Evaluating the Impact of Blended Learning on Retention of Electromagnetic Induction Concepts in Selected Zambian Secondary Schools

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ABSTRACT

This study investigated the impact of blended learning on students' retention of Electromagnetic Induction concepts in two secondary schools located in Chongwe District, Zambia. Retention of abstract physics concepts like Electromagnetic Induction poses a significant challenge in many educational contexts, particularly in resource-constrained environments. To address this issue, an Explanatory Sequential Mixed Methods Design, was used. A total of 172 students were randomly from Mukamambo II Girls' Secondary School and Margret Mwachiyeya Secondary School participated in the study. Students were divided into experimental and control groups. The experimental groups were exposed to blended learning, which incorporated digital learning tools such as simulations, animations, online quizzes, and teacher-facilitated discussions, while the control groups received conventional face-to-face instruction which included physical lessons and laboratory activities. Two post-tests were administered with one being immediately after instruction and the other two weeks later, in order to assess students' ability to retain Electromagnetic Induction concepts over time. Quantitative results indicated that students in the experimental groups consistently outperformed those in the control groups. At Mukamambo II Girls' Secondary School, the experimental group achieved a second post-test mean score of 76.00% (SD = 14.65), compared to 66.64% (SD = 16.31) in the control group. Although the differences were not statistically significant ($p > 0.05$), effect size analysis revealed small but meaningful gains in favor of blended learning, suggesting that it contributes positively to long-term retention. Qualitative data, collected through focus group discussions and teacher interviews, supported these findings, with students reporting enhanced understanding and recall due to access to visual and interactive resources. Despite facing challenges such as limited access to devices, intermittent internet connectivity, and insufficient teacher training in digital pedagogy, the implementation of blended learning demonstrated potential for improving retention of complex scientific content. The study recommends the integration of blended learning into science curricula and highlights the need for investment in teacher capacity-building and infrastructure development to fully realize the benefits of blended learning.

Keywords: Blended Learning, Electromagnetic Induction, Retention, Multimedia Tools, Science Education

INTRODUCTION

Electromagnetic Induction is a core topic in secondary school physics and forms the theoretical basis for technologies such as transformers, electric generators and induction motors. Despite its importance, Electromagnetic Induction remains conceptually difficult for learners due to its abstract and invisible nature, involving interactions between magnetic fields and electric currents [31]. Students often struggle to comprehend and retain Electromagnetic Induction concepts, especially in contexts where limited laboratory resources, large class sizes and conventional teaching methods prevail [10].

Evidence from national examination reports shows persistent underperformance in electricity and magnetism topics. The 2023 ECZ report highlighted widespread difficulties among students in interpreting circuit diagrams and explaining Electromagnetic Induction related phenomena such as transformer operations and induced electromotive force [10]. These challenges are consistent with global research, which identifies common misconceptions about magnetic field lines, electromagnetic force directions, and the function of coils and loops [27].

To address the challenges of retention in abstract scientific topics like Electromagnetic Induction, educators are increasingly turning to Blended Learning. Blended Learning combines conventional classroom instruction with digital content delivery through tools like simulations, videos and interactive quizzes [15]. Its ability to provide multimodal, self-paced and visually rich instruction makes it well-suited for improving conceptual retention in science subjects [23]. In Electromagnetic Induction instruction, digital simulations can help students visualize invisible magnetic fields and manipulate variables such as coil turns and magnet speed; thereby deepening understanding and supporting memory consolidation [2].

Studies in diverse settings have confirmed the positive impact of Blended Learning on student retention. For instance, [11] found that students taught physics using Blended Learning methods achieved significantly higher retention scores than those taught using traditional methods. Similarly, research in Nigeria by [17] concluded that Blended Learning enhanced long-term retention of physics concepts, attributing the gains to repeated exposure and interactive engagement.

In Zambia, the adoption of Blended Learning is still in its early stages, hindered by infrastructure challenges and limited digital literacy among teachers and students, [21]. Nevertheless, the potential of Blended Learning to enhance retention is considerable, especially when supported by mobile devices, open educational resources and offline-accessible content.

This study focused on evaluating the impact of Blended Learning on students’ retention of Electromagnetic Induction concepts in secondary schools in Chongwe District. It investigated whether Blended Learning helps students remember and apply Electromagnetic Induction principles after instruction, compared to conventional approaches. By drawing on post-test results and qualitative feedback, the study sought to contribute to evidence-based recommendations for enhancing science education in resource-constrained environments.

LITERATURE REVIEW

Retention of abstract scientific concepts, particularly Electromagnetic Induction, remains a significant challenge in secondary science education, especially in environments with limited teaching resources and infrastructure [4];[32]. Electromagnetic Induction involves dynamic interactions between magnetic fields and electric currents, phenomena that are invisible and highly conceptual, making them difficult for learners to grasp and retain over time through conventional teaching methods alone [29];[12]. In Zambia, the Examinations Council of Zambia reports for 2022 and 2023 indicate that students consistently underperform in topics related to electricity and magnetism, often failing to apply theoretical knowledge to real-world scenarios or laboratory-based assessments [10]. These findings highlight a gap in instructional approaches and call for innovative pedagogical strategies to promote deeper comprehension and long-term retention.

Blended Learning, which integrates face-to-face teaching with digital instructional tools, offers a promising solution to the problem of knowledge retention. Several studies affirm that Blended Learning facilitates better memory consolidation through multimodal learning environments, including videos, simulations, interactive quizzes and discussion forums [22]; [24]. In their meta-analysis, they found that students exposed to blended environments outperformed those in conventional or fully online settings, particularly when interactive digital tools were incorporated. The use of simulation tools in teaching Electromagnetic Induction, for example, helps students visualize electromagnetic field interactions, manipulate variables and observe cause-effect relationships, which are difficult to grasp from static textbook diagrams alone [16].

Blended Learning’s support for spaced repetition, where learners revisit content over intervals, has also been identified as a key factor in promoting retention. When students engage with Electromagnetic Induction content repeatedly across platforms, such as digital quizzes, animations and collaborative tasks, they are more likely to consolidate the information into long-term memory [19]. Moreover, the social aspect of Blended Learning promotes cognitive scaffolding, allowing learners to construct knowledge through peer interactions and teacher feedback, thereby enhancing recall and transfer of abstract physics concepts, [13];[14].

In the Zambian context, the potential of Blended Learning to improve Electromagnetic Induction instruction is substantial. At Kwame Nkrumah University, Blended Learning initiatives demonstrated positive outcomes in learner engagement and comprehension, even though infrastructural and policy limitations hindered full-scale implementation [21]. The same study emphasized the importance of institutional support in overcoming barriers such as unreliable internet connectivity, high costs of digital tools, and insufficient teacher training. These concerns were echoed in research by [20] and [3], who found that without systemic support, Blended Learning implementation risks worsening existing inequalities, especially in rural schools.

Despite these limitations, Blended Learning is adaptable to low-resource settings when creatively integrated. The use of Open Educational Resources (OERs), for instance, allows schools to access high-quality digital content without incurring prohibitive costs [25]. Furthermore, Blended Learning can be implemented using basic technologies like smartphones, offline video tutorials and local intranet servers to accommodate bandwidth limitations, as demonstrated in studies conducted in sub-Saharan Africa [30]. In such environments, teacher motivation and ongoing professional development are crucial for ensuring the pedagogical soundness of Blended Learning interventions.

The cognitive advantages of Blended Learning are particularly impactful in teaching abstract physics topics like Electromagnetic Induction. In a study conducted in Riyadh, students in the experimental Blended Learning group consistently demonstrated higher retention in delayed assessments compared to those taught through conventional methods [1]. Although not all score differences reached statistical significance, students reported that revisiting simulations and recorded lessons helped reinforce their understanding. Teachers similarly observed greater participation and improved recall during follow-up tasks, indicating that the flexible, visual and repetitive features of Blended Learning support long-term retention in science education.

Furthermore, studies by [8] and [6] suggest that Blended Learning environments create conditions conducive to autonomous learning, an important factor for retaining complex content. When students are empowered to choose when, where, and how they engage with material, they take more ownership of their learning, which reinforces memory pathways and improves retention outcomes. The blended structure also allows for differentiated instruction, enabling teachers to tailor content based on learner needs, further supporting the retention of difficult concepts like Electromagnetic Induction.

In conclusion, the literature supports the assertion that Blended Learning significantly enhances the retention of abstract scientific concepts, particularly in settings challenged by limited resources. By providing learners with varied modes of engagement, opportunities for repetition, and collaborative learning spaces, Blended Learning addresses both the cognitive and contextual barriers to retention. However, to realize its full potential, Blended Learning must be supported by strategic investments in teacher training, infrastructure and content development. This study contributes to the growing evidence that Blended Learning is not just a supplementary instructional method but a transformative approach to science education, especially in the teaching of Electromagnetic Induction.

METHODOLOGY

This study employed an Explanatory Sequential Mixed-methods design, which combines both quantitative and qualitative approaches in two distinct phases. The design was chosen to allow for comprehensive analysis: the quantitative phase assessed the effect of Blended Learning on students' retention of Electromagnetic Induction concepts using standardized tests, while the qualitative phase explored students' and teachers' experiences to explain and contextualize the test results [7].

Quantitative data were prioritized in the first phase, consistent with the study's primary focus on measuring retention outcomes. The qualitative data collected in the second phase helped elaborate on the numerical findings by identifying factors that influenced retention, such as accessibility of blended learning resources, student motivation and teacher support [18].

The study was guided by the objective: "To determine the effect of Blended Learning on students' retention of Electromagnetic Induction concepts in secondary schools."

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The sample consisted of 172 students, divided into experimental and control groups. At Mukamambo II Girls' Secondary School, 90 students participated, while 82 students participated at Margret Mwachiyeya Secondary School. Students were selected using stratified random sampling**,** ensuring representation from different classes while maintaining balance between the experimental and control groups. Teachers involved in the study were purposefully selected, as only those handling Grade 12 Physics were required.

Participant Profile

The study involved a total of 172 Grade 12 students drawn 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 Girls' Secondary School, being an all-girls institution, contributed exclusively female participants. In contrast, Margret Mwachiyeya Secondary School had a co-educational setup, providing 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. The inclusion of both single-gender and mixed-gender school settings provided valuable insights into how blended learning might affect student comprehension of Electromagnetic Induction concepts across varying classroom dynamics.

Data Collection

Retention was assessed using a second post-test administered two weeks after the initial post-test. While the test items in the second post-test were paraphrased, they assessed the same core Electromagnetic Induction concepts as the first post-test. This approach ensured consistency in evaluating students' long-term understanding while minimizing recall based on memorization. To deepen insights into the retention patterns, observations and informal discussions were also conducted to help contextualize the test scores and interpret underlying trends.

RESULTS

Analysis focused on comparing students' short-term and long-term understanding of Electromagnetic Induction concepts. Performance data were drawn from two post-tests: one administered immediately after instruction and another conducted two weeks later. Results from both Mukamambo II Girls' Secondary School and Margret Mwachiyeya Secondary School were analysed to determine retention patterns across different student groups.

Descriptive and Inferential Statistics

Table 1: Descriptive Statistics for First and Second Post-Tests at Mukamambo II Girls' Secondary School

Group	**Test Occasion**	**N**	**Mean (%)**
Control Group	First Post-Test	42	61.52
Control Group	Second Post-Test	42	66.64
Experimental Group	First Post-Test	41	71.56
Experimental Group	Second Post-Test	42	76.00

Interpretation

As shown in Table 1, the control group showed a mean increase of 5.12 percentage points from the first to the second post-test (61.52% to 66.64%). The experimental group also improved, with a 4.44-point increase

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(71.56% to 76.00%). The experimental group consistently outperformed the control group on both tests, suggesting a potential positive effect of the blended learning intervention.

Table 2: Independent Samples T-Test Results Comparing First and Second Post-Test Scores

Group	t	df	Sig. (2-tailed)	Mean Difference
Control Group	-1.365	82	0.176	-5.12
Experimental Group	-1.336	81	0.185	-4.44

Interpretation

For both groups, as shown in Table 2, the increase in post-test scores was not statistically significant at the 0.05 level (p = 0.176 for control, p = 0.185 for experimental). However, the experimental group maintained a higher mean score at both points, indicating better retention overall. Although the gains were modest, the consistent advantage in performance supports the argument that blended learning contributed positively to knowledge retention.

Descriptive and Inferential Statistics: Margret Mwachiyeya Secondary School

Table 3: Descriptive Statistics for First and Second Post-Tests at Margret Mwachiyeya Secondary School

Group	Test Occasion	N	Mean (%)
Control Group	First Post-Test	36	58.14
Control Group	Second Post-Test	38	61.61
Experimental Group	First Post-Test	33	69.88
Experimental Group	Second Post-Test	38	68.05

Interpretation:

As shown in Table 3, the control group at Margret Mwachiyeya showed a modest increase in mean scores from 58.14% to 61.61%. On the other hand, the experimental group displayed a slight decline in mean scores from 69.88% to 68.05%. Despite the drop, the experimental group still outperformed the control group in both post-tests, suggesting initial comprehension advantages from blended learning.

Table 4: Independent Samples T-Test Results Comparing First and Second Post-Test Scores

Group	t	df	Sig. (2-tailed)	Mean Difference
Control Group	-0.791	72	0.431	-3.47
Experimental Group	0.396	69	0.693	1.83

Interpretation:

For the control group, as shown in Table 4, the improvement in scores was not statistically significant (p = 0.431), indicating only a minimal retention effect. Similarly, the slight decline in the experimental group's performance was not statistically significant (p = 0.693). Despite this, the experimental group maintained higher overall scores, highlighting possible benefits of the blended learning approach for initial understanding.

These results were summarised in Figure 1.

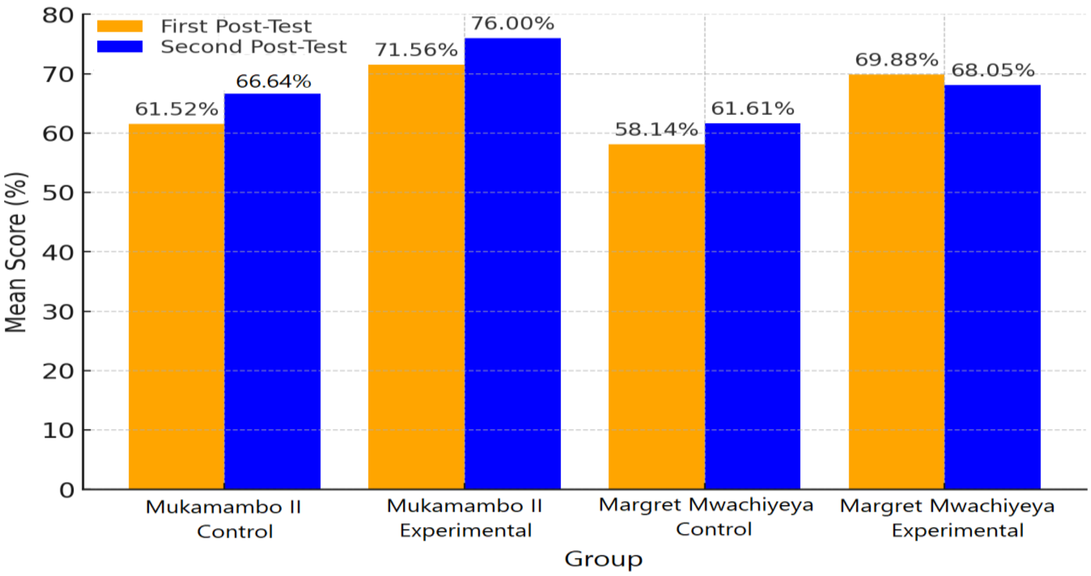

Figure 1: Figure 6.3: Post-Test Mean Scores by Group

Despite the absence of statistically significant differences, students exposed to Blended Learning consistently outperformed their peers in both post-tests. This suggests that Blended Learning facilitates a deeper understanding and supports long-term retention better than conventional approaches. These findings are consistent with prior studies [9];[28];[25], which highlight the value of repeated engagement, varied instructional modalities and learner autonomy in promoting durable knowledge retention.

Interpretation

The second post-test scores revealed that the experimental groups retained Electromagnetic Induction concepts more effectively than the control groups. For instance, at Mukamambo II Girls' Secondary School, the experimental group scored 76.00%, while the control group scored 66.64%. At Margret Mwachiyeya, the experimental group scored 68.05%, compared to 61.61% in the control group. Although these differences were not statistically significant, they suggest a trend in favor of Blended Learning for promoting retention.

QUALITATIVE FINDINGS

Qualitative findings from student and teacher feedback revealed that blended learning significantly supported content retention through various mechanisms. Students appreciated the reinforcement provided by repeated exposure to EMI concepts, which enhanced their ability to recall information during assessments.

One student from the experimental group stated,

"BL activities have significantly enhanced my understanding of EMI subjects by providing interactive simulations that allow me to experiment with electromagnetic concepts in real-time... The ability to visualize and manipulate variables helps solidify my knowledge, making the learning process more engaging and effective."

Another student emphasized the benefit of varied formats in supporting memory, explaining,

"Since engaging with online video lessons and demonstrations, I've noticed a significant improvement in my ability to solve complex EMI problems and explain concepts to my peers."

Similarly, a student during focus group discussion remarked, *"The simulations helped me to understand how a generator works. I can still picture the coil and magnet moving; it stuck in my mind."*

The flexibility of blended learning enabled learners to revisit lessons at their own pace, promoting deeper understanding. As one student explained:

"I could watch the lesson again when I didn't understand, especially the part on how EMF is induced. That helped me remember it for the test."

Additionally, the use of visual and multimedia resources helped clarify abstract ideas and strengthened memory through engaging formats. Another student summarized:

"BL makes learning more interesting and dynamic. The interactive simulations and videos made it easier for me to remember how EMI works during the final test."

However, some students faced challenges such as limited access to digital devices and unreliable internet connectivity, which occasionally hindered full participation in the blended learning experience.

DISCUSSION

The findings of this study indicate that Blended Learning positively influences students' retention of Electromagnetic Induction concepts. Students exposed to Blended Learning strategies consistently performed better in delayed post-tests compared to those taught through conventional methods. Although the differences in second post-test scores between experimental and control groups were not statistically significant, the experimental groups maintained higher mean scores, suggesting a retention advantage associated with the blended learning approach.

This aligns with constructivist learning theory, which emphasizes that knowledge is actively constructed through interaction, repetition and contextual experiences [33]. The Blended Learning model implemented in this study allowed learners to revisit digital content, engage with simulations, and receive feedback at their own pace. Such repeated exposure to EMI concepts likely reinforced cognitive structures and facilitated the consolidation of long-term memory. As noted by [5], retention improves when learners interact with content in multiple formats such as visual, auditory and kinesthetic, supported by self-directed learning activities.

Additionally, [24] observed that digital tools such as simulations and animations significantly enhance learners' ability to recall physics concepts over time. Consistent with these findings, students in the experimental group frequently cited during focus group discussions that the digital practice materials helped them 'see and remember' how Electromagnetic Induction works. Moreover, the multimodal nature of Blended Learning supports dual coding theory, which posits that combining verbal and visual representations leads to stronger encoding and retrieval [26]. Visual simulations used to demonstrate magnetic fields and induced currents may have improved students' comprehension and retention beyond what traditional verbal instruction could achieve.

It is important to contextualize the lack of statistical significance in the within-group comparisons. The second post-test, conducted two weeks after instruction, was designed to assess retention, not new learning. No further instructional interventions were introduced between the two post-tests. Therefore, a statistically significant difference between the first and second post-tests was not anticipated. Any variation in scores likely reflects natural memory processes, test familiarity, or incidental revision rather than the result of ongoing instructional support.

Interestingly, the control groups exhibited slight increases in post-test scores, while the experimental group at one school experienced a marginal decline. These changes were not statistically significant, yet the experimental groups' consistently higher scores suggest that Blended Learning supported retention more effectively than conventional methods. The flexibility of the Blended Learning environment, allowing for self-paced review, varied content delivery, and learner autonomy, may explain these performance trends.

Moreover, students in the experimental group reported greater confidence when solving EMI-related problems in delayed assessments. This confidence may stem from the multimodal engagement and flexibility afforded by Blended Learning. In contrast, students in the control group were largely dependent on static notes and brief revision sessions, limiting opportunities for reinforced learning.

Despite some challenges, such as limited access to devices and unstable internet, these did not appear to negate the retention benefits observed. This supports findings by [3] which suggest that even low-tech forms of Blended Learning, using offline simulations and pre-loaded multimedia content, can be effective in resource-limited educational settings.

Taken together, the findings indicate that while blended learning may not always yield statistically significant gains in short-term retention, it offers consistent and practical benefits for reinforcing conceptual understanding and supporting self-regulated learning in science education.

Implications

To enhance science learning, especially for abstract topics like Electromagnetic Induction, schools should integrate Blended Learning practices. Policymakers must invest in infrastructure and teacher training to overcome implementation barriers. The findings provide a basis for scaling Blended Learning initiatives to improve retention outcomes.

CONCLUSION

This study affirms that Blended Learning is a viable pedagogical strategy for enhancing retention of complex scientific content like Electromagnetic Induction. Its interactive, flexible, and student-centered nature supports cognitive processes crucial for long-term understanding. These findings advocate for the integration of Blended Learning models into Zambian science classrooms and similar contexts where improving conceptual retention remains a challenge.

Challenges In Blended Learning Implementation

Despite the benefits of Blended Learning, several challenges were identified during the implementation

process. One major challenge was the limited access to digital devices and reliable internet connectivity, particularly for students in rural settings. This inequality in technological access created a digital divide that affected some students' ability to fully engage with the Blended Learning activities.

Teacher preparedness was another issue. Many teachers lacked adequate training in digital pedagogy and instructional design for Blended Learning. This gap impacted their ability to facilitate effective Blended Learning lessons and provide timely support to learners. The integration of online platforms required not only technical proficiency but also pedagogical strategies that support active learning and engagement.

Additionally, some students expressed difficulty managing time effectively in the Blended Learning environment. Without continuous supervision, they struggled to complete tasks independently, affecting their learning outcomes. These findings suggest the need for structured orientation programs and ongoing support to maximize the benefits of Blended Learning.

Policy And Practice Recommendations

Based on the findings, it is recommended that educational policymakers prioritize the integration of Blended Learning into science curricula. This should include investment in infrastructure such as internet connectivity, smart devices, and educational platforms to ensure equitable access to all learners.

Teacher professional development must be at the core of any Blended Learning strategy. Workshops, seminars and certification programs should be designed to build teacher capacity in digital instruction, content creation, and assessment in blended settings.

Furthermore, schools should adopt policies that encourage the gradual adoption of Blended Learning, starting with hybrid models that blend limited online components with classroom instruction. This approach allows for incremental change and adaptation, especially in schools with limited resources.

Contribution To Knowledge

This study contributes to the growing body of research on Blended Learning by focusing on its impact in a low-resource context. It demonstrates that even in areas with limited digital infrastructure, Blended Learning can improve retention and engagement when thoughtfully implemented.

It also provides evidence that combining quantitative test results with qualitative feedback offers a fuller understanding of Blended Learning's effectiveness. This dual approach validates student experiences and highlights the practical benefits of using technology to teach abstract concepts like Electromagnetic Induction.

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