Integrating Experiential Approach into Design-Based Science Learning Model for Enhancing Life-Career Skills: A Critical Review

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Abstract

Design-based learning (DBL) is an innovative instructional strategy that allows learners to actively participate in the learning process and make sense of new information by matching the knowledge with different existing experiences. In this study, the Design-Based Learning Model has been modified by incorporating elements of the experiential learning cycle to support best practices that develop life-career skills and enhance social sustainability. The element of the experiential learning cycle (Concrete Experience, Reflection, Abstract Conceptualizations, and Active Experimentation) has been integrated into the three (3) phases of Weng *et al.,* (2023) model, and a six (6) phases Modified Design-Based Learning Model was developed. The phases of the modified version are generating and engaging new problems, create a situation, designing a prototype, development of prototype, evaluation, and communication & reflection. It was concluded that the modified version of the DBL Model with integrated experiential learning cycle can address the life-career skills developmental challenges and foster social sustainability. It is recommended that a trial testing of the modified version of the DBL Model should be carried out with different level of students to determine its efficacy in the development of life-career skills.

Key Words: Design-Based Learning, Best Practice, Experiential Learning Cycle, and Life-Career Skills

Introduction

In science education, students often encounter significant conceptual and mathematical difficulties. Physics is inherently abstract and mathematically intensive, involving concepts such as electric and magnetic fields, electromagnetic induction, and circuit analysis. Mastery of these concepts requires a solid understanding of mathematical principles, including algebraic manipulation, vector representation, proportional reasoning, and graphical interpretation. However, evidence from Nigerian classrooms indicates that many students struggle to meaningfully connect mathematical formulations with physical phenomena, resulting in rote memorization, low achievement, and increased cognitive fatigue or learning burnout. The disconnect between mathematics and physics instruction has been identified as a major barrier to effective learning in electromagnetism. In many cases, mathematics is taught in isolation, without explicit links to its application in scientific contexts, while physics instruction often assumes prior mathematical competence that students may not possess. This fragmentation limits students' ability to apply mathematical reasoning in solving physics problems and undermines their overall academic performance. Therefore, there is a need for integrative instructional strategies that explicitly bridge mathematics and electromagnetism coherently and engagingly.

Design-Based Learning offers a promising framework for addressing this challenge by embedding mathematical reasoning within authentic, problem-based tasks in electromagnetism. Through activities such as designing electric circuits, constructing simple electromagnetic devices, and modeling field interactions, students are required to apply mathematical concepts in meaningful contexts. These tasks promote both hands-on engagement and minds-on reasoning, enabling learners to visualize abstract relationships, test hypotheses, and refine their understanding through iterative processes. In doing so, DBL facilitates the integration of conceptual knowledge and mathematical skills, leading to improved comprehension and retention. Design-based learning is an innovative instructional strategy that allows learners to actively participate in the learning process and make sense of new information by matching the knowledge with different existing experiences. Design-Based Learning provides a learning situation in which teacher and learners have different roles to play, unlike the lecture method, whereby the teacher dominates the class and has the role of actively giving information, while the learners have the role of passively receiving information. Chunmeng *et al.,* (2022) maintained that, learning process in Design-Based Learning is supported by real life problems or scenarios that requires learners' engagement and participation, teachers' facilitation and supervision during the process (Zhang *et al.,* 2021)On the other hand, the DBL strategy allows students to actively participate in the learning process by providing opportunities to identify problems and solve such problems through designing prototype that could ensure the development of cognitive aspect of the learners. In developing cognitive knowledge of learners, elements like hands-on activities and mind-on-activities are embedded in the design-based learning model

Design-Based Learning (DBL) instructional methodology is able to empower teachers to shift their classroom practices away from teacher-centered modes of instruction to create a student-centered learning environment aligned with requirements of current educational reform. Historically, educators have often debated the usefulness of student-centered, constructivist methods of instruction as opposed to those perceived to be more traditional and teacher-centered, basing their arguments on ideas and recommendations from theorists in the fields of education, psychology, and child development. The DBL methodology was formed on the principles of constructivism and the fundamental idea that a student-centered classroom leads to the cultivation of higher-level thinking skills, mastery of content, and engagement in collaborative decision-making in a democratic classroom setting. Rather than relying on lecture and other passive activities, teachers of the DBL methodology hold the value that they are facilitators of student learning and discovery as they build collaborative student-centered classroom environments (Azizan & Abu-Shamsi, 2022).

Kolb (1984) state that learning involves the acquisition of abstract concepts that can be applied flexibly in a range of situation, he further view learning as a process whereby knowledge is created through the transformation of experiences. Kolb's experiential learning theory works on two levels: a four stage cycle of learning and four separate learning styles. The four stages are namely; Concrete Experience, Reflection, and Abstract Conceptualizations and Active Experimentation. According to Kolb, experiential learning can be described as a four-stage process, in which an individual can start from any stage but the sequence of the stages remain the same. Two stages (Concrete Experience and Abstract Conceptualization) in the cycle involves experience while the other two (Reflection and Active Experimentation) involves the transformation. Integrating these stages into Design-Based Learning Model could allow for the development of life-career skills.

Today's students need to develop life-career skills such as thinking skills, content knowledge, and social and emotional competencies to navigate complex life and work environments. Partnership for 21st-Century Skills provides essential Life and Career Skills, including: Flexibility and Adaptability; Initiative and Self-Direction; Social and Cross-Cultural Skills; Productivity and

Accountability; and Leadership and Responsibility**.** Partnership for 21st-Century Skills Model advocates that basic constructs of life-career skills could be developed through DBL. DBL encourages students to approach problems from multiple perspectives. As they work through design challenges, they must adapt to changing variables, respond to feedback, and iterate on their designs. This process builds flexibility as students learn to adjust their ideas and methods when faced with new information or setbacks, preparing them for real-world problem-solving where adaptability is crucial. Students often take ownership of their learning by defining problems, exploring resources, and coming up with solutions. This environment fosters initiative, as students are encouraged to explore solutions independently and proactively. The iterative nature of DBL also enhances self-direction, as students must monitor their own progress, set goals, and push through challenges without direct guidance at every step by teacher.

The collaborative teamwork embedded in DBL, often in diverse groups, helps students develop social skills like communication, cooperation, and empathy. In settings where students come from various cultural backgrounds, DBL fosters cross-cultural competencies by requiring them to work together to address particular problems. DBL's structure requires students to manage their time, resources, and deliverables effectively. Students must remain productive, as the success of their design often hinges on meeting deadlines and achieving specific goals. Additionally, the iterative design process involves clear milestones, holding students accountable for their contributions to the group and for the final outcome of the project. DBL tasks often require students to take on leadership roles within their teams, guiding discussions, delegating, and making critical decisions. This fosters responsibility, as they are accountable for both their leadership and the collective success of the project. The responsibility also extends to reflecting on failures or mistakes and using them as learning experiences to improve future designs.

Design-Based Learning Frameworks

A plethora of frameworks were developed and implemented in the classroom with different levels of students using Design-Based Learning. These frameworks combine design and scientific methods to create prototypes. According to Easterday, Rees-Lewis and Gerber (2014) the Design-Based Learning approach involves four phases:

1. An analysis of real-world issues.
2. Solution development based on existing design concepts and technological advancements.
3. Evaluating and refining solutions in iterative cycles.
4. Reflection to develop design ideas and improve solution implementation.

These phases are systematic yet flexible, and the principles are adjustable and feasible for others interested in studying similar settings. However, despite a variety of design-based research processes highlighted in the literature, there is no one-size-fits-all design-based research process as the planning and implementation of research projects differ depending on the situation (Rossi, 2021) and can, therefore, change depending on the design goals and circumstances. A research conducted by Azizan and Abu Shamsi (2022) provided the following phases to be followed when teaching science through Design-Based Learning. The phases are:

1. Identify problem in the context of current situation and generate idea
2. Define a solution objectives
3. Designing and development
4. Demonstration and reflection

5. Communication and evaluation

Geitz and de Geus (2019) developed a design-based Learning model which involves five phases: (i) identify problems in the context of current situations and generate ideas; (ii) define a solution's objectives (iii) design and development; (iv) demonstration and reflection; (v) communication and evaluation. This design-based learning model focuses on identifying issues in situations at present and producing innovative ideas to encourage students to design a solution based on their 21st-century skills. Weng, Cheng and Ai (2023) DBL proposed a model for fostering deep learning and understanding and is presented in figure 1.

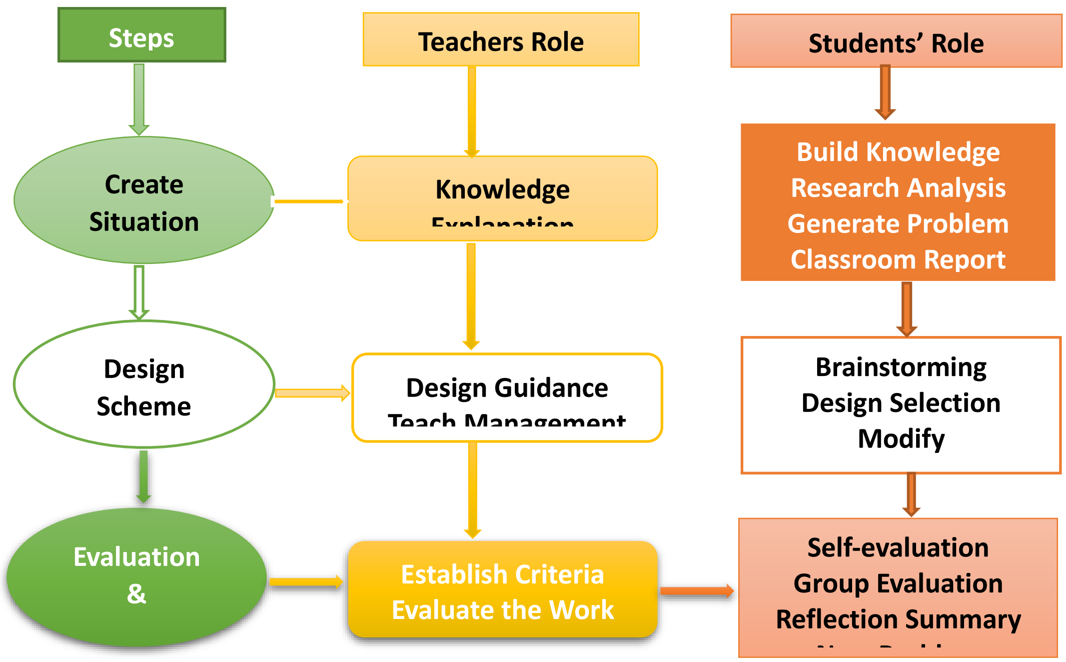

Figure 1: DBL Model for Deep Learning and Understanding (Weng *et al.,* 2023)

Another framework developed by Prommin and Kantathanawat (2020) to determine the effects of Design-Based Learning on computational thinking skills. The framework contained four (4) steps which includes: plan (prototype, design review and collection of information), action (identification of the need), observe (production) and reflect (evaluation). The model is presented in Figure 2

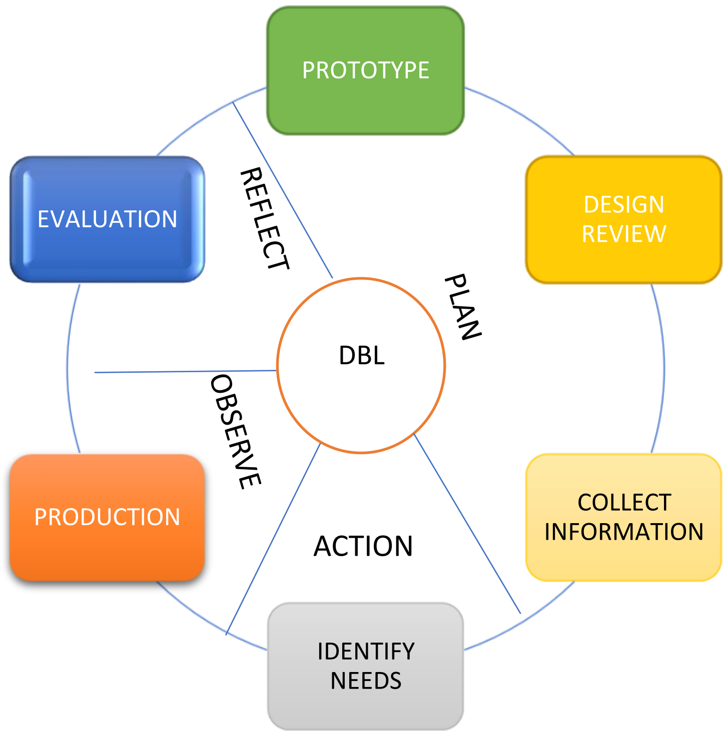

Figure 2: DBL Model for Developing Computational Thinking (Prommin and Kantathanawat, 2020).

Altan, Yamak, Kirikkaya and Kavak (2018) have developed Design-Based Learning model for the development of decision-making skills. The model contained five (5) section with nine (9) steps which includes: unpack the unit grand engineering challenge (identification of the problem), development of scientific knowledge and skills through series of mini-challenge and investigation (research need, development of possible solution, selection of the best solution and construction of the prototype), apply findings to potential design solution (test and evaluate), construct a solution to a grand design challenge (evaluation and communication) and test, improve and communicate (redesign and make decision).

Reviewed framework indicated that all the Design-Based Learning models are related to this study because, they provide a learning activity characterized by open-ended problem, giving both teachers and students enough flexibility for teaching and learning, presenting real-life scenarios for positioning the design challenge and arriving at a solution, multidisciplinary activity, development of prototype, hands-on techniques, tools, and materials for prototyping or testing, minds-on tools for design documentation and visualization during the defining phases. All the framework reviewed have some elements in common. Looking at the stages in each model, so many elements are common to each other and have similar meaning. The summary of the DBL model reviewed is presented in Table 1.

Table 1: Summary of the Design-Based Learning Model Reviewed.

Model Stages	Easterday *et al.* (2014)	Azizan & Abu Shamsi (2022)	Geitz & de Geus (2019)	Weng *et al.,* (2023)	Prommin & Kantathanawat (2020)	Altan *et al.,* (2018).
1	Analysis of real-world issues	Identification of problem	Identification of problem	Create situation	Plan	Identification of problem
2	Solution development	Define objectives	Define objectives	Design scheme	Action	Research need and Development
3	Evaluating and refining	Design & development	Design & development	Reflection and evaluation	Observe	Redesign and make decision
4	Reflection	Demonstration and reflection	Demonstration and reflection		Reflection	Evaluation and communication
5		Communication & evaluation	Communication & evaluation			

Integrating Experiential Learning Elements into the Design-Based Learning Model

It was indicated from Table 1 that Easerday et al; Prommin & Kantathanawat; and Altan proposed and used four (4) stages Design-Based Learning model while Azizan & Abu Shamsi and Geitz & de Geus utilized a five stages Design-Based Learning model in their studies. In addition, Weng et al. developed and implement three (3) stages Design-Based Learning model for fostering conceptual understanding. However, this study proposed six (6) phases of Design-Based Learning model modified from the Weng et al. models which has five stage due to the fact that it align with present study's objectives. These phases are: ***create situation***: this is where the teacher provides knowledge explanation and allow students to build knowledge, carryout research analysis, generate a problem that is real world scenario, defining objectives and make classroom report; ***designing prototype***: it is a stage where teacher gives design guidance and technical management. The phase will allow students to brainstorming on the identified problem and come up with the possible solution through designing a prototype; ***development of prototype***: selection and modification of the best designed solution as well as prototype construction are carried out at this stage. However, report is made on the design process and challenges; ***evaluation***: this is where the teacher establish evaluation criteria and evaluate the work. In this step, self-evaluation, group evaluation are done; ***communication and reflection***: teacher will guide the student on how to communicate their finding to class members, school and society in general if needs arise and initiate reflection session; ***generate and engaging new problem***: students will now come up with a new problem that could be solved by designing a prototype which will in turn create situation for its solution as an ongoing cyclic process. The schematic diagram of the proposed DBL model is presented in Figure 3.

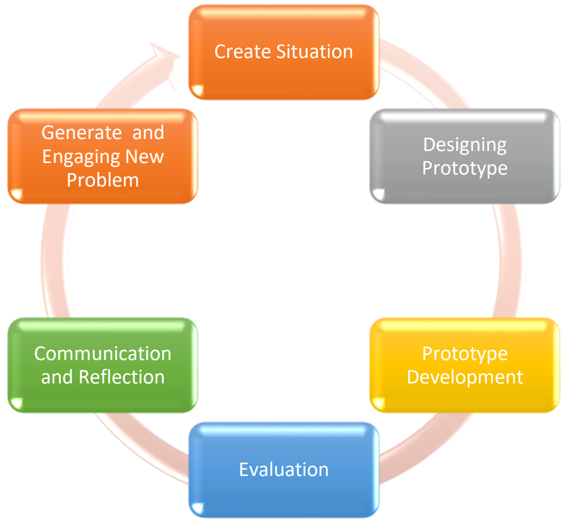

Figure 3: Modified Design-Based Learning Model with Experiential Learning Elements Embedded

It is believe that this modified version of DBL would allow pre-service teachers to interact with problems (concrete experience), reflect on their experiences, adjust their understanding, and apply new ideas (active experimentation). This iterative process enhances conceptual understanding and practical skills. Furthermore, learners will actively build new knowledge structures through hands-on design task, developing life-career skills, reduce the risk of burnout and improve academic achievement. DBL, being grounded in experiential learning principles, involves students actively engaging in design tasks that mirror real-world problems. This aligns with concrete experience in Experiential Learning Theory, where learners engage directly with the material. Through reflective observation and abstract conceptualization, students can critically think about their designs, consider theoretical implications, and relate them to academic concepts. This iterative process, where students apply their designs in active experimentation, may significantly enhance academic achievement, as students not only understand concepts but also apply and test them in practical contexts.

In Experiential Learning Theory, conceptual understanding is developed through the interaction of theory and practice. DBL provides opportunities for students to abstractly conceptualize their design ideas and then apply them through concrete experimentation. As students design and test their projects, they cycle through reflection and abstraction, deepening their understanding of core concepts. For instance, in electromagnetism, students can create projects that physically demonstrate principles like electromagnetic fields, reinforcing their theoretical knowledge through hands-on experiences, leading to stronger conceptual understanding. DBL naturally aligns with life-career skills by promoting flexibility and adaptability; initiative and self-direction; social and cross-cultural skills; productivity and accountability and leadership and responsibility highly valued in professional contexts.

Conclusion

The modified Design-Based Learning model integrated with element of the Experiential Learning Cycle has the potential to transforming education by promoting best practices, addressing learning difficulties, and contributing to sustainable development thereby foster the development of life-career skills. However, successful implementation requires a collaborative effort among stakeholders, investment in resources, and systemic changes to the curriculum. By employing these modified model, teachers can empower their students with the skills and knowledge needed to drive innovation and sustainable development in the 21st century.

Recommendation

The following recommendations are made for the successful implementation of the modified Design-Based Learning. These are:

1. A trial testing of the modified version of the DBL Model should be carried out with different level of students to determine its efficacy in the development of life-career skills.
2. Locally relevant materials should be employed and used by teachers and students in designing and developing prototype.
3. Advocacy for supportive educational policies and continuous research to evaluate the effectiveness of these approaches will help create a more inclusive and effective physics education system in Nigeria.
4. To support this innovative pedagogy in Nigeria, government and other stakeholders should invest in technological infrastructure, ensuring access to reliable internet and digital devices for both teachers and students.
5. Collaboration and effective synergy between teachers, entrepreneurs, and industry experts should be encouraged.

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