



Qualitative study of Design-Based Learning Strategy on ... Muhammad, S. & Garba, S. (2026)

Qualitative Study of Design-Based Learning Strategy on Achievement and Conceptual Understanding in Electromagnetism among University Undergraduate Physics Education Students in Northwest, Nigeria

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Abstract

The study explores the effectiveness of design-based learning on academic achievement and conceptual understanding, in electromagnetism among undergraduate university students in northwest, Nigeria. Two (2) research objectives, and two (2) research questions were raised to guide the study. The study employed phenomenological qualitative research design. The population for this study comprised Nine Hundred and Forty-One (941) 300L Undergraduate pre-service physics teachers in the Department of Science Education. The sample for the study were Eight (8) undergraduate physics students purposefully selected for the study. Validated Observation Schedule and Interview Protocol were used to collect data. Thematic analysis was used to analyze the data. The findings from the study revealed that Undergraduate University physics students had positive learning experiences, actively participated during the process. It was concluded among others the use of DBL improve undergraduate university physics students' academic achievement and foster students conceptual understanding in electromagnetism. It was recommended that lecturers should incorporate design-based learning strategy element such as real-world problem, prototyping, and collaboration to illustrate physics concepts particularly electromagnetism, making the subject more relevant and engaging for students and government should provide resources and support for curriculum innovation and development, encourage interdisciplinary collaboration between physics educators and engineers to develop interdisciplinary courses and projects that promote real-world applications.

Keywords: Design-Based Learning, Achievement, Conceptual Understanding, Electromagnetism

Introduction

Electromagnetism is a branch of physics that deals with the study of electric and magnetic fields and their interactions with matter. The study of electromagnetism began with the observation of natural phenomena like lightning and magnetism in ancient times and that rubbing amber with fur would attract small objects, an early observation of static electricity. Electromagnetism is fundamental to understanding a wide range of physical phenomena and has numerous applications in technology, including electrical engineering, telecommunications, and medical imaging. Majority of physics students encounter difficulties in the process of learning Electromagnetism, due its abstract nature, lack of interest, negative influence of pre-scientific concepts, cognitive impairment of learning, mathematical learning disability and learning burnout (Liu, 2019). These learning difficulties have led to low achievement at universities (Mahmudah *et al.*, 2022; Delen & Sen, 2023; Dognia & Dah, 2023). Nabilah *et al.*, (2019) found that students have difficulties in understanding the meaning of electricity, alternating current, magnetism and AC Circuit. As a result, several researches on students' conceptual understanding of electricity and magnetism have been carried out and several instructional strategies have been suggested for conceptual change in this topic (Mboniyiriyuze *et al.*, 2019) and design-based learning could form part of the innovative strategy that can provide conceptual changes (Shin *et al.*, 2023).

Electromagnetism is a critical component of physics education, with applications in various fields, including engineering, technology, and medicine. However, students' understanding of electromagnetism concepts has been a subject of concern, with many students exhibiting misconceptions and difficulties in applying the principles to real-world problems. In Nigeria, the teaching and learning of electromagnetism at the university level face several challenges, including inadequate resources, poor teaching methods, and a lack of valid assessment tools. The development of a valid and reliable achievement test in electromagnetism can help identify areas where students need improvement, inform instruction, and enhance student learning outcomes.



Qualitative study of Design-Based Learning Strategy on ... Muhammad, S. & Garba, S. (2026)

Academic achievement as a measure of what a person has accomplished after exposure to an educational programme. It is a means of accomplishment or proficiency of performance in a given skills or body of knowledge. Abumchukwu and Okeke (2020) opined that students' academic achievement corresponds to their performance in school subjects as symbolized by a score on achievement test. It is commonly measured by means of examination or continuous assessments, it represent the level of success of the teaching and learning process, it indicate the extent to which the established goal have been achieved, it also provides feedback to the teacher and student. Surino *et al.*, (2024) noted that one of the most worrying issues in learning physics is how students understand concept and suggested the use of innovative and more engaging instructional strategy that could make students have deeper understanding of concept, gain reasonable academic achievement thereby reducing students learning burnout.

Conceptual understanding is the ability of learners to connect and organize knowledge, which were useful in integrating theory and practice in daily life (Nur'aini *et al.*, 2023). When the relationship between theory and practice are established, then learning were more meaningful and hence conceptual understanding is attained which may positively affect the development of life-career skills. Conceptual understanding is very important for developing life-career skills such as flexibility, adaptability, initiative, self-direction, productivity, accountability, leadership and responsibility which are also essential for higher academic achievement and life in the 21st century. Conceptual understanding are developed when real life problems are used to teach a concept. Students' understanding of concepts changes through active participation and designing solutions to related problems through identifying real life problems, generating information, designing prototype and evaluation of the designed prototype thereby enhancing students' academic achievement (Santika & Herdi, 2020).

Electromagnetism is a fundamental concept in physics that is crucial for understanding various technological applications, including electric motors, generators, and transformers. Despite its significance, electromagnetism is often reported as a challenging topic for students, leading to poor academic achievement and misconceptions. Traditional teaching methods, which emphasize theoretical and lecture-based approaches, have been criticized for failing to engage students and promote deep understanding. In contrast, design-based learning offers an innovative approach that combines hands-on design activities with conceptual learning, fostering creativity, problem-solving skills, and deeper understanding of scientific concepts (Dessie *et al.*, 2023). The Nigerian educational context, characterized by large class sizes and limited resources, further underscores the need for effective and engaging teaching approaches like design-based learning. This study aims to investigate the impact of design-based learning on senior secondary school students' academic achievement and conceptual understanding of electromagnetism.

Statement of the Problem

Despite all the importance of physics education to the development of any nation, pre-service physics teachers find learning physics concepts difficult specifically the aspect of electromagnetism. Common learning difficulties students face in Physics could range from students inability to visualize both electric and magnetic fields as they are invisible and often have trouble linking theoretical concepts to real-world applications, such as in generators, transformers and everyday electronics (Ergül & Çalıř, 2021). These learning difficulties have led to low achievement of students at Universities and other level of education. The persistent poor academic achievement and inadequate conceptual understanding of electromagnetism among senior secondary school students in Nigeria, despite its importance in physics and everyday applications, necessitates an exploration of innovative teaching approaches. Design-based learning, which integrates hands-on design activities with conceptual learning, has shown promise in enhancing student learning outcomes in STEM subjects. However, its effectiveness in improving academic achievement and conceptual understanding of electromagnetism in Nigerian senior secondary schools remains unexplored.

Research Objectives

The main aim of this study is to explore the effectiveness of design-based learning on academic achievement and conceptual understanding in electromagnetism among undergraduate university students in Northwest, Nigeria. The specific objectives are set to:

1. explore undergraduate students experiences to Design-Based Learning Instructional Strategy and how it could influence their achievement in Electromagnetism.
2. explore undergraduate students experiences to Design-Based Learning Instructional Strategy and how it could influence Conceptual Understanding in Electromagnetism.

Qualitative study of Design-Based Learning Strategy on ... Muhammad, S. & Garba, S. (2026)

Research Questions

Based on the stated research objectives, the following research questions were raised to guide the study:

1. What are the undergraduate students' experiences to Design-Based Learning Instructional Strategy and how it could influence their achievement in Electromagnetism?
2. What are the undergraduate students experiences to Design-Based Learning Instructional Strategy and how it could influence Conceptual Understanding in Electromagnetism?

The study employed qualitative research design specifically phenomenological design. This is a type of qualitative research design that allow researcher to collect views, feelings and thought from a number of participants which was used to describe what all participants have in common as they experience a phenomenon (Creswell, 2014). The design was used to seek pre-service teachers' views regarding their experience with Design-Based Learning and its effectiveness in fostering conceptual understanding, improving academic achievement and reducing burnout. The design is illustrated as in figure 1.

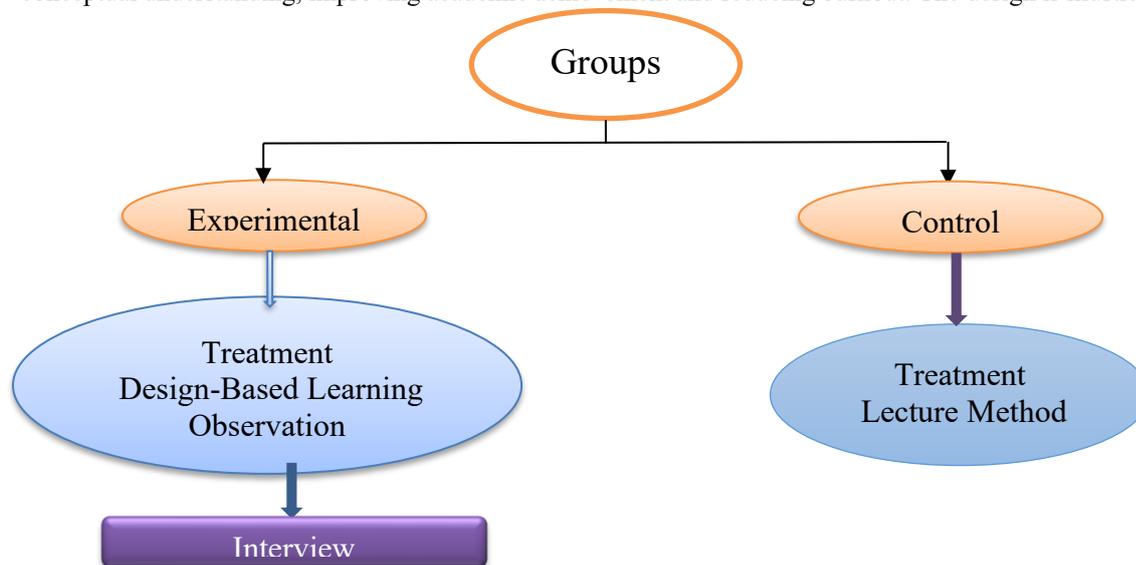


Figure 1: Qualitative Research Design Layout

The population for this study comprised all the 300L undergraduate pre-service University physics teachers from the thirteen (13) Universities in North-West, Nigeria, offering Physics Education as a course with total number of Nine Hundred and Forty One (941) 300L Undergraduate pre-service physics teachers in the Department of Science Education. The sample for the qualitative aspect was determined using recommendation made by Bekele and Ago (2022); Adler and Adler as cited in Daniela (2020) whom suggested that if a selected sample is relatively homogeneous, 6-12 participant are enough for one qualitative research. Since the population is relatively homogeneous, eight (8) undergraduate physics students were used for the interview. Purposive sampling technique was used to select Eight (8) undergraduate pre-service Physics teachers from the population of the study based on the following criteria: participant who have experienced the phenomena through exposure to Design-based Learning instructional strategy, students that can communicate and feel free to respond to the interview question, and gender consideration. On that basis, only experimental group that were taught using design-based learning instructional model are selected and participated in the qualitative part of the study.

Two instruments were used for data collection and these are: Undergraduate Physics Students' Observation Schedule developed by the researcher and it consist of three (3) sections. Section (A) contained basic information of students such as; University code, gender, research group, time, observer and location. Section (B) titled preliminaries which contained data on the number of students enrolled and attended for the class based on gender. Section (C) titled observation items contained two (2) sub-sections viz: instructional resources where observer noted the available instructional resources presented by lecturer and students including the developed prototype, and classroom activities where lecturers and students activities are recorded accordingly. And Undergraduate Physics Students' Interview Protocol developed by the researcher and it consist of two (2) sections. Section (A) contained basic information of students such as; University code, gender, research group, time, interviewer and location. Section B titled Interview Questions (IQ) and will consist of ten (8) items

Qualitative study of Design-Based Learning Strategy on ... Muhammad, S. & Garba, S. (2026)

on undergraduate University Physics students experience with DBL and how it affects their academic achievement, conceptual understanding, and learning burnout. The interview protocol and observation schedules were given to one professor, two senior lecturer from Science Education Department, Federal University of Technology Minna and One Associate Professor from Science Education Department, Kaduna State University for validation. Their corrections were considered in the construction of the final instruments. Introduction letter containing research objective, research question and research hypotheses were sent together with the instrument to assist in validating the instruments. The reliability of qualitative research instrument (Interview Protocol and Observation Schedule) were carried out using inter-rater reliability method. Two raters were assigned to rate the items of the instrument as to appropriate or not appropriate and the reliability index was calculated using Cohen's' Kappa reliability formula using $K = \frac{P_O - P_E}{1 - P_E}$. Where K is Cohens' Kappa, P_o represents the actual observed agreement and P_E represents agreement by chance. McHugh (2012) suggested that inter-rater reliability should be calculated using both percentage agreement and using Kappa formula so as to take care of guessing issue among the raters. The result for the Kappa Reliability Values obtained and raters' percentage agreement were found to 0.82 and 0.66 for the interview and observation schedule respectively

DBL Lesson Plan Models for four lesson were design to teach the group within four (4) weeks. Before the actual experiment started the researcher conducted a one day workshop for the pre-service teachers in experimental group on the features and practices involved in design-based learning. The treatment was done by the researcher and research assistant. The designed lesson model was strictly followed. However, an observation schedule designed by the researcher was strictly followed to observed pre-service teacher in DBL and how different DBL activities influence their academic achievement, conceptual understanding. Design-Based Learning Lesson Model and teachers/pre-service teachers' activities summary according to the phases are presented in Figure 2.



Figure 2: Design-Based Learning Lesson Model

Introduction: This is where teacher provides background explanation about the concept to be taught and group the students into small groups. *Identification and engaging the problem:* The teacher present an open-ended, real world problem scenario related to electromagnetism. Students here brainstorm, understand and define the problem, analyze the problem by breaking down the problem into smaller segment and students fill in “the need to know worksheet”. *Create situation:* In this stage, the teacher provides knowledge explanation (concept and principle that will be applied), scaffold the generation of ideas through pictures, videos, textbooks, and links to Open Educational Resources and develop a plan and establish strategy while Students brainstorm and gather information by searching ideas in textbooks, Online, and other sources provided by the teacher individually and meet in a group to collaborate, generate an innovative idea to solve the identified problem and select and report the best idea. *Designing prototype:* The teacher provides design guidance, monitor the design process and provide appropriate scaffolds and Students here brainstorm, sketch and interpret design and select and report the best



Qualitative study of Design-Based Learning Strategy on ... Muhammad, S. & Garba, S. (2026)

design. *Development of prototype:* The teacher monitor the construction process and provide appropriate guidance while students here convert the design into prototype, test the constructed prototype and report and document result. *Evaluation:* The teacher provides the evaluation question and worksheet. In this step, self-evaluation and group evaluation will be done by the students and they will answer the question as to whether the objective were achieved or not. *Communicate and Reflection:* The teacher moderates the presentation of the findings and scores the students using scoring rubric. Students share, and defend findings and argumentation. Immediately after the treatment, the researcher conduct an interview to explore pre-service teacher’s experiences and feelings after exposure to design-based learning strategy. The interview will be recorded using recorder and transcribed thereafter. Simultaneous thematic procedure was employed to analyze the data collected. Data analysis through this procedure proceed hand in hand with data collection and write-up of findings (Creswell and Creswell, 2023). The data were winnowed focusing on some of the data and disregarding other part of it, this is because, the text and image data are so plentiful and therefore all the information cannot be used in the study (Guest *et al.*, 2012). The analysis of the data collected was done through a sequential process of organizing and preparing the data (transcribing, scanning materials, sorting and arranging), reading through the data, coding the data, identifying sub-themes (grouping the codes into sub-themes), identifying themes (grouping sub-themes into themes), developing a story line interpretation, adding analytical framework and interpreting the data.

Presentation of Results

The findings from interview and observation field notes revealed that students learning with DBL characterized by collaborative, engaging and student centered learning which could foster meaningful learning through the generation of idea, hands-on and minds-on activities, development of prototype and presentation of ideas which improved students' academic achievement, fostered conceptual understanding and reduced learning burn-out. These experiences with DBL are described by the students and are classified into four themes. Learning experiences, active participation, collaboration and reduced learning burn-out. These themes are explained below:

Learning Experiences

Increased in academic achievement and conceptual understanding are associated with positive learning experiences. Students’ interview responses and observation field notes provide evidence that could be described as learning experiences. It was observed that students were excited and curious to learn through DBL. This showed that students were having positive interest and motivation and the theme was made up of sub-theme such as empowered learning, conceptual understanding, and enhanced achievement. These sub-themes are highlighted in a tabular form as presented in Table 1.

Table 1: Learning Experiences Theme, Sub-Themes, and their Definition

S/N	Themes	Sub-theme	Definitions
1	Learning experiences	Empowered learning	Refers to knowledge gain, self-assessment, positive interest and curiosity among learners. In this sub-theme, students reflect, taking control of their learning, and interact with each other.
Conceptual understanding		Students demonstrate knowledge and deeper understanding of key concepts, principles, and theories and recognize relationships between them. It is characterized by deeper understanding and connection between concept/real-world applications.	
Enhanced achievement		Refers to mastery of subject matter knowledge and development of skills. In this sub-theme, students show progress and improvement in their academic performance.	

Empowered learning

Knowledge gain, self-assessment, positive interest and curiosity among learners characterizes the DBL. Activities such as reflection, students taking control of their learning, and students interaction are classified under this sub-theme. This findings suggest that students gained more knowledge and remembered so many things they forgot before in electromagnetism as indicated in the students’ excerpts presented below;

It doesn't affect me, but, like, it's helped me gain. Like, how will I even put it? I have experiences now.

(Participant A Interview, 19/09/2025)

I remember so many things that I forgot before, but during this experiment, or during this designing, I did remember a lot of things, and I learned so many things else.

Qualitative study of Design-Based Learning Strategy on ... Muhammad, S. & Garba, S. (2026)

(Participant B Interview, 19/09/2025)

I am interested in this course, previously I have not acquired such skills. When the lecture was going on I was not exhausted because I am interested and that my attitude, skills and knowledge were improving

(Participant C Interview, 19/09/2025)

Students were observed working in team, sharing ideas, designing and constructing electromagnetic crane and electromagnet. Students were also seen happy as they took ownership of their project.

(Observation, 5/09/2025)

The verbal also indicated that students were excited, happy, comfortable and eagerly seeking for solution to different problems in electromagnetism. This affirmed that students have developed positive interest and showed increased in their curiosity to learn and find solution to problems in electromagnetism as indicated in the excerpt presented below;

Honestly, I enjoyed the iterative process of designing and testing my project. It helped me refine my ideas.

(Participant D Interview, 19/09/2025)

When learning or studying physics now I am eager and happy most a times.

(Participant D Interview, 19/09/2025)

I felt more comfortable during this process, I am happy and highly interested in the strategy

(Participant E Interview, 19/09/2025)

I felt very comfortable and learning with this method is interested. And I like the way we created that magnet. Sincerely it was interesting.

(Participant F Interview, 19/09/2025)

Actually, I felt happy, it's kind of the second time. I felt happy because it's kind of the second time me been designing a project, actually. I also like the way you teach us. You've been jovial, and I love the way you speak.

(Participant Interview, 19/09/2025)

A-I like the way our teacher used real example from our daily activities which made us think critically even outside the box, come up with the solution and develop a prototype of the solved problem

(Participant B Interview, 19/09/2025)

Students were observed constructing the electromagnet and electromagnetic crane and were seen laughing at the initial construction, they unpacked and constructed again trying to correct the initial mistake. They were seen sticking and re-sticking, measuring and cutting material (wood and wire) to the desired length.

(Observation, 12/09/2025)

Apart from students' excitement, happiness, comfort and eagerness to seeking for solution to different problems in electromagnetism, students had better experiences with DBL which led to an increase in their interest and fostered their skills. To support this findings, students' excerpts are presented below;

I felt better experience and happy. I experienced so many things that could improve my skills and enhance them and I sow so many things can be learnt experimentally. I am interested in this course, previously I have not acquired such skills. When the lecture was going on I was not exhausted because I am interested and that my attitude, skills and knowledge were improving

(Participant C Interview, 19/09/2025)

Throughout the process we work in group and the most interesting thing is that we had to share our work to class through presentation where we evaluate each other

(Participant G Interview, 19/09/2025)

Conceptual Understanding

Students demonstrate knowledge and understanding of key concepts, principles, and theories and recognize relationships between concepts, principles, and ideas. Students also apply conceptual understanding to real-world situations and demonstrate a deep understanding of concepts. It is characterized by deeper understanding and connection between concept/real-world applications. These findings suggest that students gained more conceptual knowledge in electromagnetism as indicated in the students' excerpts presented below;

Yes it increases my understanding of concept. Working in group assist me in getting a lot of views on electromagnetism. Members' responses help me gain more understanding.

Qualitative study of Design-Based Learning Strategy on ... Muhammad, S. & Garba, S. (2026)

(Participant G Interview, 19/09/2025)

I mean likeworking on the design project helped me understand the concepts of electromagnetism more deeply. And feel like I am achieving my goals. I was less frustrated with learning electromagnetism after these lessons. I understood the concept better and felt more in control

(Participant D Interview, 19/09/2025)

The study's findings also suggest that students have demonstrated knowledge on the integration of concepts during development of prototype to real world problem and this can be seen in the excerpts below;

We had to apply concepts from physics, mathematics and engineering to design and develop electromagnetic crane.

(Participant C Interview, 19/09/2025)

Year, I do understand more on facts, concept integration and procedures in solving problems associated with electric field and electric flux. I can also transfer my understanding to new situation.

(Participant B Interview, 19/09/2025)

Through the design process I get to understand more on how concept from different area are interconnected and how they can be used to solve real world problems.

(Participant G Interview, 19/09/2025)

Before now, I cannot differentiate between electric field and electric flux, but now I do.

(Participant Interview, 19/09/2025)

Enhanced Achievement

Students demonstrate mastery of subject matter knowledge and develop and refine skills. Students show progress and improvement in their academic performance in electromagnetism. Students have also demonstrated their ability to remember facts and concept, score better marks at test or exam and showed an increase in their skills level such as critical thinking, perseverance, communication and leadership. Activities such as coordinating group work, minds-on activities and presentation are classified under this sub-section. Findings suggest that students' academic achievement could be enhanced when learn using DBL as shown in the students' excerpts below;

It affects me positively because I have improved my learning performance. And I liked the way we conduct it and the performance is giving us very excellent. =

=Yes it increases my understanding of concept which help me score good marks at test

(Participant H Interview, 19/09/2025)

I remember so many things that I forgot before, but during this experiment, or during this designing, I did remember a lot of things, and I learned so many things else

(Participant E Interview, 19/09/2025)

I felt better experience and happy. I experienced so many things that could improve my skills and enhance them and I saw so many things can be learnt experimentally

(Participant C Interview, 19/09/2025)

The best way to solve the problem is working in team was what make me like this approach, this is because from ideas in my group we were able to proffer solutions. =

=We kept discussing till we reach consensus on the best idea=

=I mean I was appointed as group leader where I coordinated the activities of my group right from brainstorming up to the presentation of our developed prototype.

(Participant D Interview, 19/09/2025)

I played an important role while conducting the experiment, I have been the leader of the group.

(Participant H Interview, 19/09/2025)

The findings from the interview also revealed that students had increased in engagement through working in group as presented in the students' excerpts below;

I coordinated the activities of my group right from brainstorming up to the presentation of our developed prototype. We designed and developed electromagnet and throughout the process we work in group. =

=Hmmm The class was quite noisy, each group was busy discussing and defending their opinions, and everyone participated by sharing their points We were searching and reading books, information and ideas from the internet and others were jotting down information from the internet and textbooks.



Qualitative study of Design-Based Learning Strategy on ... Muhammad, S. & Garba, S. (2026)

(Participant D Interview, 19/09/2025)

Well, it's kind of first time I learnt using design-based where we engaged with practical activities, we designed and developed electromagnet. We brainstorm and generated idea and solve the problem identified by our teacher.

(Participant B Interview, 19/09/2025)

It was observed that group leaders coordinated the activities of their group and the class was seen to be quite noisy, each group was busy discussing and defending their opinions.

(Observation, 12/09/2025)

Active Participation

Learners engaged in several activities during learning process using DBL. Activities such as hands-on activities, minds-on activities and searching for ideas from the internet and textbooks about electromagnetism are associated with this theme. Students' interaction and teacher-students interaction also characterize this theme. Students' interview responses and observation field notes provide evidence that could be described as active participation. This theme was made up of sub-theme such as engagement and classroom interaction. These sub-themes are highlighted in a tabular form as presented in Table 2.

Table 2: Active Participation Theme, Sub-Themes, and their Definition

S/N	Themes	Sub-theme	Definitions
2	Active Participation	engagement	Refers to the participation in design process through hands-on and minds-on activities.
		class interaction	Exchange of idea among students and between students and teacher with a view to achieving the learning objectives.

Engagement

The verbal and non-verbal data described students' engagement with activities such as iterative design process, communication and collaboration. Students were engaged in hands-on activities and minds-on activities. To support this findings, excerpt from students interview suggest that;

..... Where I coordinated the activities of my group right from brainstorming up to the presentation of our developed prototype

(Participant D Interview, 19/09/2025)

We designed and developed electromagnet and throughout the process we work in group.

(Participant G Interview, 19/09/2025)

Well, it's kind of first time I learnt using design-based where we engaged with practical activities, we designed and developed electromagnet

(Participant B Interview, 19/09/2025)

Yes, I help in designing and developing prototype.

(Participant A Interview, 19/09/2025)

Non-verbal data from observation field notes suggested that learners engage in hands-on activities with their group members to demonstrate how electric field and magnetic field are visualized.

The students were observed searching and reading their books while others were seen searching for relevant information and ideas from the internet. Some students were observed jotting down information from the internet and textbooks. Students are always excited to meet in a group to brainstorm and share ideas. Students are heard arguing and defending their ideas among group members

(Observation, 5/09/2025)

Non-verbal data suggest that students could be seen designing prototype before development and each group presented their work to the class.

(Observation, 12/09/2025)

The interview also indicated that students had participated actively as they engaged in minds-on activities where they brainstormed and generated ideas that led to the solution of problem as indicated in the students' excerpts below;

We brainstorm and generated idea and solve the problem identified by our teacher.

(Participant C Interview, 19/09/2025)

Qualitative study of Design-Based Learning Strategy on ... Muhammad, S. & Garba, S. (2026)

We brainstorm and generated idea and solve the problem identified by our teacher.

(Participant G Interview, 19/09/2025)

A-I like the way our teacher used real example from our daily activities which made us think critically even outside the box, come up with the solution and develop a prototype of the solved problem

(Participant B Interview, 19/09/2025)

The students were observed sketching their ideas on how their electromagnetic crane or electromagnet should look like as indicated below

The students were observed constructing electromagnetic crane and electromagnet, engaging in group project based on the goal of solving the problem identified by the teacher.

The students seem to engage in co-construction of ideas during group interaction and discussion as indicated in the observation field notes. Students were also observed presenting several ideas, all the ideas were reviewed, and the best idea was adopted, or sometimes a new idea is developed from the ones presented.

(Observation, 5/09/2025)

Classroom Interaction

The finding shows that students were committed to their learning process, interact positively with each other, collaborate and interact with our teacher. The students work individually to search for relevant information and ideas and meet in a group to brainstorm and interact. This findings can be justified from the students' excerpt presented below;

We were searching and reading books, information and ideas from the internet and others were jotting down information from the internet and textbooks. =

=Hmmm The class was quite noisy, each group was busy discussing and defending their opinions, and everyone participated by sharing their points

(Participant D Interview, 19/09/2025)

Our teacher initiated the lesson though real world example and guide us when doing the remaining process. =

= During group discussion, we try to figure out what will work best and what will not by identifying possible idea that best solve the problem.

(Participant G Interview, 19/09/2025)

His role was going round guiding us while we are solving the problem, and he played and social role, not standing just active always.

(Participant H Interview, 19/09/2025)

Our teacher gave us instructions and coach us when conducting the experiment.

(Participant C Interview, 19/09/2025)

We kept discussing till we reach consensus on the best idea.

(Participant G Interview, 19/09/2025)

During group discussion, students were observed presenting their ideas and justifying their position as other members of the group seek for clarity. Students were seen engaging in the reflection of what has been done in the previous phase.

Group Leader: any idea to be considered should meet the requirement necessary for solving the problem

Member 4: one of the condition is that the electromagnetic separator should have the strength to lift ferromagnetic materials with varying sizes and weights and that we can use local materials.

Member 2: we should use local resources like scraps metal

Member 3: knowledge of engineering is require to construct switch

Group leader: Any more contribution

Member 1: yes, we can use wood for the mechanical aspect and construct our crane

Member 4: let us know the material to be used please

Member 7: we need wood, connecting wires, and copper wire.

Member 5: good idea but we should use constantan wire

Member 5: no brother, I think this wire cannot give us the expected result, we should go for the first one (sales' proposal).

Member 3: let us look at the proposals

Member 5: After all the argument we have now come up with idea that is expected to work.



Qualitative study of Design-Based Learning Strategy on ... Muhammad, S. & Garba, S. (2026)

(Observation, 5/09/2025).

Students were observed constructing the electromagnet and electromagnetic crane and were seen laughing at the initial construction, they unpacked and constructed again trying to correct the initial mistake. They were seen sticking and re-sticking, measuring and cutting material (wood and wire) to the desired length.

(Observation, 12/09/2025)

Verbal data also revealed that students work in team, present and share their work to the class, asked and answered questions and indicated confidence that they conducted the experiment themselves as shown in the students' excerpts below;

I also struggled with the design process, but my team helped me work through the challenges.

(Participant D Interview, 19/09/2025)

Throughout the process we work in group and the most interesting thing is that we had to share our work to class through presentation where we evaluate each other.

(Participant B Interview, 19/09/2025)

I'm not a group leader, but answered questions actually during presentation.

(Participant A Interview, 19/09/2025)

We did the experiment ourselves and the teacher was just going round to see how we were doing the activities

(Participant C Interview, 19/09/2025)

Discussion of Findings

Findings that revealed that undergraduate physics students experienced enhanced academic achievement that is characterized by mastery of subject matter knowledge, development of skills and improvement in academic performance. It was also affirmed from the study that DBL is characterized by students' active participation, hands-on and minds-on activities which could have contributed to students' empowered learning of physics. Students demonstrate mastery of subject matter knowledge, develop and refine skills. Students show progress and improvement in their academic performance in electromagnetism. Students have also demonstrated their ability to remember facts and concept, score better marks at test and exam and showed an increase in their skills level such as critical thinking, perseverance, communication and leadership. Students engage in activities such as coordinating group work, minds-on activities and presentation. Findings suggest that students' academic achievement could be enhanced when learn using DBL.

This findings concur with qualitative findings from Hanna *et al.*, (2025) whom conducted a study on monitoring multiple aspects of learning when design-based learning meets science education using qualitative approach and found that the teacher monitored diverse aspects of learning, namely students' chemical thinking, design practices, research practices, social interactions, ownership, behavior and emotions and how the teacher connected different aspects of learning which could support her interpretation of student learning and improve academic achievement. This qualitative findings also align with findings from Wei *et al.*, (2023) that carried out a study on the effectiveness of design-based engineering learning: the mediating role of cognitive engagement and the moderating role of modes of engagement whom found that all four features of DBEL (design practice, interactive reflection, knowledge integration, and circular iteration) were found to exert significant and positive effects on learning outcomes and that design-based learning approach can enhance engineering students' learning outcomes.

The positive result of this present study could be traced to the learning environment provided by the DBL through learning opportunities where students worked in group, understand and define problems, search for information/generate idea, engage in hands-on activities to visualize electric and magnetic field. This may have reduced students' misconceptions of electromagnetism. DBL hands-on approach enables students to develop critical thinking and problem-solving skills, leading to better academic achievement and interactive nature of DBL promotes deeper learning, increased motivation, and a sense of ownership, contributing to improved academic performance. In addition, DBL allows students to work at their own pace, receive feedback, and develop a more nuanced understanding of complex systems which fosters essential skills like communication, and collaboration thereby very vital for academic success. Another possible reason for the similar findings could be attributed to the fact that teachers serve as facilitators, providing guidance and support as needed, which can lead to more effective learning outcomes.



Qualitative study of Design-Based Learning Strategy on ... Muhammad, S. & Garba, S. (2026)

The also revealed that conceptual understanding sub-theme emerged from the learning experiences theme where students demonstrate knowledge and understanding of key concepts, principles, and theories and recognize relationships between concepts, principles, and ideas. Students also apply conceptual understanding to real-world situations and demonstrate a deep understanding of concepts. These findings suggest that students gained more conceptual knowledge in electromagnetism. The study's findings also revealed that students have demonstrated knowledge on the integration of concepts during development of prototype to real world problem where students applied concepts from physics, mathematics and engineering to design and develop electromagnetic crane, and electromagnet. The findings also indicated that students' higher-order thinking and higher-order capabilities are enhanced, such as critical thinking ability and problem-solving ability. At the same time, they are satisfied with the DBL instructional strategy. These findings suggest that the DBL approach is effective in promoting students' deep learning and improving the quality of teaching and learning.

This finding is in agreement with findings of Weng *et al.* (2023) whom found that the DBL approach is effective in promoting students' deep learning and improving the quality of teaching and learning and that DBL approach has distinctively stimulated the students' motivation to learn, making them more actively engaged in study. At the same time, they are satisfied with the DBL approach. The findings also concur with findings of Ladachart *et al.* (2022) orientation towards learning by making and testing and mindfulness of the process and impact on other people are the dimensions that facilitate conceptual learning on pulleys. In another similar study, Leung (2022) conducted a research on Developing a Framework for Blended Design-Based Learning in a First-Year Multidisciplinary Design Course. Quantitative results demonstrated increases in students' design competencies and intrinsic motivations leading to the emergence of four themes representing both positive and negative views of DBL.

On contrary to this study's findings, Dognia and Dah (2023) found from their study that majority of the students had the misconception that gravity is selective and therefore acts more on heavier objects compared to lighter objects. As a result, they are of the opinion that larger object should hit the ground first before a light object dropped from the same height, which is not scientifically accurate and therefore reported that students are having misconceptions in physics. Mihret *et al.*, (2023) study also contradict the presents finding where the results of the one sample t-test showed that the conceptual understanding test scores for electricity and magnetism were considerably below the national standard pass mark points and the baseline for certification of competency to the teaching profession.

Conclusion

Undergraduate University physics students had positive learning experiences after exposed to DBL as revealed in the themes and sub-themes that emerged in this study. Students experienced empowered learning characterized by knowledge gain, self-assessment, positive interest and curiosity among learners. Students actively participated during learning with DBL as indicated in the second theme that emerged. And DBL could reduce or increase learning burn-out as indicated in the third theme that emerged with three sub-theme: reduced physics students emotional exhaustion, increased students efficacy as they showed confidence and ability to achieve goal and overcome challenges and student experienced challenges during learning with DBL as some students had difficulty in construction and concentration, frustrated and stressed.

Recommendations

Based on the findings of this study, the following recommendations were made:

1. Incorporate design-based learning strategy element such as real-world examples, prototyping, and collaboration to illustrate physics concepts particularly electromagnetism, making the subject more relevant and engaging for students as it leads to higher academic achievement compared to lecture method.
2. Lecturers should provide equal access and opportunities for all students when learning through DBL as it is effective for both male and female students in terms of academic achievement
3. Facilitators should use the same instructional strategy (DBL or lecture method) for both male and female students as the effectiveness does not depend on gender. This was confirmed by non-interaction effect between methods and gender on academic achievement and conceptual understanding in electromagnetism.



Qualitative study of Design-Based Learning Strategy on ... Muhammad, S. & Garba, S. (2026)

4. Lecturers should encourage collaborative learning and teamwork to promote social interaction, communication, and problem-solving skills since DBL was found to improve conceptual understanding of physics students in electromagnetism, as it outperforms traditional lecture methods.
5. Curriculum developers should integrate design-based learning principles and strategies into the undergraduate physics curriculum to promote conceptual understanding as DBL is equally effective for both male and female physics undergraduate students in promoting conceptual understanding.
6. University management should mandate the implementation of DBL in teaching physics to reduce learning burn-out, as it leads to lower burn-out compared to lecture methods.

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