Sometimes it doesn't display options clearly or freezes mid-lesson, causing alignment issues. Teachers end up using regular whiteboards instead of the IWB."*

Participants also highlighted the need for training to improve IWB usage in teaching and learning. T2 stated:

> *"We need training because some features are difficult to understand on our own. Busy schedules and lesson planning make self-learning tough and certain functions are tricky, leaving us unsure how to use them effectively."*

Students shared similar concerns. S2 added:

> *"Some teachers need training because they lack confidence and aren't able to use the IWB properly. I also think students need training."*

The semi-structured data from both EG and STEM teachers were organized and analysed thematically, following Creswell & Creswell (2018). The interview data from these sources were sorted, organized, and transcribed into texts. A table matrix was created, with rows showing themes and columns showing teacher and student participants' responses. Texts with similar meanings were coded with same colour for data triangulation. Themes sharing the same colours were identified and interconnected as narratives. The key findings were generated from the integrated data.

DISCUSSION

Teachers' and Students' Perception on Effects of IWB in Students' Learning

In investigating the effects of IWBs on students' learning, pre-test scores showed no significant difference between EG and CG, indicating comparable prior knowledge (Table 6). This finding aligns with previous studies by Yuliati et al. (2020) and Adolphus et al. (2015), which reported similar pre-test scores for the two groups. It suggests that both groups possessed similar levels of knowledge and understanding of electromagnetic induction prior to the intervention. The present results are significant in measuring the change in scores from the pre-test to the post-test in both groups to accurately assess the effect of the intervention. The findings suggest improvements in the learning.

The results showed significant improvement in post-test scores of EG compared to the CG (Table 8), which is consistent with the findings of various studies (Adel & Abdelrahman, 2019; Carter & Mehta, 2015; Veen & Berg, 2012). This suggests that IWB use may have catered to diverse learning styles, enhancing students' understanding of the abstract concepts. It also signifies the efficacy of IWBs in conceptualising abstract content. Moreover, a significant improvement in pre-test and post-test scores of the EG (gain of 5.77; Table 11) further confirmed their potential effectiveness, corroborating findings of Akar (2020). The findings suggest that IWBs could enhance learning outcomes across other complex physics topics as well. Teachers' reports of better understanding of concepts and improved exam performance were attributed to IWBs' interactive features, which catered to students' various learning preferences - visual, auditory, and kinaesthetic, increasing engagement, attentiveness, and retention. Consequently, both teachers and students preferred IWBs over the lecture teaching method. Additionally, increased confidence among teachers and students, while using IWBs was supported by various studies (Koc & Bakir, 2015; Koc & Yigit, 2016). This suggests that IWB use has a positive impact on self-assurance and increases motivation to tackle challenges. These findings emphasized the potential of IWBs not only improve academic performance but also foster confidence and create a learning environment that has long-lasting effects on students.

Teachers and Students' Perception on Benefits of Using IWBs

The study found that teachers and students could save teaching and learning resources and reuse them in the future. This finding aligns with various studies (Lazar, 2013; Millar & Glover, 2010). The results indicated that IWBs have improved resource efficiency and easy accessibility to teaching and learning materials. It clearly implies IWBs help reduce the consumption of physical materials such as textbooks, marker pens, chart papers, and chalk. It also provides evidence that IWBs facilitate access to learning materials beyond instructional hours and promote independent learning. The findings highlight the importance of professional learning opportunities for teachers to harness the full potential of IWBs. Institutions, colleges, and schools may promote eco-friendly digitized learning technologies such as IWBs.

Teachers and Students' Perceptions of the Challenges of Using IWBs

The most prominent challenge identified was frequent power failures. Both teachers and students noted that frequent power outages disrupted lessons. This finding aligns with the study by Saadany (2012), who noted that power failures hinder the effective use of IWBs resulting in time wastage. This highlights the importance of preparedness for such unforeseen challenges. It also signifies the need for teachers to have backup lessons to use during power failures. Another challenge was the calibration errors, which is consistent with the findings from Karsenti (2016) and Tertemiz et al. (2014). The study suggests that calibration issues may arise from inconsistent classroom lighting, dust on the IWB surface, or connectivity problems between the IWB and the computer. Such issue implies that IWBs may require frequent recalibration, which can be time-consuming and expensive. The findings indicate that IWBs could be prioritized for teaching abstract topics, and their use may be piloted centrally in selected schools.

To address unforeseen technical issues, training to equip both teachers and students with troubleshooting skills was emphasized. This provides evidence that schools could benefit from skilled technician proficient in resolving recurrent issues. Timely professional development for teachers is also important to keep up with evolving features of the technology. Moreover, a reliable electricity supply is essential for effective classroom use.

However, the findings should be interpreted with caution due to the small sample size, which may limit generalizability, and the lack of random assignment in group selection, which may be influenced the findings based on participants' prior knowledge. In addition, the potential novelty effect of using IWBs may have temporarily increased learning performance, suggesting that the benefits might not reflect long-term outcomes.

CONCLUSION

IWBs are increasingly being used in schools and colleges, with several studies showing their positive impact on student learning, particularly in understanding abstract concepts like electromagnetic induction. The interactive and visual features of IWBs cater to diverse learning needs, boost students' confidence in subjects like physics, and provide easy access to saved learning resources. However, issues such as frequent power failures and calibration errors remain significant barriers. Addressing these challenges requires reliable power solutions and training for both teachers and students to troubleshoot technical problems effectively.

Despite these challenges, the study findings hold significant educational value, especially for Bhutan. Theoretically, it provides preliminary evidence of the positive effects of IWBs on teaching and learning. Practically, it may offer baseline data for researchers, policymakers, educators, and other stakeholders. The findings suggest that IWBs may improve students' understanding of abstract topics and enhance learning performance.

The findings may also lend to a recommendation that relevant stakeholders provide training for both teachers and students to effectively utilize the features of IWBs and enhance teaching and learning. It also highlights the potential value of conducting further research on the use of IWBs in other subjects. However, given the small sample size and the context-specific nature of this study, caution is required when generalizing the findings. Further research across diverse schools is recommended before implementing IWBs on a wider scale.

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