Impact of Blended Learning on Comprehension of Electromagnetic Induction Concepts: A Case Study in Chongwe District Schools

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ABSTRACT

This study explored the impact of blended learning on students' comprehension of Electromagnetic Induction concepts in secondary schools in Chongwe District, Zambia. A mixed-methods research design was employed, involving 172 Grade 12 students from Mukamambo II Girls' Secondary School and Margret Mwachiyeya Secondary School, divided into experimental and control groups. The experimental groups were exposed to a blended learning approach that integrated traditional face-to-face instruction with multimedia simulations, self-paced online tools and interactive presentations. The control groups received conventional textbook-based instruction. Post-test results indicated that students in the experimental groups significantly outperformed their counterparts. At Mukamambo II, the experimental group achieved a mean score of 71.56%, compared to 61.52% in the control group ($p < 0.05$). Similarly, at Margret Mwachiyeya, the experimental group scored 69.88%, while the control group obtained 58.14% ($p < 0.05$). Qualitative data from focus group discussions and classroom observations reinforced these findings, with students reporting increased engagement, clearer understanding and improved visualization of abstract EMI concepts. Teachers also observed enhanced participation and interest in lessons. Despite some technological limitations, the intervention was effectively implemented using shared devices and offline digital resources. These findings suggest that blended learning is a viable and impactful instructional model for improving comprehension in science education, especially in under-resourced contexts.

Keywords: Blended Learning, Electromagnetic Induction, Comprehension, Science Education, Zambia

INTRODUCTION

Electromagnetic Induction is a fundamental yet abstract concept in physics that underpins a wide range of modern technologies, including electric generators, transformers, and magnetic levitation systems. Despite its theoretical and practical significance, Electromagnetic Induction remains one of the most conceptually demanding topics for learners, particularly in under-resourced educational settings like those in Chongwe District, Zambia. The invisibility of magnetic field interactions and the abstract nature of induced currents often hinder students' ability to grasp the topic meaningfully, leading to superficial learning, persistent misconceptions, and poor academic performance [9].

In most Zambian secondary schools, the dominant pedagogical approach is conventional, relying heavily on face-to-face instruction using chalk-and-talk methods, printed textbooks, and rote memorization. While these methods can effectively transmit basic knowledge, they fall short in conveying the dynamic and spatial-temporal characteristics of electromagnetic processes [4]. This situation calls for more innovative and interactive instructional approaches.

Blended Learning, which combines traditional face-to-face teaching with digital tools such as simulations, animations, and interactive videos, has emerged as a promising strategy for enhancing science instruction. By integrating multiple modes of content delivery, Blended Learning not only caters to diverse learning preferences but also facilitates conceptual visualization and self-paced learning [2], [16]. According to [1], blended learning has been shown to produce moderate to strong positive effects on student achievement across various subjects, particularly in STEM education. Furthermore, [15] concluded that students in blended learning environments perform better than those in purely face-to-face or purely online settings.

In the context of physics education, blended learning (BL) facilitates the use of simulations and virtual laboratories, making abstract concepts like Electromagnetic Induction more tangible and engaging [13],[6]. This study investigates the impact of blended learning on students' comprehension of Electromagnetic Induction concepts in secondary schools in the Chongwe District. It aims to evaluate the pedagogical potential of BL in addressing learning barriers related to Electromagnetic Induction in low-resource educational environments.

LITERATURE REVIEW

Blended learning has become an increasingly prominent instructional strategy in science education due to its potential to bridge the gap between abstract theoretical content and students' understanding, particularly in complex domains like Electromagnetic Induction [2], [10].

Electromagnetic Induction involves invisible and dynamic interactions between magnetic fields and electric currents—concepts that are often difficult for students to grasp through conventional teaching methods alone [9]. In many secondary schools, especially in developing countries like Zambia, instruction is primarily delivered through teacher-centered approaches such as chalkboard demonstrations and textbook explanations, which have proven insufficient for fostering deep learning of scientific concepts [2].

Blended learning, which combines face-to-face interaction with digital technologies such as simulations, animations, and virtual laboratories, offers a more interactive and student-centered alternative. According to [7], integrating ICT tools into the teaching-learning process enhances interactivity and provides students with flexible pathways to understanding, particularly critical for challenging topics like Electromagnetic Induction. Furthermore, [10] demonstrated that student engagement and learning outcomes significantly improve when blended learning aligns well with learner characteristics and instructional design.

The theoretical foundation of blended learning draws heavily from constructivist and connectivist theories, which emphasize active knowledge construction, learner autonomy, and collaborative learning [6]. Tools such as interactive simulations enable students to visualize electric and magnetic field interactions, adjust parameters, and observe real-time feedback, promoting inquiry-based exploration [4]. These tools are especially beneficial for translating abstract Electromagnetic Induction laws, such as Faraday's and Lenz's laws, into concrete, manipulatable visual experiences.

[13J found that students who engaged with virtual labs prior to real laboratory exercises demonstrated greater cognitive gains and developed critical non-cognitive skills, such as scientific reasoning and confidence. Similarly, [11] observed improved conceptual understanding when students utilized optimized simulations in quantum mechanics—another content area characterized by high abstraction—supporting the argument that digital tools enhance comprehension in complex physics topics.

In Zambia, [12] highlighted the transformative role of blended learning in higher education institutions like Kwame Nkrumah University, noting improvements in students' motivation, academic performance, and engagement when digital content was integrated with traditional lectures. These findings are encouraging for secondary schools in resource-constrained districts like Chongwe, where similar benefits could be realized through strategic blended learning implementation.

Moreover, blended learning provides opportunities for differentiated instruction. Students with varying learning paces and preferences can interact with content multiple times, revisiting challenging segments as needed. This individualized learning experience is particularly important in heterogeneous classrooms, where learners come from diverse academic backgrounds [16]; [17]. According to Bernard et al. (2014), meta-analytic evidence confirms that blended learning has a moderate to strong effect on student performance in STEM subjects, reinforcing its instructional value.

Despite these pedagogical benefits, challenges in implementing blended learning persist, particularly in low-income contexts. Infrastructural limitations, insufficient teacher training, and lack of access to reliable digital content have been identified as key obstacles to effective blended learning integration [3]; [8]; [14]. These constraints must be addressed to fully harness the potential of blended learning for conceptual development in science education.

In summary, the literature supports the hypothesis that blended learning enhances students' comprehension of Electromagnetic Induction by promoting visualization, interactivity, and learner autonomy. While implementation challenges exist, particularly in under-resourced settings, the potential of blended learning to transform science instruction remains strong. This study, therefore, assesses the effect of blended learning on students' understanding of Electromagnetic Induction concepts in Chongwe District secondary schools, contributing to the ongoing discourse on context-appropriate science pedagogy.

METHODOLOGY

Hypothesis

To rigorously evaluate the effectiveness of the blended learning approach in enhancing students' comprehension of Electromagnetic Induction concepts, the study was guided by the following hypothesis:

Null Hypothesis (H_0):

There is no significant difference in the understanding of electromagnetic induction concepts between students taught using a blended learning approach and those taught through conventional methods.

Alternative Hypothesis (H_1):

There is a significant difference in the understanding of electromagnetic induction concepts between students taught using a blended learning approach and those taught through conventional methods.

This hypothesis was tested using post-test scores from both control and experimental groups. Independent samples t-tests were conducted to determine whether the differences in comprehension levels were statistically significant.

A mixed-methods research design was adopted to investigate the impact of blended learning on students' comprehension of electromagnetic induction concepts. The study was conducted in two secondary schools in the Chongwe District: Mukamambo II Girls' Secondary School (n = 90) and Margret Mwachiyeya Secondary School (n = 82), comprising a total of 172 Grade 12 students. Participants were selected through stratified random sampling to ensure diverse representation and were then randomly assigned to either the experimental group, which received blended learning instruction, or the control group, which followed conventional teaching methods.

The study was guided by the objective: "To assess the effect of blended learning on students' understanding of electromagnetic induction concepts in secondary schools."

Data were gathered through post-tests, focus group discussions, classroom observations, and interviews. The experimental group experienced blended learning, integrating videos, online simulations, and self-paced learning with teacher instruction. The control group learned through standard classroom practices.

Participant Profile

The study involved 172 Grade 12 students from two secondary schools in Chongwe District: Mukamambo II Girls' Secondary School and Margret Mwachiyeya Secondary School. Of these, 135 participants were girls, representing 78.5% of the sample, while 37 were boys, accounting for 21.5%. Mukamambo II, being an all-girls institution, contributed exclusively female participants. In contrast, Margret Mwachiyeya Secondary School, which operates in a co-educational setup, provided a more balanced gender representation within its portion of the sample. This distribution ensured that the study captured diverse learning experiences across different school contexts. Including both single-gender and mixed-gender school settings offered valuable insights into how blended learning might affect student comprehension of Electromagnetic Induction concepts across varying classroom dynamics.

The gender composition and school type appeared to have subtle influences on how students interacted with the Blended Learning approach. At Mukamambo II Girls' Secondary School, all participants were female, and many showed strong enthusiasm toward using digital simulations and videos. Teachers at the school noted that the girls exhibited increased confidence in class discussions, possibly due to the supportive single-gender learning environment.

Conversely, Margret Mwachiyeya Secondary School's co-educational setup revealed some variability in engagement levels between boys and girls. While both male and female students benefited from the blended approach, female students often relied on peer collaboration more actively. These insights suggest that the effectiveness of Blended Learning may be shaped by gender dynamics and classroom context, warranting further exploration in future studies.

Data Collection

Post-tests were administered to assess students' understanding following instruction. The experimental group engaged with simulations and multimedia tools, while the control group relied solely on textbooks and teacher-led lessons. Qualitative data from observations and discussions enriched the quantitative findings by providing insights into student experiences with blended learning.

RESULTS

Post-test analysis at Mukamambo II Girls' Secondary School indicated that students taught through blended learning outperformed those instructed using conventional methods. Table I presents the mean scores for the control and experimental groups, highlighting the effectiveness of the blended approach in enhancing comprehension of Electromagnetic Induction concepts.

Table I: Post-Test Scores for Control and Experimental Groups at Mukamambo II

Group	N	Mean (%)	Std. Deviation	Std. Error Mean
Control Group	42	61.52	18.02	2.78
Experimental Group	41	71.56	15.62	2.44

These results suggest that students in the experimental group, who were exposed to blended learning strategies, demonstrated a higher level of comprehension of electromagnetic induction concepts than their counterparts in the control group. To determine whether the difference in performance was statistically significant, an independent samples t-test was conducted, and the results are summarized in Table II.

Table II: Independent Samples t-Test Results Comparing Control and Experimental Groups

Measure	Equal Variances	Unequal Variances
F	1.66	-
Sig.	0.20	-
t	-2.71	-2.71
df	81	79.90
Sig. (2-tailed)	0.008	0.008
95% Confidence Interval (Lower)	-17.41	-17.40
95% Confidence Interval (Upper)	-2.66	-2.68

The t-test results indicate a statistically significant difference in post-test scores between the control and experimental groups ($p = 0.008$), with the experimental group outperforming the control group. The 95%

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confidence interval for the mean difference ranges from approximately -17.4 to -2.7, confirming that the improvement in scores was not due to random variation. These findings provide strong evidence that blended learning positively contributed to students' comprehension of electromagnetic induction concepts at Mukamambo II Girls' Secondary School.

Similarly, at Margret Mwachiyeya Secondary School, students exposed to the blended learning approach outperformed those taught using traditional methods. The experimental group achieved higher post-test scores, indicating a better grasp of electromagnetic induction concepts. Descriptive statistics are presented in Table III.

Table III: Margret Mwachiyeya Secondary Post-Test Scores for Control and Experimental Groups

Group	**N**	**Mean (%)**	**Std. Deviation**
Control Group	36	58.14	20.21
Experimental Group	33	69.88	22.58

The mean score difference of over 11 percentage points indicates a significant gain for the experimental group, which was exposed to interactive simulations, videos, and other digital tools integrated with traditional lessons. To assess the statistical significance of this difference, an independent samples t-test was conducted. The results are presented in Table IV.

Table IV: Independent Samples t-Test Results Comparing Post-Test Scores of Control and Experimental Groups at Margret Mwachiyeya Secondary

Measure	Equal Variances	Unequal Variances
F	1.64	-
Sig.	0.21	-
t	-2.28	-2.27
df	67	64.47
Sig. (2-tailed)	0.03	0.03
95% Confidence Interval (Lower)	-22.02	-22.08
95% Confidence Interval (Upper)	-1.46	-1.40

The t-test revealed a statistically significant performance difference between the two groups ($p = 0.03$). The 95% confidence interval, which ranges from approximately -22 to -1.4, supports the conclusion that the higher scores of the experimental group were not due to chance. These findings affirm that the blended learning approach at Margret Mwachiyeya Secondary School had a positive and meaningful effect on students' comprehension of Electromagnetic Induction concepts.

Interpretation

At both schools, the post-test performance of the experimental groups was significantly higher than that of the control groups. The low p-values (0.008 and 0.03) indicate that these results are unlikely to be due to chance. Given the statistically significant difference observed between the experimental and control groups ($p < 0.05$), the null hypothesis was rejected, and the alternative hypothesis was accepted. This confirms that the blended learning approach significantly enhances students' comprehension of abstract scientific content, such as Electromagnetic Induction.

QUALITATIVE FINDINGS

Focus group discussions and classroom observations revealed four key themes that characterized students' and teachers' experiences with the blended learning approach. First, students highlighted the value of interactive learning, noting that simulations and educational videos helped them visualize electromagnetic induction processes more clearly, making the abstract content easier to grasp. One student shared, *"Before, I used to memorize EMI like a story, but when I saw it happen in the simulation, it clicked in my head."* Another stated,

"We could replay the videos to understand exactly how the current was induced, especially using the right-hand rule."

Second, many learners appreciated the opportunity for self-paced study, which allowed them to revisit complex concepts multiple times and learn at their own speed. A student expressed, *"I liked that I could pause the lesson and go back if I didn't understand. That helped me not to be left behind."*

This flexibility was particularly beneficial for those who found certain aspects of electromagnetic induction challenging. Additionally, the use of blended learning tools facilitated greater engagement and peer collaboration. Students reported that group discussions and online interactions enhanced their participation and deepened their understanding through shared insights and clarification of difficult topics. One student noted,

"During group chats, we helped each other. Someone would explain in Bemba or Nyanja if you didn't understand."

A teacher added, *"They were more active when using digital tools. Even the quiet ones spoke during the video sessions."*

However, despite these benefits, several challenges were noted. Teachers expressed concerns about limited access to technological resources and emphasized the need for further training to effectively integrate digital tools into their teaching practices. A teacher remarked, *"We shared laptops, but it was worth it. Even with limited gadgets, the girls stayed focused."* Another commented, *"Training was needed for us teachers. At first it was hard, but we do manage with peer support."*

To address technological constraints, both schools implemented practical workarounds. Offline versions of video tutorials were shared using USB drives and projected via school laptops. Computer labs were scheduled so that students could access simulations in small rotating groups. At times, groups of three to four students shared one device, which encouraged peer teaching. These creative strategies enabled the intervention to proceed despite infrastructure limitations.

DISCUSSION

Findings from this study affirm that blended learning significantly enhances students' understanding of electromagnetic induction, particularly in resource-constrained educational settings such as those in Chongwe District. Students in the experimental groups, who engaged with digital tools such as simulations, animations, and multimedia presentations, consistently demonstrated higher comprehension levels than their counterparts taught through conventional lecture-based methods. These outcomes suggest that integrating visual and interactive components into instruction is particularly effective for abstract physics concepts like electromagnetic induction, which students often find difficult to grasp through text-based explanations alone.

The improved performance observed among experimental groups in both Mukamambo II and Margret Mwachiyeya Secondary Schools supports previous findings that emphasize the instructional value of blended learning. Studies [17] and [1] found that blended learning not only increases content mastery but also promotes student motivation and engagement, which key factors are contributing to meaningful learning. This study also aligns with the work of [13], which demonstrated that interactive simulations help learners construct mental models of scientific processes, leading to deeper conceptual understanding.

Moreover, the success of blended learning in this context can be attributed to its support for differentiated and self-paced learning. Students were able to revisit complex ideas, pause instructional content, and reflect on their learning without the pressure of classroom time constraints. This flexibility, coupled with immediate feedback from digital assessments, allowed learners to identify and address misconceptions more effectively.

The study also highlighted how demographic factors, especially gender and school context, played a role in shaping learning outcomes. Mukamambo II, an all-girls school, recorded enthusiastic adoption of BL tools. Students appeared to value the visual and repeatable nature of digital content, which they cited as reducing anxiety in learning abstract physics topics.

Meanwhile, in the mixed-gender setting of Margret Mwachiyeya, some gender-based differences in digital engagement emerged. Female students often formed peer-support clusters, while some male students were more inclined to explore simulations independently. Although these observations were not statistically tested for significance, they provide important qualitative cues about differentiated engagement in Blended Learning environments. These demographic patterns merit deeper investigation in subsequent research.

However, the findings must be interpreted in light of contextual challenges. While Blended Learning demonstrated strong positive outcomes, the study revealed that its implementation heavily depends on the availability of digital infrastructure and teacher readiness. Teachers expressed a need for professional development to fully leverage the pedagogical benefits of digital tools. These insights indicate that, although blended learning has significant potential to transform science education, its scalability and sustainability in rural or underserved schools require systemic support and investment.

In conclusion, the evidence strongly supports integrating blended learning into the science curriculum to enhance conceptual understanding. Continued research is needed to explore long-term impacts and how specific components of blended learning, such as types of simulations or learning platforms, influence learning outcomes in physics and other STEM subjects.

Implications

The success of blended learning in enhancing comprehension of electromagnetic induction indicates that educational policies should support its integration. Investment in teacher training and digital infrastructure is essential. Educators are encouraged to combine traditional instruction with interactive digital content to meet the needs of diverse learners.

CONCLUSION

This study confirmed that Blended Learning significantly improves students' comprehension of Electromagnetic Induction concepts in secondary schools in Chongwe District. The use of interactive simulations, multimedia presentations, and online self-paced learning tools enabled learners to visualize abstract Electromagnetic Induction concepts and revisit complex ideas at their own pace. These features of Blended Learning created a more student-centered and flexible learning environment compared to traditional methods.

Findings revealed that students in the experimental groups consistently outperformed their counterparts in the control groups on post-test scores, with statistically significant differences at both Mukamambo II Girls' Secondary School and Margret Mwachiyeya Secondary School.

From a qualitative perspective, the integration of direct student and teacher quotes deepens the themes identified. One student remarked, "*I used to struggle with Electromagnetic Induction before, but with the video and simulations, it made more sense. I could repeat the lesson on my own*." A teacher added, "*These tools help us bring the invisible to life, and students respond more actively.*" These voices highlight the active role Blended Learning played in engagement and conceptual clarity.

Demographic variables like gender and school type also influenced the implementation and outcomes. At Mukamambo II, an all-girls school, the results suggested that female students responded positively to the visual and repetitive aspects of Blended Learning. Meanwhile, at the co-educational Margret Mwachiyeya, the comparative performance of male and female students further emphasized the inclusive appeal of Blended Learning, though deeper gender-based analysis is needed in future research.

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Technological limitations such as limited internet access and lack of personal digital devices were partially mitigated through structured schedules for shared resources, offline video content, and use of school computer labs. These practical adjustments allowed the schools to implement Blended Learning effectively despite infrastructural constraints.

In conclusion, the synthesis of quantitative and qualitative findings reinforces the value of Blended Learning in fostering deeper conceptual understanding, enhancing student engagement, and enabling flexible learning. Educational stakeholders are encouraged to invest in digital infrastructure, provide teacher training and create policies that support blended instructional models in science education. Future research should explore gender-based outcomes and longitudinal impacts of Blended Learning on science performance.

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