# Design-Based Learning (DBL) Under Contextual Constraints: A Framework for Form 3 Design and Technology Education in Rural Malaysia

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***Jessy Totong[a,c] and Umawathy Techanamurthy[a,b]****
*[a]Department of Engineering Education, Faculty of Engineering & Built Enviroment, Universiti Kebangsaan Malaysia (UKM), 43600 Bangi, Selangor, Malaysia*
*[b]Centre of Engineering Education (P3K), Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia*
*[c]Department of Technical and Vocational Education, Sikuati Secondary School, PO Box 355, 89058 Kudat, Sabah, Malaysia*
**t.umawathy@ukm.edu.my*

**Abstract**

Design-Based Learning (DBL) has been widely promoted as a learner-centred pedagogy that engages students in creative, hands-on, and problem-solving tasks. In Malaysia, DBL aligns closely with the Design and Technology subject (Rekabentuk dan Teknologi – RBT) introduced under the Secondary School Standard Curriculum (KSSM). However, most DBL models are often conceptualised in well-resourced environments that assume access to specialised tools and digital technologies. Limited empirical research has examined how the approach is enacted in under-resourced rural settings. This qualitative study explores how DBL is enacted, adapted, and constrained in rural school contexts in three rural secondary schools in Kudat, Sabah. Drawing on semi-structured interviews with nine RBT teachers, including three school administrators who also teach RBT, and six Form 3 RBT students, alongside document analysis, the study employed inductive thematic analysis to examine classroom realities and contextual challenges. Four interrelated themes emerged: inadequate material and infrastructural resources, tensions in integrating theory and practice, difficulties in assessing design processes, and limited professional and community support. Guided by constructivist, place-based, and social learning perspectives, these findings were interpreted to develop a contextualised DBL framework that responds to the realities of under-resourced rural settings. The proposed framework emphasises pedagogical flexibility, process-oriented assessment, and enabling support structures to support more inclusive and sustainable DBL implementation. This study contributes to the literature by extending existing understandings of Design-Based Learning through an examination of how DBL is reshaped by contextual constraints in rural and under-resourced secondary school environments. The study contributes to ongoing efforts to reduce educational inequities in line with the Malaysia Education Blueprint 2013–2025 and aligns with Sustainable Development Goals 4, 5, 9, 10, and 17 by advancing equity, innovation, and collaborative learning in underserved communities.

**Keywords**: Design-Based Learning, Design and Technology, rural education, technical and vocational education and training

## Introduction

Design-Based Learning (DBL) involves students applying theoretical knowledge to solve real-world design problems, fostering an understanding of both technical and practical skills (Clavert & Paloposki, 2015). DBL involves students working on the design of artifacts, systems and innovative solutions in project settings (Fayonto et al., 2024). This method is particularly effective in promoting deep learning and problem-solving abilities among students (Gómez Puente, van Eijck, and Jochems, 2015). Moreover, the hands-on nature of DBL projects (Radulescu et al., 2021) fosters a sense of accomplishment and satisfaction (Kasliwal et al., 2023). For example, in DBL, students actively engage in problem exploration, idea generation, prototype construction and iterative evaluation, thereby creating learning experiences that are more authentic and meaningful (Aksela and Haatainen, 2019; Kangas et al., 2021). The projects should be open-ended and multidisciplinary to encourage comprehensive learning (Gómez Puente et al., 2015), thus incorporating design thinking to foster creativity, empathy and collaborative problem solving is highly encouraged (Gómez Puente, van Eijck, & Jochems, 2013). Fried et al. (2020, 2021), for example, found that biomimicry projects enabled students to connect biological concepts with real-world problem-solving without compromising foundational theoretical understanding. Similarly, Gonzalez-Almaguer et al. (2021) demonstrated that integrating Design Thinking and Design of Experiments (DOE) strengthens students' systematic reasoning and problem-solving abilities.

Globally, DBL has shown promise in enhancing student engagement, interdisciplinary learning outcomes and development of essential 21st century skills (Aksela and Haatainen, 2019; Kangas et al., 2021; Veldhuis et al., 2022; Kasliwal et al., 2023). In this study, Design-Based Learning (DBL) is conceptualised as a learner-centred pedagogical approach characterised by authentic design challenges, iterative problem-solving processes, integration of theory and practice, collaborative learning, and process-oriented assessment, based on DBL characteristics outlined by Gómez Puente et al., (2015). This differentiates DBL from general project-based learning because DBL requires iteration, reflection, and process evidence. Moreover, in DBL, teachers act as facilitators, guiding students through the design process and helping them develop problem-solving skills (Gómez Puente et al.,2015). They provide scaffolding to support students' learning and encourage them to take ownership of their projects.

DBL seems to align closely with the aspirations of the Malaysian Secondary School Standard Curriculum (KSSM), particularly in the Design and Technology (RBT) subject. This subject was introduced in 2017. Prior to the introduction of this subject, the Living Skills (or *Kemahiran Hidup*) subject was taught from 1989 to 1991 (Transition Program) and Integrated Skills in accordance with the objectives of the Integrated Secondary School Curriculum (KBSM) from 1991 to 2016, which was then changed to the RBT subject starting in 2017 until now. The RBT subject focused on developing students' skills so that they would be more confident, selective, and productive in the world of technology, as well as instilling positive values. This subject was taught in lower secondary schools according to KBSM to replace elective subjects such as industrial arts, commerce and entrepreneurship, home economics, and agricultural science. However, RBT was introduced in 2017 to replace KHB because RBT emphasizes higher-order thinking skills (HOTS), problem-solving, innovation, and the use of the latest technology in line with the Malaysian Education Plan 2013-2025.

According to the Curriculum and Assessment Standard Document (DSKP), RBT emphasises project-based learning, product development, and the application of contemporary technologies (Ministry of Education Malaysia, 2016). The curriculum is fundamentally interdisciplinary, integrating elements of Science, Technology, Engineering, and Mathematics (STEM) with creative and reflective components, thus promoting mastery of technical skills, design, innovation and critical thinking through iterative design cycles. This marks a significant shift from traditional content-driven instruction towards a more contextual, experiential, and design-focused pedagogy.

The Form 3 RBT syllabus covers three core domains: Application of Technology (Mechatronic Design), Product Development, and Design in Business, which are purposefully aligned with the principles of Design-Based Learning (DBL) and Project-Based Learning as mandated in the KSSM curriculum. These domains operationalize the Design Cycle by engaging students in problem analysis, idea generation, conceptual design, prototype construction, testing, and documentation. The Mechatronics domain embeds DBL through activities that require students to identify system components, analyze existing mechanisms, propose design improvements, and evaluate their functionality. The Product Development domain serves as the central DBL context, guiding students through customer needs analysis, design conceptualization, production planning, product fabrication, and performance testing thereby fostering critical, creative, innovative, and entrepreneurial competencies. The Design in Business domain extends the design process into commercial relevance by requiring students to analyze marketing strategies and create promotional materials that enhance the marketability of their products. Collectively, these domains position DBL as an essential pedagogical core through which students develop authentic design, problem-solving, and evaluative capabilities within real-world contexts. Overall, the RBT curriculum articulates a clear vision for embedding DBL within secondary education and aligns closely with Malaysia's shifting technical and vocational education (TVET) agenda that is increasingly oriented towards creativity, flexibility, and technological fluency.

This study is significant because it highlights the practical realities and contextual constraints that influence the implementation of Design-Based Learning (DBL) in rural secondary schools. While DBL has been widely discussed in well-resourced educational environments, limited empirical research has examined how the approach is enacted in under-resourced rural settings such as those in Sabah. By documenting the lived experiences of teachers and students, this study provides important insights into the structural, pedagogical, and institutional challenges that shape DBL implementation in rural contexts. The findings contribute to implementation research by demonstrating how contextual factors influence pedagogical enactment and by proposing a contextualised DBL framework that can guide teachers, school leaders, and policymakers in strengthening design-based learning practices in rural Malaysian schools.

### DBL Challenges in Rural and Under-resourced Contexts

The implementation of DBL in rural schools remains far from ideal. Remote locations in Sabah are very different settings that contrast sharply with the typical Western, urban, tech-centered classroom where most educational innovations are usually tested (Mohamad et al., 2018; Pariyar et al., 2019). For example, studies show that rural schools face severe resource limitations, including outdated infrastructure and inadequate devices (Sepadi et al., 2025; Maja, 2024). Moreover, teachers often struggle with the technical complexity of integrating new technologies into their classrooms, which hinders effective integration of technology (Sepadi et al, 2025; Ndjama & Ajani, 2025) and dealing with technical issues (Ga et al., 2024). This leads to students in rural schools having fewer opportunities to engage in hands-on, real world related project, which are crucial for developing problem-solving and critical thinking (Ali & Lande, 2018). The lack of access of necessary tools and resources further limits their ability to prototype and explore collaboratively (Ayer, Leicht, & Smith, 2012). Nevertheless, encouraging students to engage in collaborative prototyping projects can improve their understanding of the design process and enhance their ability to communicate design ideas (Ali & Lande, 2018; Hansen, Eifler, & Deininger, 2021).

Similar constraints may also be evident in rural Sabah as reported by past studies. Sabah remains one of Malaysia's most underdeveloped states, particularly in terms of infrastructure, technology, and communication systems. According to Deenerwan (2024), Sabah remains one of the states with the highest concentration of underperforming districts in national examinations. Rural schools in Sabah often record lower performance levels compared to urban areas, influenced by a lack of exposure to alternative teaching methods and insufficient educational resources (Ong & Mohd Tajuddin, 2021; Deenerwan,2024; Jafar et al., 2022).

While higher education institutions nationwide are shifting toward digital and interactive pedagogies, including virtual platforms and hands-on learning models such as Design-Based Learning (DBL), schools in Sabah are expected to keep pace despite limited resources and structural disadvantages. This expectation places rural teachers and students at a disadvantage, especially in subjects like Design and Technology (RBT), where DBL requires access to digital tools, internet connectivity, and prototyping equipment. These inequities risk undermining the effectiveness of DBL and widening existing educational disparities. Thus, this research is conducted in Sabah due to the well-documented educational disparities between rural and urban regions in Malaysia, particularly in student performance and resource accessibility. Furthermore, the lack of exposure to alternative teaching methods, such as design-based learning, compounds the challenges faced by rural learners. Therefore, this study explores the unique challenges of implementing DBL in rural Sabah schools, especially in Kudat, the Tip of Borneo. This study seeks to further explore the critical need of design based pedagogical models tailored to the rural Sabah context, thereby contributing to the national goal of reducing education inequality as outlined in the Malaysian Education Blueprint 2013–2025. Moreover, little is known about incorporating local values and community needs can make learning more relevant and impactful (Mohamad et al., 2018). Thus, targeted contextual research and focused interventions are therefore essential, especially for rural schools that continue to experience systemic disadvantages.

### DBL and the RBT Curriculum in Malaysia

The Design and Technology (RBT) subject in Malaysian secondary schools seems to provide a naturally conducive ecosystem for the implementation of Design-Based Learning (DBL), as both emphasise project-based learning, technological application, and product development. However, little is known how to effectively implement DBL in rural areas. Moreover, teachers need professional development to effectively implement DBL. For example, Gómez Puente et al., 2015 suggested that training should focus on experiential learning cycles and the application of DBL frameworks. This is to ensure teachers encourage students to explore and innovate, rather than direct teaching (Clavert & Paloposki, 2015).

Another notable issue concerns teachers' mastery of technological tools and design methodologies. Research shows that the structure of the RBT curriculum which emphasises design processes, the use of technologies such as Arduino, and the development of functional products naturally corresponds with the phases of DBL (Ajit et al., 2022; Barak, 2020). Nonetheless, many teachers encounter limitations in both technical and pedagogical competencies. However, a significant number continue to rely on textbooks and express limited confidence in operating tools such as CAD software or mechatronic components. In large classroom settings, limited tools and space often require DBL activities to be organised through staggered stations or mini-sprints, a practice consistent with Barak's (2020) observations on adapting DBL for resource-constrained environments. Besides, teachers need professional development and support to effectively implement DBL (Veldhuis et al., 2022). This includes training in facilitating open-ended projects and integrating multidisciplinary activities. This is crucial as designing effective DBL projects requires careful consideration of the project's scope, complexity, and relevance to ensure they are challenging yet achievable for students.

Moreover, the open-ended and non-standardised nature of DBL assessment presents further hurdles, often leading to inconsistencies or uncertainty among teachers (Dumitrescu & Stănescu, 2022). This is due to the challenge of assessing DBL projects which can be complex, as it involves evaluating both the process and the final product (Gómez Puente et al., 2013). These issues highlight a widening gap between curricular aspirations and classroom realities, underscoring the need for enhanced teacher training and clearer assessment mechanisms. The integration of Outcome-Based Education (OBE) has been shown to enhance alignment between learning outcomes, design activities, and assessment practices (Zhang et al., 2021). The use of dual-layer rubrics one focusing on process elements (ideation, collaboration, reflection) and another on technical competency (safety, documentation) can support more equitable and formative assessment strategies (Hennessy & Mueller, 2020). Similarly, Lovejoy et al. (2021) demonstrated that interdisciplinary approaches within DBL, such as combining art and technology, enhance content connectedness and student motivation.

In terms of activity design, Huang et al. (2020) found that short DBL modules, such as sensor or actuator tasks conducted over two to three weeks, are sufficient to strengthen students' practical understanding of systems. Studies also advocate for the use of low-cost kits, locally sourced materials, and the establishment of community tool banks as medium-term strategies to address resource limitations in rural schools (Ajit et al., 2022). However, emerging evidence suggests that when DBL is contextualized to local realities, such as incorporating community-based design problems and using low-cost materials, can significantly enhance students' creative confidence and engagement (Saaya et al., 2023).Despite these challenges, research also highlights the potential of DBL to enhance student engagement, creativity and understanding of technical concepts when the approach is contextualised to the local environment (Saaya et al., 2023). Hence, there is a pressing need to develop a DBL implementation guide specifically tailored for rural schools such as those in Kudat. Such a guide must consider real constraints, local resources, cultural practices and the existing capacity of teachers and infrastructure. Beyond supporting RBT teachers in planning and conducting instruction, the guide can also assist schools, administrators and policymakers in strengthening the DBL ecosystem more systematically. Moreover, this study contributes to engineering education by demonstrating how DBL within the RBT subject can serve as an early platform for developing engineering design thinking, problem-solving, and prototyping skills among secondary school students. By contextualising DBL implementation in rural oriented classrooms, the study highlights how foundational engineering competencies can be nurtured even in resource-constrained educational environments.

## Theoretical Framework Guiding This Study

Consistent with qualitative research traditions, theoretical perspectives were used to interpret emerging themes and inform framework development rather than to predefine analytic categories or test theoretical propositions. Design-Based Learning (DBL) is a complex pedagogical approach that integrates cognitive processes, contextual conditions, and social interactions in the construction of knowledge. In rural secondary school settings, where limitations related to infrastructure, resources, and professional support are prevalent, the enactment of DBL cannot be adequately understood through pedagogical description alone. A theoretical framework is therefore necessary to support qualitative sense-making of how DBL is experienced, adapted, and constrained in practice. This study adopts a multi-theoretical framework drawing on Constructivism, Place-Based (Situated) Learning, and Social Learning Theory to guide interpretation of participants' experiences and to inform the development of a contextualised DBL framework for Form 3 RBT education in rural schools.

Design-Based Learning aligns well with constructivist principles by promoting active, collaborative, and contextually relevant learning experiences (Fitriani, Shefeld, & Koul, 2025). Moreover, the iterative nature of DBL, combined with real-world problem-solving and scaffolding, supports the constructivist view that knowledge is actively constructed through meaningful engagement and social interaction (Clavert & Paloposki, 2015; Asrifan et al., 2025). This alignment enhances learning outcomes, critical thinking, and professional development, preparing learners for future challenges (Clavert & Paloposki, 2015; (Özüdoğru, 2025). Within the RBT context, DBL enables theoretical concepts to be embedded within hands-on design tasks, supporting meaningful integration of theory and practice.

Next, place-based and situated learning theories emphasise that learning is inherently shaped by the physical, social, cultural, and material contexts in which it occurs (Lave & Wenger, 1991; Sobel, 2004), Lave and Wenger (1991) and Sobel (2004) emphasise that learning is shaped by participation in authentic practices and local contexts. Moreover, Arvaja (2007) found that different backgrounds and contextual resources influence how students create and interpret context, negotiate meanings, and engage in knowledge construction activities.

In addition, Social Learning Theory (SLT) by Bandura (1986) highlights that learning occurs through observation, imitation, and modeling. It posits that people can learn new behaviors and skills by observing others, which involves attention, retention, reproduction, and motivation (Saka, 2024). These steps are interrelated and collectively influence learning. Consequently, teachers who adopt SLT should design instruction with these stages in mind, recognise their role as behavioural models, and intentionally structure learning environments that sustain learners' attention, support memory retention, facilitate behavioural reproduction, and enhance motivation. This principle is crucial in DBL, where students often learn by observing instructors or peers demonstrating design processes and technique (van Diggelen et al., 2021). Teachers act as models and provide the necessary support to help students progress through their design projects (van Diggelen et al., 2021). DBL requires teachers to adopt facilitative roles and develop new pedagogical and technical competencies, which can be challenging in rural contexts where access to professional development and peer support is limited. From a social learning perspective, sustained DBL implementation depends on collaborative support structures such as professional learning communities, school leadership involvement, and community partnerships. In this study, social learning theory informs interpretation of findings related to limited professional and community support, reinforcing the view that DBL enactment is a collective endeavour rather than an individual teacher responsibility. Thus, taken together, constructivism, place-based learning, and social learning theory provide a complementary framework for interpreting DBL implementation in rural RBT classrooms. Constructivism explains how learning occurs through active engagement, iteration, and reflection; place-based learning explains how local contexts and resources shape pedagogical enactment; and social learning theory explains how collaboration and institutional support mediate practice. These theoretical perspectives guided interpretation of the study's findings and informed the development of the contextualised DBL framework proposed in this research. Consistent with qualitative research traditions, these theories were employed as interpretive lenses to support sense-making of participants' experiences rather than as prescriptive frameworks to predetermine categories or test theoretical propositions.

This study addresses the following research question:
*(i) What are the critical challenges and contextual needs for implementing Design-Based Learning in Form 3 RBT education in rural Kudat, and (ii) how can a conceptual framework be developed to support its effective enactment?*

Accordingly, the research question is framed to explore the processes, challenges, and contextual needs associated with DBL enactment, rather than to measure outcomes or implementation fidelity. Rather than evaluating the effectiveness of DBL, this study adopts an interpretive qualitative approach to capture in-depth perspectives of teachers and students and to explore how Design-Based Learning is enacted and experienced within the contextual realities of rural secondary school settings. Thus, by examining the experiences of teachers, students and school administrators in Kudat, this study aims to design a pedagogical guide for implementing DBL in Form 3 RBT in Kudat, drawing on qualitative findings from teachers, students and school administrators. This initiative is expected to help close the gap between curriculum aspirations and classroom realities, while supporting the objectives of the Malaysia Education Blueprint (PPPM) 2013–2025 and contributing to Sustainable Development Goal 4, which emphasises quality, inclusive and equitable education.

## Conceptual Framework of Design-Based Learning Implementation in rural school contexts

Design-Based Learning (DBL) is described through pedagogical models that emphasise iterative design processes, problem solving, and authentic learning. Gómez Puente, et.al (2015) propose a widely recognised framework that structures DBL around several design phases, including problem analysis, idea generation, prototype development, testing, and evaluation. Together, these stages support conceptual understanding while also developing practical design skills.

In Design and Technology (RBT) education, this framework aligns closely with the Malaysian curriculum, where students analyse problems, generate ideas, construct prototypes, and evaluate product functionality. The iterative process allows theoretical knowledge to connect with hands-on activities, making learning more meaningful through authentic design tasks.

However, many DBL frameworks assume well-resourced environments with advanced technologies and specialised facilities. Thus, drawing on the literature on Design-Based Learning (DBL), rural education, and contextualised pedagogical practices, this study proposes a conceptual framework to guide the investigation of DBL implementation in rural RBT classrooms. See Figure 1.

The framework integrates insights from prior research with the contextual realities of rural secondary schools to examine how teachers and students experience, adapt, and respond to DBL practices. It also provides a structured lens for analysing current teaching practices, implementation challenges, and the needs of teachers and students in resource-constrained environments. By synthesising these elements, the framework guides the identification of contextualised strategies for DBL implementation and supports the development of a pedagogical guide tailored to rural Design and Technology education. The framework begins with rural school contextual conditions, which represent the environmental and structural factors influencing teaching and learning in rural settings, including limitations in infrastructure, resources, and technological access.

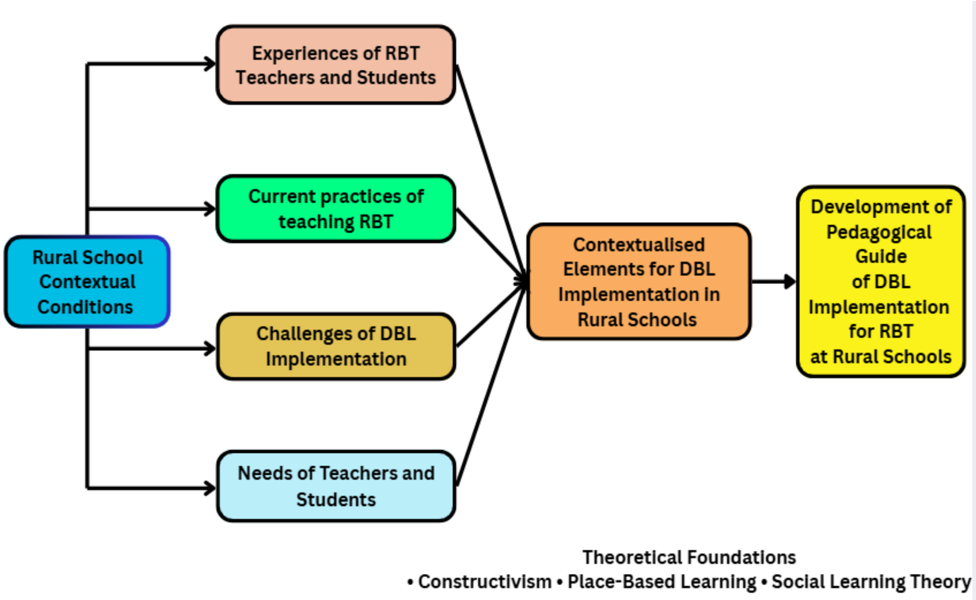


**Figure 1. Conceptual framework**

Within this context, the study explores four key dimensions derived from teachers' and students' perspectives: experiences of RBT teachers and students, current practices of teaching RBT, challenges of DBL implementation, and the needs of teachers and students. These dimensions represent the primary sources of empirical insights gathered through interviews and document analysis.

The findings from these dimensions are synthesised to identify contextualised elements for DBL implementation in rural schools, which reflect practical strategies and pedagogical approaches suited to rural learning environments. These elements ultimately will inform the development of a pedagogical guide for DBL implementation in RBT classrooms, aimed at supporting teachers in implementing design-based learning effectively in rural secondary schools (which is not covered in this study).

## Methodology

### *Research Design*

This study employed a qualitative research design to explore the key challenges faced by nine RBT teachers, including three school administrators who also teach Form 3 RBT and six Form 3 RBT students (15-year-olds) who have taken this subject since they were in Form 1(13 years old). The qualitative approach was selected to enable an in-depth examination of how teachers and students experience, interpret and make sense of DBL within environments characterised by limited resources, restricted access to technology, and various infrastructural constraints. This research design provides flexibility to investigate the complex issues surrounding DBL implementation in rural RBT classrooms, including inadequate facilities, financial and material constraints, contextual suitability, and levels of student engagement.

### *Participants*

Participants were purposively selected based on their direct involvement in the teaching, administration, and learning of Form 3 Design and Technology (RBT), ensuring that multiple perspectives on DBL enactment could be captured (Table 1). The participants of this study consisted of the Heads of TVET Program at schools who also teach RBT and RBT teachers who had experience teaching RBT subjects between 2 to 8 years in rural secondary schools in Kudat. This sample helps to understand the challenges teachers face at various levels from multiple perspectives, thus providing richer data.

**Table 1. Participants Head of TVET and RBT Secondary School Teacher**

| Pseudonyms | Category | School | Sex | Overall Teaching Experience (years) | Years of Experience Teaching RBT |
|---|---|---|---|---|---|
| Sari | (TVET Programme Head) | 1 | F | 28 | 8 |
| May | (TVET Programme Head) | 2 | F | 11 | 8 |
| Won | (TVET Programme Head) | 3 | M | 17 | 2 |
| Ken | RBT Teacher | 3 | M | 9 | 8 |

| | | | | | |
|---|---|---|---|---|---|
| Jamal | RBT Teacher | 3 | M | 15 | 8 |
| Maria | RBT Teacher | 1 | F | 28 | 8 |
| Massa | RBT Teacher | 1 | F | 28 | 8 |
| Kaya | RBT Teacher | 2 | M | 2 | 2 |
| Minah | RBT Teacher | 2 | F | 18 | 6 |

In addition to the teachers, we also interviewed six rural secondary school students studying in three rural secondary schools in Kudat who studied RBT subjects from form 1 to form 3 (Table 2). This is to gain a deeper understanding of the challenges and requirements in the implementation of DBL for form 3 RBT subjects in the schools involved.

**Table 2. Participants Head of TVET and RBT Secondary School Teacher**

| Pseudonyms | School | Sex | Age | Years of Experience Learning RBT |
|---|---|---|---|---|
| Kay | 1 | F | 15 | 3 |
| Glo | 1 | F | 15 | 3 |
| Jel | 2 | M | 15 | 3 |
| Joe | 2 | F | 15 | 3 |
| Syed | 3 | M | 15 | 3 |
| Zani | 3 | F | 15 | 3 |

*Data Collection*

This study was conducted using a qualitative approach. Semi structured interviews were conducted with RBT teachers and students taking RBT to find out about current teaching practices, challenges faced in the implementation of Design-Based Learning (DBL) and critical needs to overcome the challenges faced. In addition, interviews with school administrators who were also RBT teachers were also conducted to understand the perspective of the school leadership on the challenges of DBL implementation as well as to identify the needs to improve the implementation of DBL. Semi-structured interviews were used to elicit participants' experiences and perceptions of DBL implementation. The interview sessions were conducted at the school, after school hours and each session lasted approximately 30 minutes. Data collection continued until thematic saturation was reached, whereby no substantively new insights emerged from additional interviews. All interviews were audio recorded and transcribed verbatim to ensure the accuracy of the transcription process and data analysis. Next, document analysis of lesson plans, RBT project logs and student work, and curriculum documents provided contextual and informal observation of instructional evidence was used to support data triangulation. Trustworthiness of the findings was enhanced through data triangulation across teachers, students, and documents, systematic analytic procedures, and the use of verbatim excerpts to support transparency and confirmability. Ethical considerations included informed consent, confidentiality through the use of pseudonyms, and sensitivity to participants' professional and learning contexts.

*Pedagogical Process of DBL Implementation*

Within the participating schools, Design-Based Learning (DBL) activities followed an iterative design process aligned with the principles of the RBT curriculum. The pedagogical process typically involved several interconnected stages. First, students engaged in problem analysis, where they identified real-world design problems related to everyday needs or community contexts. This stage involved brainstorming sessions, needs identification, and discussion of possible design directions. Second, students proceeded to idea generation and conceptual design, where they developed sketches, proposed solutions, and discussed alternative design ideas with peers and teachers. Third, students engaged in prototype development, during which they constructed physical or digital prototypes using available materials such as recycled resources, basic workshop tools, or low-cost kits. Fourth, prototypes were subjected to testing and evaluation, where students examined the functionality, durability, and effectiveness of their designs. Finally, students documented their design process through design logs, sketches, reflections, and reports, which provided evidence of iterative learning and design improvement. This pedagogical process allowed theoretical concepts from the RBT curriculum to be integrated with hands-on design activities, thereby reflecting the iterative and experiential nature of Design-Based Learning.

*Data Analysis*

The audio-recorded interviews were transcribed verbatim and subsequently analysed using thematic analysis, a widely adopted qualitative method that enables the identification of patterns, themes, and categories within the data (Braun & Clarke, 2021). During the analysis process, all interviews were transcribed word-for-word to ensure accurate representation of participants' responses. The transcripts were then coded, and the codes were organised into themes based on similarities and conceptual relationships. Thematic analysis was conducted inductively to allow patterns and themes to emerge from the data, after which constructivism, place-based learning, and social learning theory were applied at the interpretive stage to deepen understanding of the findings and inform the development of the contextualised DBL pedagogical guide. Furthermore, thematic analysis allowed for a comprehensive understanding of participants' lived experiences, offering rich insights into the challenges faced by teachers and students in implementing DBL for the Form 3 RBT subject in rural secondary schools, as well as the specific needs required to strengthen DBL practices in such contexts by experienced DBL practitioners. Through this approach, the study generated a holistic understanding of DBL implementation in rural areas.

## Findings and Discussion

This section presents and interprets the findings derived from interviews with RBT teachers, school administrators and Form 3 RBT students from three rural secondary schools in Kudat, Sabah. Using inductive thematic analysis, four interrelated themes were identified that reflect how Design-Based Learning (DBL) is enacted, adapted, and constrained in rural school contexts. The themes reflect material, pedagogical, assessment-related, and systemic conditions that shape DBL practice. Rather than treating these themes as isolated barriers, the discussion interprets them through constructivist, place-based, and social learning perspectives to explain how contextual realities influence DBL implementation and to inform the development of a contextualised DBL framework.

*Theme 1: Resource Constraints and Contextual Adaptation of DBL*

Findings indicate that limited workshop facilities, outdated equipment, and restricted access to materials significantly shape how DBL is enacted in rural RBT classrooms (Table 3). From a place-based and situated learning perspective, these constraints should not be viewed solely as deficiencies, but as contextual conditions that define the boundaries within which learning occurs. DBL models are often conceptualised in well-resourced environments that assume access to specialised tools and digital technologies. In contrast, teachers and students in this study described the need to modify project ideas, delay activities due to shared equipment, and rely on low-cost or recycled materials to complete design tasks.

These adaptations illustrate how DBL is recontextualised rather than abandoned in rural settings. Teachers actively adjusted design activities to align with locally available resources, reflecting situated learning principles where meaning-making emerges through engagement with familiar tools and materials. However, such adaptations were often constrained by systemic issues, including inflexible funding structures and curriculum expectations that do not adequately account for rural disparities. This finding extends existing DBL literature by demonstrating that resource constraints reshape the form and depth of design activity, reinforcing the need to conceptualise DBL as a flexible pedagogy whose authenticity is grounded in contextual relevance rather than technological sophistication.

**Table 3. Recommendations based on Theme 1: Limited Workshop Facilities and Inadequate Infrastructure**

| Sample Excerpt | Recommendations |
|---|---|
| "The RBT workshop still uses Kemahiran Hidup subject's equipment... many machines are also damaged... the equipment used to produce products is limited..." (Tcr. Ken, L85–95)<br><br>"…The equipment is indeed insufficient, so many activities cannot be carried out... if you get into the topic of coding, without a computer and the internet, it cannot be implemented." (Tcr. Jamal, L70–80)<br><br>"The main difficulty is the lack of materials in the RBT workshop... the original project idea had to be changed." (Glo, L46–54)<br><br>"We have to wait our turn to use the equipment... the process of preparing the project is slow.." (Kay, L55–60) | Improve workshop facilities and provide minimum basic equipment every year.<br><br>Establish a community tool bank with the Parent Teacher Association/ community.<br><br>Use low-cost DBL kits and alternative materials.<br><br>Arrange a workshop schedule to minimize congestion.<br><br>Integrate design activities using local materials and do-it-yourself projects/ kits. |

*Theme 2: Financial Constraints and the Scope of Design Activity*

Closely linked to infrastructural limitations were financial constraints arising from limited per capita grant allocations, which restricted schools' ability to procure materials and technologies required for DBL projects. This was due to the insufficient PCG allocation (RM6 per student) limits the ability to purchase materials, tools, and technology required for DBL projects. Projects often must be simplified or conducted using recycled materials Teachers reported having to simplify design tasks, reduce the number of projects conducted, or substitute intended materials with recycled alternatives. Students similarly expressed that insufficient materials affected their ability to fully execute design ideas (Table 4).

From a place-based learning perspective, these financial constraints further highlight how local resource ecosystems shape pedagogical enactment. While the use of recycled materials and small-scale projects reflects adaptive practice, persistent funding limitations risk narrowing the scope of design experiences and reducing opportunities for iterative experimentation. Rather than reflecting pedagogical inadequacy, these constraints point to structural inequities embedded within funding models that disadvantage rural schools. This finding underscores the importance of school–community collaboration and external support mechanisms as mediating strategies that can expand the material affordances available for DBL without compromising contextual authenticity.

**Table 4. Recommendations based on Theme 2: Limited Funding and Financial Constraints**

| Sample Excerpt | Recommendations |
|---|---|
| "Only one 3D printer can be purchased using PCG... not all students can use it... it takes 3 days to complete one product.." (Tcr. Ken, L100–110)<br><br>"Epoxy resin is too expensive... RM50 for 1 liter... cannot afford to buy it all the time..." (Tcr. Jamal, L115–120)<br><br>"There are many projects, but the budget is insufficient... can only do one DBL project per class..." (Tcr. May, L145–150)<br><br>"We do not have enough materials... we cannot properly execute the project..." (Joe, L60–65)<br><br>"If tools are not available, you have to change the original idea... use recycled materials." (Zani, L51–52) | - Apply for external grant (CSR of Corporate Companies, District Education Office, STEM NGOs).<br>Using a small-scale but meaningful project model.<br><br>Systematically utilize recycled materials & community resources.<br><br>Train teachers to plan low-cost DBL.<br><br>Encourage school-community collaboration for material sponsorship. |

*Theme 3: Integrating Theory and Practice in DBL Instruction*

Another prominent theme concerned difficulties in balancing theoretical instruction with hands-on design activities. Teachers described challenges in allocating sufficient time for practical work due to syllabus demands, large class sizes, and limited access to equipment. As a result, DBL activities were sometimes positioned as supplementary to theory-heavy instruction rather than as the central mode of learning. Students, however, consistently expressed greater engagement and understanding when involved in practical, design-oriented tasks (Table 5).

From a constructivist perspective, this tension reflects a misalignment between DBL's emphasis on learning through active engagement and traditional instructional practices that prioritise content transmission. Constructivism posits that conceptual understanding is constructed through experience and reflection, suggesting that theory is most meaningful when embedded within design activity. The findings therefore indicate that challenges in integrating theory and practice are not simply a matter of teacher preference or skill but are shaped by structural conditions that limit opportunities for sustained design engagement. Addressing this tension requires pedagogical strategies that embed theoretical concepts within design tasks, as well as systemic support that allows DBL to function as a core instructional approach rather than an add-on.

**Table 5. Recommendations based on Theme 3**

| Sample Excerpt | Recommendations |
|---|---|
| "The topic of RBT (*Reka Bentuk dan Teknologi*) has many theories... so the DBL (Design Based Learning) activity becomes just an additional activity." (Tcr. Massa, L25–35)<br><br>"I use a two-in-one approach... the theory goes into the project once..." (Tcr. May, L60–70)<br><br>"Sometimes bored because busy listening to the teacher explain the concepts..." (Jel, L40–45)<br><br>"It was fun to work on a 3D project... more understanding and creative." (Zani, L60–65) | Integrating theory into design activities (embedded theory).<br><br>Using micro-prototyping to save time and cost.<br><br>Providing DBL lesson templates for teachers.<br><br>Increasing teacher training in theory practice integration.<br><br>Using digital simulation if physical materials are insufficient. |

The excerpts presented in Table 5 illustrate how teachers experience tension in balancing theoretical instruction and hands-on design activities. For example, Teacher Massa explained that the theoretical content within the RBT syllabus often requires substantial instructional time, which consequently reduces opportunities for extended design activities. This suggests that DBL is sometimes positioned as an additional activity rather than the central pedagogical approach. Similarly, Teacher May described using a “two-in-one” approach in which theoretical explanations are embedded within project tasks. This strategy reflects teachers’ attempts to reconcile curricular demands with DBL principles. Student responses further reinforce this theme. While some students expressed boredom when lessons were dominated by teacher explanations, they reported higher engagement when participating in design projects. Taken together, these excerpts indicate that the challenge lies not merely in teacher preferences but in structural constraints such as time allocation, curriculum demands, and limited workshop access, which shape how theory and practice are integrated in DBL instruction.

*Theme 4: Assessment Practices and Process-Oriented Learning*

Assessment emerged as a critical challenge in DBL implementation, with teachers often relying on final products as the primary basis for evaluation due to time constraints, large class sizes, and the absence of structured assessment tools. Teachers experience difficulty assessing DBL holistically due to time constraints, large class sizes, and lack of structured rubrics. Assessment often focuses on the final product rather than the entire design process (ideation, iteration, teamwork, reflection). Students feel their effort throughout the process is not fairly evaluated.

Students perceived this emphasis as inequitable, as their effort, iteration, and problem-solving throughout the design process were not consistently recognised. From a constructivist learning perspective, product-focused assessment conflicts with DBL’s process-oriented philosophy, which values ideation, experimentation, collaboration, and reflection as integral components of learning. The findings suggest that assessment challenges are rooted in systemic misalignments between DBL pedagogy and prevailing assessment cultures that prioritise efficiency and observable outcomes. In resource-constrained rural contexts, these misalignments are further intensified, potentially undermining DBL’s transformative potential. Process-oriented assessment strategies, such as design checkpoints, reflection journals, and simplified rubrics, offer practical pathways to align assessment with DBL principles while remaining feasible within existing constraints (Table 6).

**Table 6. Recommendations based on Theme 4**

| Sample Excerpt | Recommendations |
|---|---|
| “Time is not enough, so I assess what can be seen... I evaluate the student's product achievements and effectiveness... Is the product durable... and the finish” (Tcr. Ken, L150–160)<br><br>“I also look at the reports and functions, but in the end I still look at the final result... that's the easiest to evaluate.” (Tcr. Jamal, L165–175)<br><br>“We tried to assess from the beginning,the idea, sketches, the process of making..but when there are many students, there is no time to observe everything..” (Pn. Sari, L180–190)<br><br>“We have been trying from the beginning... but the teacher only looks at the final result. It feels like a waste of effort... we have to change a lot of times because it doesn't work..” (Joe, L80–85)<br><br>“Sometimes creative ideas are not valued... the teacher only monitors to avoid missteps.” (Glo, L90–95) | Developing a DBL Process Rubric (idea → sketch → prototype → reflection).<br><br>Incorporating formative assessment such as reflection journal, logbook, sketches and process videos.<br><br>Using individual + team rubrics to ensure fairness. Implementing mini checkpoints at each design phase to address time constraints.<br><br>Providing training to teachers on process-based & evidence-based assessment.<br><br>Utilizing simple technology like Google Forms to record the process. |

*Theme 5: Professional and Community Support as Enabling Conditions*

This theme highlights the role of sustained professional development and community engagement as critical enabling conditions for effective Design-Based Learning (DBL) implementation in rural secondary schools. The findings indicate that continuous teacher training, professional learning communities (PLCs), and collaboration with local stakeholders are essential to compensate for limited resources, facilities, and expertise commonly faced in rural contexts. Limited professional development opportunities and community support were identified as additional factors constraining DBL sustainability.

Social learning theory provides a lens to interpret these findings, emphasising that learning and innovation are socially mediated processes supported through collaboration and shared practice. DBL requires teachers to adopt facilitative roles and develop new pedagogical and technical competencies, which can be difficult to sustain in rural contexts where teachers often work in isolation. The findings indicate that DBL enactment depends not only on individual teacher effort, but also on meso-level support structures such as school leadership, professional learning communities, and partnerships with parents and local organisations. Initiatives such as community tool banks and collaborative planning reflect social learning principles by distributing expertise and resources across a broader educational ecosystem. This interpretation extends existing DBL research by foregrounding the importance of collective and institutional responsibility in sustaining pedagogical innovation in under-resourced settings (Table 7).

**Table 7. Recommendations based on Theme 5**

| Sample Excerpt | Recommendations |
|---|---|
| "If there are DBL courses and PLCs, teachers will be more prepared and can share experiences and ideas." (Teacher Joliwin, L200–205)<br><br>"With more frequent DBL training, teachers can implement DBL with greater confidence." (Teacher Jamalit, L190–195)<br><br>"Design-based learning can be more effective when teachers collaborate with the community." (Expert Tony, L85–90) | Provide continuous, practice-oriented professional development on DBL tailored to rural RBT teachers.<br><br>Strengthen Professional Learning Communities (PLCs) at district and state levels to facilitate peer support and sharing of best practices.<br><br>Foster partnerships with local communities, small industries, NGOs, and educational agencies to support materials, expertise, and contextualised DBL projects.<br><br>Integrate community and professional support into a sustainable ecosystem for DBL implementation in rural schools. |

Taken together, the findings demonstrate that DBL implementation in rural RBT classrooms is shaped by the interplay of contextual constraints, pedagogical practices, assessment norms, and support structures. Constructivism explains the importance of active, process-oriented learning; place-based learning highlights how local material and financial conditions shape pedagogical enactment; and social learning theory underscores the role of collaboration and institutional support in sustaining practice. These perspectives informed the development of the contextualised DBL framework proposed in this study.

Based on the findings of this study, the DBL implementation can be contextualized as a layered and adaptive process that begins with contextual realities and is mediated by enabling support structures. Rather than assuming ideal conditions, it reframes constraints as design parameters and emphasises pedagogical flexibility, process-oriented assessment, and collective responsibility. In doing so, the framework extends existing DBL models by offering a theoretically informed and empirically grounded approach for supporting inclusive and sustainable DBL enactment in rural secondary school contexts.

Figure 2 presents a contextualised Design-Based Learning (DBL) framework derived from the study's qualitative findings and informed by constructivist, place-based, and social learning perspectives. The framework conceptualises DBL enactment as a nested and adaptive process shaped by contextual conditions in rural schools. Rather than assuming ideal instructional settings, contextual constraints form the outer conditions within which pedagogical practice occurs. Enabling support structures mediate between these conditions and classroom practice, influencing how the core DBL pedagogical process is enacted. Learning outcomes are understood as emergent rather than guaranteed, reflecting the interaction between context, support structures, and iterative design-based learning processes.

Recognising contextual limitations enables DBL to be reframed as a flexible pedagogy rather than a resource dependent approach, particularly in rural and under resourced settings. Recent studies emphasise that instructional effectiveness is strongly shaped by alignment between pedagogy, learner characteristics, and available resources, rather than by technology alone (Nik Abdul Majid et al., 2025). A key contribution of the framework lies in its emphasis on enabling support structures as mediating mechanisms between constraints and pedagogical practice. Resource adaptation, professional learning, and curriculum flexibility collectively enhance teachers' capacity to enact DBL in constrained contexts. This shift foregrounds systemic and institutional responsibility, rather than relying solely on individual teacher agency. Evidence from rural education contexts indicates that sustained pedagogical innovation requires structured professional development and organisational support, particularly where access to resources is limited (Daminar & Galusan, 2025). At the core of the framework, the DBL pedagogical process reinforces constructivist and experiential learning principles by prioritising iteration, reflection, and problem solving within authentic contexts. From a constructivist perspective, challenges related to balancing theoretical instruction with practical activities and assessing

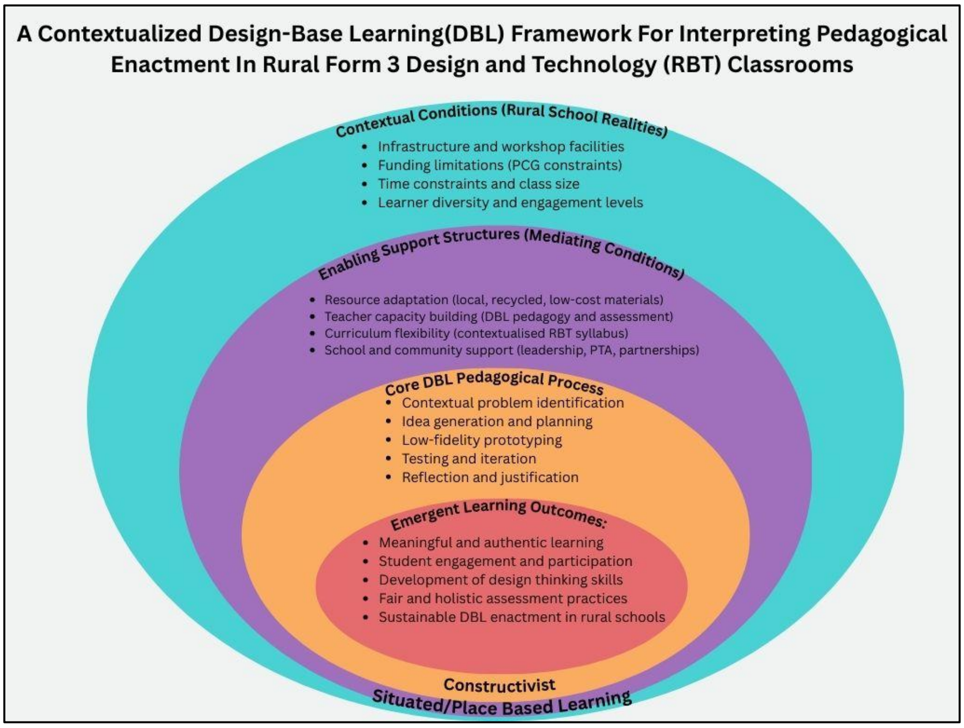


**Figure 2. A Contextualised Design-Based Learning (DBL) Framework for Interpreting Pedagogical Enactment in Rural Form 3 Design and Technology (RBT) Classrooms**

learning beyond final products reflect tensions between traditional instructional practices and process-oriented learning. Constructivism therefore provides a lens to interpret the importance of iteration, reflection, and formative assessment in supporting students' learning journeys within DBL environments.

Importantly, the findings demonstrate that effective DBL does not depend on sophisticated technology. Meaningful learning can occur through low fidelity prototyping, locally available materials, and community relevant design challenges. This might seem counterintuitive. Still, recent research in rural learning environments similarly shows that students demonstrate stronger engagement when learning activities are hands on, contextualised, and connected to their lived experiences (Tagare et al., 2026).

In rural secondary schools in Sabah, DBL implementation is strongly affected by limited workshop facilities, restricted funding, and reduced access to digital technologies. This theoretical perspective frames such constraints not simply as deficits, but as contextual conditions that shape how DBL can be meaningfully enacted. The use of locally available materials, recycled resources, and community-relevant design problems reflects situated learning principles and supports the enactment of authentic DBL despite resource limitations. Place-based learning thus legitimises pedagogical adaptation and contextual alignment in rural DBL practice.

The framework's focus on expected outcomes extends beyond technical skill acquisition. By foregrounding process oriented assessment, it values students' learning journeys, collaboration, and reflective thinking. In a way, this addresses persistent concerns regarding product focused evaluation, which can disadvantage learners in resource constrained contexts. Process based assessment has been shown to support more equitable learning opportunities by recognising diverse forms of participation and progress, particularly in heterogeneous and rural classrooms (Nik Abdul Majid et al., 2025).

From a policy and sustainability perspective, the framework aligns with several Sustainable Development Goals. It supports SDG 4 (Quality Education) by promoting inclusive and equitable learning opportunities for students in rural settings. It also contributes to SDG 9 (Industry, Innovation and Infrastructure) through the development of adaptable design thinking and innovation skills. In addition, by encouraging the use of local and recycled materials in learning activities, the framework aligns with SDG 12 (Responsible Consumption and Production), reinforcing sustainability principles within everyday pedagogical practice.

The recommendations presented in Tables 3–7 were derived through an iterative analytic process during thematic analysis. After identifying key themes related to resource constraints, financial limitations, pedagogical integration, assessment challenges, and support structures, the researchers examined patterns across teacher and student responses to identify potential strategies suggested implicitly or explicitly within the data. For example, teachers frequently described adapting DBL activities using recycled materials and simplified projects, which informed recommendations related to low-cost design kits and community resource utilisation. Similarly, teachers' reported difficulties in assessing design processes led to recommendations concerning process-oriented rubrics and formative assessment checkpoints. Thus, the recommendations were not externally imposed but emerged inductively from participants' experiences and were further interpreted through the theoretical lenses of constructivism, place-based learning, and social learning theory.

## Conclusion

This study examined how Design-Based Learning (DBL) is enacted within the contextual realities of under resourced, rural secondary schools offering Form 3 Design and Technology (RBT) in Kudat, Sabah. Through an interpretive qualitative approach, the findings reveal that DBL implementation in rural contexts is shaped by an interrelated set of material, pedagogical, assessment-related, and systemic conditions. While teachers and students demonstrate strong awareness of DBL's process-oriented and experiential learning principles, persistent constraints related to infrastructure, funding, instructional time, assessment practices, and professional support significantly influence how DBL is enacted in practice.

This study highlights several substantive challenges that affect the implementation of Design-Based Learning (DBL) in rural secondary schools in Kudat. The findings indicate that limitations in teacher professionalism, inadequate infrastructure, contextual constraints related to students and the wider community, as well as the inherent pedagogical complexities of DBL, collectively hinder its effective enactment in RBT classrooms. Nevertheless, the study also demonstrates that DBL holds strong potential when it is contextualised to local realities particularly through the use of community-based problem scenarios, low-cost materials, and design tasks that resonate with rural livelihoods. Importantly, the study has developed a conceptual framework and a set of guiding principles for implementing DBL in rural contexts, grounded in Constructivism, Place-Based Education, and Social Learning Theory. The findings also extend engineering education literature by illustrating how pedagogical approaches commonly used in engineering design education, such as iterative design, prototyping, and reflective evaluation, can be adapted to secondary education. In doing so, the study positions rural RBT classrooms as an important entry point in the engineering education pipeline that fosters early engineering thinking and innovation skills. This framework offers practical direction for teachers, school leaders, and policymakers seeking to strengthen equitable, meaningful, and context-responsive engineering design education in rural Malaysia. It also provides a foundation for future efforts to enhance DBL implementation in ways that better reflect the unique needs, assets, and lived experiences of rural learners.

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## Conflict of Interest

The authors declare no conflict of interest

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