

9-2025

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Awang Mohamad, Awang Najib; Nordin, Zaimuariffudin; and Hashim, Mohd Hafizan (2025) "Exploring Design-Based Research: Enhancing Methodologies for Educational Innovation," *Journal of Research Initiatives*: Vol. 9: Iss. 1, Article 3.

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Keywords

Design-based research, Educational Methodologies, Conjecture Mapping

Cover Page Footnote

The authors would like to express their sincere appreciation to Universiti Malaysia Sarawak (UNIMAS) for the academic support provided during the preparation of this manuscript. We also thank the colleagues and reviewers whose constructive feedback contributed to improving the quality of this paper.



Exploring Design-Based Research: Enhancing Methodologies for Educational Innovation

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Abstract

Design-based research (DBR) has proven to be a robust methodology for transforming educational practice through a systematic cycle of analysis, design, development, and real-world implementation. Its distinctive strength lies in fostering close collaboration between researchers and educators within authentic learning contexts, producing design principles and theories that are deeply responsive to local needs. This paper presents a critical and comprehensive examination of the three core phases of the McKenney and Reeves (2012) generic DBR model, illustrating how it integrates rigorous inquiry with practical problem-solving. It also introduces Sandoval's (2014) concept of conjecture mapping as a strategic tool for aligning theoretical assumptions with design decisions, thereby strengthening the explanatory power of DBR studies. The discussion is grounded in three diverse applications of DBR in educational technology, including blended learning in higher education, computational thinking in elementary science, and digital escape rooms in medical education, showcasing how iterative, context-sensitive design can generate both practical innovations and theoretical insights.

Introduction

Design-based research (DBR) methodology employs a structured process designed to enhance educational practices through repeated cycles of analysis, design, development, and implementation. It relies on collaboration between researchers and practitioners in authentic environments to generate design principles and theories that are responsive to specific contexts (McKenney & Reeves, 2018; Parmaxi & Zaphiris, 2020). DBR is particularly appropriate for addressing open or "wicked problems," which is a term introduced by design theorists to describe situations involving complex and interdependent variables where the starting points, desired outcomes, or the means to transition between them are either unknown or ill-defined (Reinking, 2021; Waddell, 2015).

Furman Shaharabani and Yarden (2019) identified four categories of criticism related to research in the education field, highlighting the gap between educational research and practice. The category list includes: i) educational research yields only a few conclusive results, ii) educational research yields only a few practical results, iii) practitioners believe that educational research is not conclusive or practical, and iv) practitioners make only little (appropriate) use of educational research. With the adoption of DBR, it not only sheds light on the variables within authentic educational settings but also documents the outcomes arising from multiple iterations of diverse intervention approaches (Di Biase, 2020).

Key Concepts of DBR

DBR is an educational approach that emphasizes the active involvement of learners in the process of designing, developing, and evaluating solutions to complex, real-world problems or challenges (Handyside, 2016). Rooted in both theory and practice, DBR seeks to bridge the gap between research and classroom implementation by promoting collaborative innovation within authentic learning environments. Rather than isolating learning within controlled settings, DBR integrates pedagogical inquiry with practical experimentation, allowing both researchers and participants to co-construct knowledge through iterative cycles of design and analysis.

This approach is commonly employed in disciplines such as science, technology, engineering, and mathematics (STEM), where problem-solving, experimentation, and design thinking are integral. However, the principles of DBR are not limited to STEM. They are equally applicable to fields such as social sciences, humanities, and education, where researchers aim to improve learning practices and outcomes through context-sensitive interventions. By situating research within real educational contexts and involving multiple stakeholders, including students, teachers, and curriculum designers, DBR facilitates the development of sustainable, theory-informed solutions to complex educational issues. The following are some of the key concepts that underpin the DBR methodology:

a) Problem-Solving

DBR focuses on real-world problems or challenges that students need to address. Researchers are encouraged to identify, analyze, and solve these problems using a combination of critical thinking, creativity, and technical skills.

b) Hands-On Experience

Students engage in hands-on activities and projects that are designed and built by researchers to test solutions. The data on hands-on experience allows researchers to apply theoretical knowledge in practical ways.

c) Iterative Process

DBR often involves an iterative process where researchers refine and improve their designs through multiple cycles of prototyping, testing, and redesigning. This iterative approach encourages experimentation and learning from failures.

d) Collaboration

Collaboration is a key component of design-based learning. Researchers often work in teams to tackle complex problems, allowing them to share ideas, pool resources, and benefit from diverse perspectives.

e) Authentic Context

DBR strives to create authentic learning contexts that mimic real-world challenges and situations. This helps researchers to identify problems for intervention and practical solutions in future learning.

f) Reflection

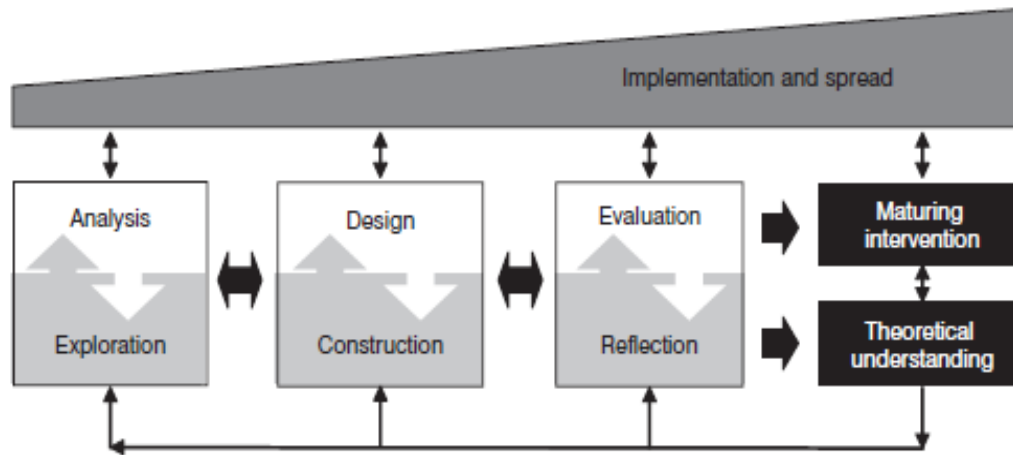
Researchers are encouraged to reflect on their design process, consider the implications of their decisions, and evaluate the effectiveness of their solutions. This reflective component promotes metacognition and deeper understanding.

g) Multidisciplinary Approach

DBR often integrates knowledge and skills from multiple disciplines. It encourages researchers to draw from various fields to develop comprehensive solutions.

McKenney & Reeves DBR Model

This paper provides an in-depth examination of the generic DBR model proposed by McKenney and Reeves (2018) as depicted in Figure 1. In this section, the three core phases of the DBR generic model will be discussed.

Figure 1*Generic DBR Model*

Note: Adapted from *Conducting Educational Design Research* (p. 77), by S. McKenney & T. C. Reeves, 2018, Routledge. Copyright 2018 by Routledge.

Phase 1: Analysis & Exploration Phase- Inputs and Outputs

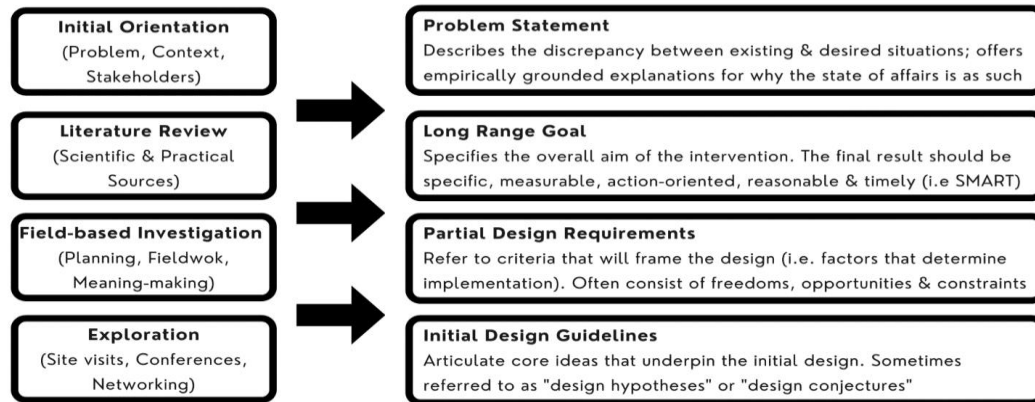
The first input of this analysis and exploration phase is the initial orientation, as shown in Figure 2, where the researcher begins by deeply considering the problem, its context, and the relevant stakeholders involved. This step lays the foundation for subsequent inquiry by encouraging a comprehensive understanding of the educational landscape. The second input is the literature review. It is designed to accomplish three primary purposes: (i) to develop a broader and deeper understanding of the problem at hand, (ii) to provide ideas and direction that can inform the planning of data collection, and (iii) to assist in identifying suitable theoretical or analytical frameworks for interpreting data. The third input is a field-based investigation. McKenney and Reeves (2018) emphasize the critical importance of this input. Engaging in fieldwork allows the researcher to immerse themselves in the actual context of the problem, facilitating the development of grounded ideas about why specific conditions or challenges are occurring.

Ideally, field-based investigation helps refine the definition of the problem, deepen contextual understanding, and capture the perspectives and needs of key stakeholders. The fourth input is exploration, which refers to the process of creatively and critically examining the problem space. This includes identifying novel perspectives, reviewing existing innovations or

previously developed “wheels,” and analyzing the strengths and weaknesses of past solutions to draw practical lessons and avoid redundancy.

Figure 2

Inputs & Outputs of Analysis-Exploration Phase



Following these inputs are the four core outputs of the analysis and exploration phase. Although there are four inputs and four outputs, there is no direct one-to-one mapping; instead, each input collectively influences all outputs, and the outputs reciprocally influence one another.

The first output is the problem statement. A well-crafted problem statement defines the gap between the current and desired conditions and provides evidence-based explanations for the situation. Ideally, it is descriptive, explanatory, relevant, and accurate, serving as the anchor for the rest of the research design.

The second output is the long-range goal. This goal sets the overarching aim of the intended intervention and should be articulated in a manner that is specific, measurable, action-oriented, realistic, and time-bound (SMART). McKenney and Reeves (2018) propose using the time-ability-behaviour-standard heuristic to guide this formulation.

The third output is partial design requirements. These are essential criteria that define the parameters for designing a successful intervention, including implementation factors such as constraints, opportunities, and degrees of freedom. They help frame what is possible and necessary within the real-world context.

The fourth and final output is the initial design guidelines. These guidelines represent the core principles, assumptions, or "design conjectures" that shape the initial development of the

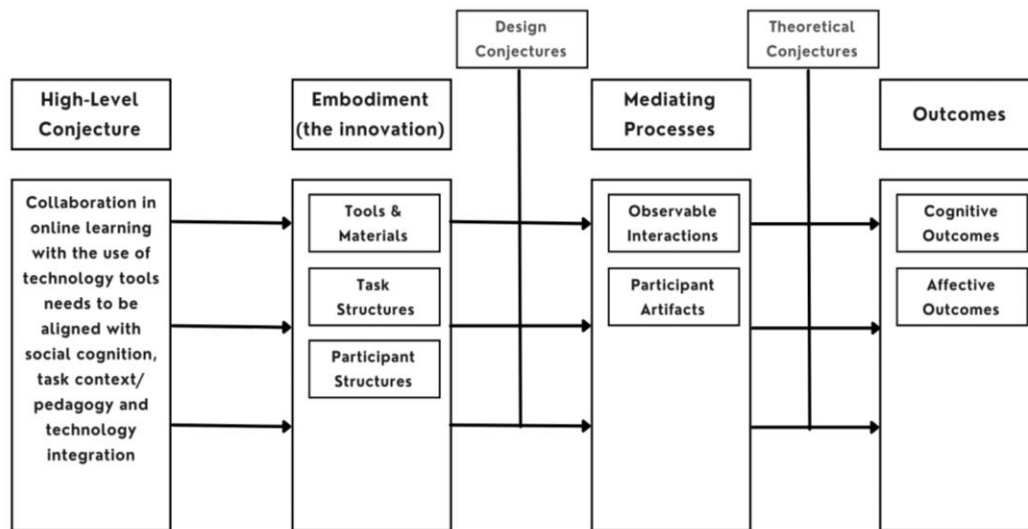
intervention. Collectively, these outputs enable the researcher to begin constructing a coherent and justified design argument that integrates theoretical understanding with practical considerations, setting the stage for the iterative development process.

Phase II: Design & Construction Phase

This design and construction phase will help the researcher think about how to study the

FIGURE 3

Example of Conjecture Mapping of Design & Construction Phase



proposed solution. The goal of this phase is to design a well-considered intervention that is grounded in both theory and reality. In terms of process, McKenney and Reeves (2018) labelled the first part of the design phase as exploring solutions. This has to do with figuring out what might be designed. In the exploring stage of solutions, a wide net will be cast, switching back and forth between creative thinking and analytical thinking. Some of the activities include idea generation, idea consideration, and idea checking. The next part of the design phase involves mapping solutions. At this point, the purpose is really to understand the potential of possible solutions. To achieve this, key activities include refining design requirements and propositions, identifying the "skeleton" of a solution, and considering the materials, resources, activities, processes, participants, and implementation details.

Finally, the detailed specifications of the chosen design will be finalized. This will bring to the idea of conjecture mapping illustrated in Figure 3 from the work of Sandoval (2014). The introduction of this conjecture mapping is to support and strengthen the ideas of McKenney and

Reeves, making this DBR model more useful. According to Sandoval (2014), conjecture mapping is a method used to identify key theoretical elements within the design of a learning environment and to outline how these elements are expected to interact to achieve the intended learning outcomes. Conjecture mapping is a way to concretize the *what*, *why*, and *how* of current designed ideas; it is a way of conceptualizing design research. There are four main parts of conjecture mapping. Taking the example of students' collaboration in online learning, the first part of a conjecture map is a high-level conjecture, a supposition, or a hypothesis. Sandoval (2014) defines a high-level conjecture as a theoretically principal idea for supporting some desired form of learning. It is a general idea about how to foster some educational goal. A critical responsibility of the researcher is to take that high-level conjecture and figure out how it can be embodied in a specific design solution.

The embodiment of conjecture articulates the features of that design. This usually involves specifying four kinds of elements. The first element has to do with the tools and materials of the solution. These examples include software programs, instruments, media, or other resources; these are the things that researchers usually have in mind when designing an intervention or a solution. The second element, task structures (e.g., ill-structured problems), describes the tasks that students are expected to complete in order to solve the problem, based on the goal, criteria, and standards. The third element explains how students are expected to participate in those tasks; what their roles and responsibilities are that they will be asked to take on via the proposed solution (e.g., small-group work). The fourth element of embodiment is discursive practices (ways of interaction), which refer to how students discuss, reflect, and interact about the task and materials they are working on. All of these four elements are dependent on each other, where they are designed deliberately to work together to achieve the envisioned design.

A critical concept in conjecture mapping is that embodied design elements do not directly lead to outcomes; instead, they give rise to mediating processes, which in turn produce the desired outcomes. One way to understand these processes is by observing how students interact with the design solution, as these interactions can reveal how design elements influence learning. Another approach is to analyze artifacts produced by students during their activity. These outputs act as proxies for learning, offering insight into engagement and the types of thinking the design

aims to support. Ultimately, mediating processes are expected to result in various learning outcomes, which may be cognitive, affective, psychomotor, or interpersonal. Capturing these outcomes requires a diverse set of evidence-gathering methods tailored to the specific goals of the design research.

Additionally, this mapping requires both design conjectures and theoretical conjectures. According to Sandoval (2014), design conjectures typically propose that when students participate in a specific activity structure using particular tools and engaging in defined forms of discourse, specific mediating processes are likely to arise. These conjectures should be tested to determine whether the anticipated processes occur in real educational settings and to trace them back to the underlying design components, such as tools, materials, and tasks. The methods for evaluating these design conjectures must be clearly defined. In contrast, theoretical conjectures suggest that if the expected mediating process takes place, it will result in a specific learning outcome. Like design conjectures, theoretical conjectures must also be empirically tested by tracing outcomes back to the underlying processes, which requires valid and reliable measurement tools. Altogether, the components of embodiment, mediating processes, and outcomes form a framework for identifying and testing specific conjectures and understanding how they relate to one another. Conjecture mapping thus enables design researchers to focus both on the practical implementation of an intervention and the theoretical insights it generates.

Phase III: Evaluation & Reflection Phase

The evaluation and reflection phase in DBR serves a dual purpose: i) to refine the intervention, and ii) to contribute findings to the broader scientific and educational communities. This ensures that the design process not only improves educational practice but also yields theoretically meaningful insights (McKenney & Reeves, 2018). Researchers focus on evaluating the intervention's feasibility, usefulness, and relevance within authentic learning contexts. Key activities in this phase include detailed planning, data collection through fieldwork, interpretation of results, and reflective analysis. These steps enable a deeper understanding of how the intervention functions in practice, how well it meets its intended objectives, and what effects it produces. Among the most valuable contributions of this phase is the strategic use of evaluation methods, both formative (to improve the intervention during development) and summative (to assess the final impact), to generate sound evidence for decision-making and future designs.

According to McKenney and Reeves (2018), evaluation refers to any process of data collection used to gain insight into an intervention, whether at the design stage or in prototype form. To structure this process, they proposed three evaluation stages: alpha testing, beta testing, and gamma testing, adapted from software development. Each stage addresses specific evaluation functions and employs appropriate strategies, as outlined in Table 1.

Table 1
Functions & Strategies in the Evaluation Stage of DBR

Functions		Strategies			
		Developer Screening	Expert Appraisal	Pilot	Tryout
Alpha	Feasibility				
	Soundness				
Beta	Local viability				
	Institutionalization				
Gamma	Effectiveness				
	Impact				

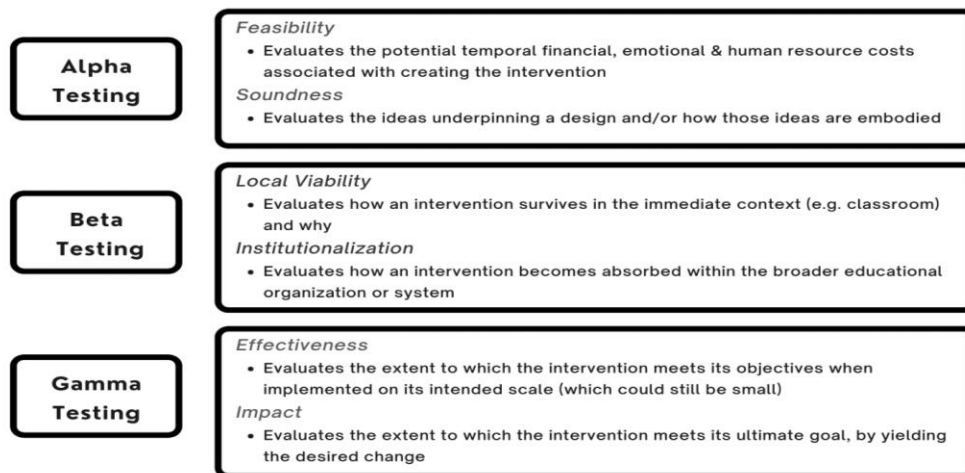
- a) **Alpha testing:** Conducted early in the DBR cycle, alpha testing focuses on assessing foundational aspects of the design. It involves two main functions: *feasibility*, which evaluates the estimated time, financial costs, emotional demands, and human resources required for developing the intervention; and *soundness*, which assesses the theoretical grounding of the design and how well these ideas are embodied in the proposed components. Common strategies used at this stage include developer screening and expert appraisal.
- b) **Beta testing:** This stage occurs once the intervention is functionally developed and ready to be tested in its intended context. It focuses on two key functions: *local viability*, which examines how well the intervention performs in a specific environment (e.g., a classroom) and why it succeeds or fails; and *institutionalization*, which evaluates how the intervention becomes integrated into broader educational systems, indicating its potential

for sustainability. Pilot studies and structured try-outs are frequently used during this phase.

- c) **Gamma testing:** Conducted on a stable or near-final version of the intervention, gamma testing evaluates the effectiveness of the intervention, assessing the extent to which it achieves its intended learning objectives under real-world conditions. It also assesses *impact*, which refers to the degree to which the intervention produces the desired educational change.

Figure 4

Functions in the Evaluation & Reflection Phase



Each of these testing stages —alpha, beta, and gamma —represents not only a progression in the maturity of the intervention but also provides structured opportunities for evaluation that are both formative and summative in nature. These stages are not strictly linear; instead, the DBR process encourages iteration. Insights gained during beta or gamma testing may prompt researchers to revisit earlier stages to adjust the design based on emerging needs, feedback, or contextual shifts. Crucially, the evaluation strategies used within each stage must align with the purpose of that phase. For instance, developer screening and expert appraisal in alpha testing are appropriate for examining theoretical coherence and feasibility before real-world implementation. Pilot studies and tryouts during beta testing enable researchers to observe the intervention in action, assess usability, and gather feedback from actual users, such as students or teachers. Field implementation and impact studies in gamma testing, on the other

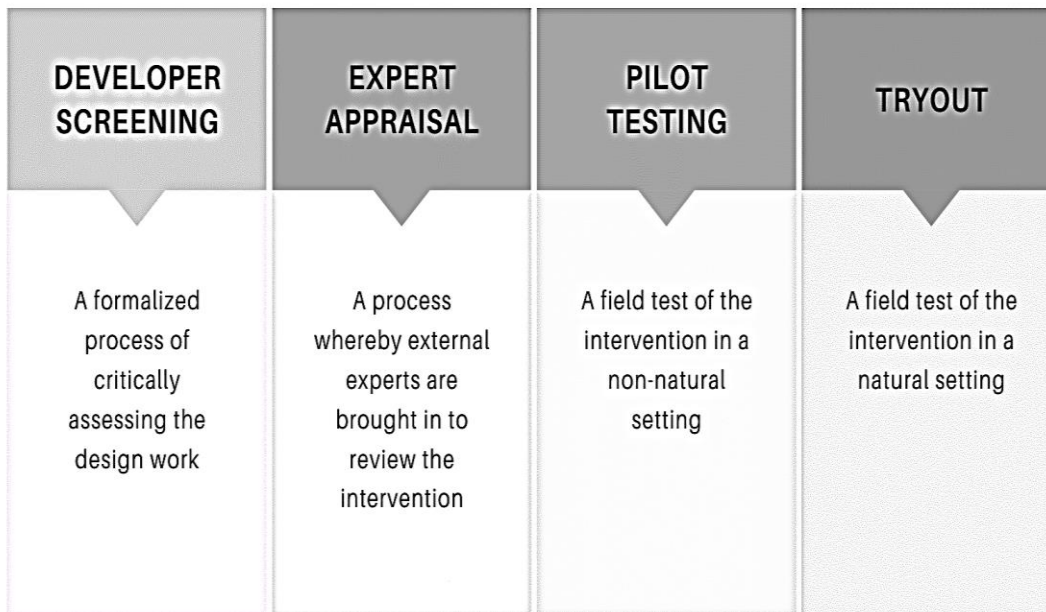
hand, are designed to provide evidence on whether the intervention accomplishes its intended educational outcomes and generates meaningful improvements.

The structured nature of these functions and strategies ensures that the evaluation process is not merely an endpoint but a central part of the iterative design cycle. Each function, whether it relates to feasibility, soundness, viability, institutionalization, effectiveness, or impact, can contribute to a holistic understanding of how and why an intervention works (or fails to work) in each context. Furthermore, the visual summary in Figure 4 helps to clearly differentiate the six evaluation functions and how they map onto the three testing stages. This visual mapping supports DBR practitioners in selecting appropriate evaluation methods and aligning them with the current stage of design maturity.

Finally, the evaluation and reflection phase not only provides evidence for refining the design but also plays a critical role in building theoretical understanding. It enables researchers to trace observed outcomes back to the mediating processes, design conjectures, and theoretical assumptions that shaped the intervention. This recursive process of refinement and theorization is what distinguishes design-based research from conventional educational research approaches.

Evaluation Strategies

McKenney and Reeves (2018) outline four core strategies for conducting evaluations within the design-based research (DBR) framework. These strategies: developer screening, expert appraisal, pilot testing, and tryout are integral to the evaluation and reflection phase and serve distinct purposes depending on the stage and maturity of the intervention. As shown in Figure 5, these strategies help guide researchers in selecting appropriate methods and aligning them with the goals of each testing phase, ensuring the evaluation process remains structured and purposeful throughout the DBR cycle.

Figure 5*Strategies in the Evaluation & Reflection Phase*

The first strategy is developer screening, a formalized process used to assess the design work critically. It typically involves a reflective review by the development team, often facilitated by an external individual to promote objectivity and encourage deeper engagement. This early-stage strategy helps identify inconsistencies, flaws, or usability issues before they are implemented. Common data collection methods include focus group discussions, questionnaires, and structured checklists, which help surface preliminary concerns and guide design refinement. The second strategy, expert appraisal, involves inviting external experts to evaluate the intervention from various disciplinary perspectives. These experts may include subject-matter specialists, instructional designers, or graphic designers, depending on the nature of the intervention. The aim is to gather critical feedback and insights that may not emerge from within the internal team. Methods typically include interviews, focus groups, questionnaires, and expert review checklists.

Pilot testing, the third strategy, involves implementing the intervention in a non-naturalistic setting. Conditions are often controlled or simplified; for example, using a small student group or having the researcher deliver instruction. This strategy assesses functionality, identifies implementation challenges, and provides early evidence of effectiveness. Common

methods include video analysis, discourse analysis, participant observation, interviews, questionnaires, assessments, logbooks, document reviews, and digital activity logs. The final strategy is the try-out, which tests the intervention in its intended natural setting, such as a real classroom with regular teachers and students. It provides insight into how the intervention performs under typical conditions, what participants experience, and the outcomes it produces. Try-out methods often overlap with those used in pilot testing and may include focus groups, observations, video recordings, learner feedback, and analysis of artefacts.

Importantly, these four strategies are not isolated or used exclusively within a single phase. In most DBR projects, multiple strategies are employed in sequence or even concurrently, depending on the stage of the intervention and the specific evaluation objectives. For instance, developer screening and expert appraisal may be more prominent during alpha testing, while pilot and try-out strategies are more appropriate during beta and gamma testing. By integrating these strategies thoughtfully, researchers can conduct evaluations that are both methodologically rigorous and contextually meaningful, ultimately supporting the iterative refinement of the design and the generation of robust theoretical insights.

DBR Practical Implementation and Theoretical Advancement

Following the evaluation and reflection phases, DBR transitions toward generating tangible outputs. These outputs aim not only to improve practice within the immediate research setting but also to contribute to the broader educational landscape through dissemination, adoption, and theoretical advancement. The three DBR phases interact with practical implementation through anticipatory planning. Rather than deferring implementation considerations, researchers and practitioners collaboratively engage in forward-thinking efforts from the beginning. This involves identifying realistic goals, anticipating contextual constraints, and aligning theoretical aims with practical realities. Effective planning balances idealism with pragmatism, considering policy, institutional norms, assessment practices, and available resources. These efforts involve diverse stakeholders, including teachers, school leaders, curriculum developers, exam boards, inspectorates, policymakers, and textbook publishers.

In the generic DBR model, two primary outcomes are emphasized: the development of mature interventions and the advancement of theoretical understanding (McKenney & Reeves, 2018). These outcomes evolve concurrently over multiple design cycles. Interventions are

grounded in empirical testing and iterative refinement, resulting in tools, strategies, or frameworks that are contextually relevant and adaptable to diverse settings. The maturity of an intervention is reflected in its usability, effectiveness, sustainability, and capacity for integration. Such interventions demonstrate how design principles can be translated into real-world practice.

At the same time, DBR contributes to theory building by generating insights and refining models based on observed outcomes and mediating processes. These theoretical outputs emerge from multiple cycles of micro- and meso-level research and often form the basis for new conjectures or explanatory frameworks. Although these theories are designed for particular situations, they could gain wider significance when tested and modified in different settings.

Both practical and theoretical outputs have the potential for scalability. Locally designed interventions may guide future projects, or be shared broadly through networks, published materials, or policy advice. As these outputs disseminate, they influence broader educational practices, establishing a feedback loop between design, implementation, and theory that fosters continuous improvement and innovation.

Applications of Design-Based Research Across Educational Contexts

To demonstrate the diversity and applicability of design-based research (DBR) in educational settings, this paper highlights three sample studies from different subfields of education. These studies exemplify how DBR is used to address complex, practice-based problems through iterative design, implementation, and theory-building processes.

The first study, conducted by Ustun and Tracey (2021), focuses on the adoption of blended learning (BL) in higher education. The DBR project aimed to support an educator who was relatively inexperienced in designing and teaching BL courses, particularly during the transition from traditional face-to-face (F2F) instruction to a blended format. The study explored best practices for designing an efficient and effective BL course. Over three iterative design cycles, the researchers collected data through observations, interviews, and student surveys, alongside reflections documented in the course's Blackboard site. The findings highlighted BL's potential to promote active learning, foster critical thinking, and enhance collaboration. The study ultimately provided practical guidance for selecting appropriate technologies and adopting a flexible, iterative approach to designing and implementing BL courses.

The second study by Coenraad et al. (2022) investigates the integration of computational thinking (CT) into elementary science education. Many educators remain unfamiliar with CT due to limited exposure during their own schooling or pre-service teacher education. To address this gap, the researchers implemented a DBR approach involving a dual-track design: in-class CT instruction embedded within a science methods course for pre-service teachers, and a professional development (PD) program for both pre- and in-service teachers. Over five years, the team refined its design through iterative cycles. The study offers insights into the challenges and opportunities of embedding CT into science curricula and outlines implications for instructional design and curriculum development.

The third study, conducted by Moffett et al. (2023), explores the use of digital educational escape rooms (DEERs) in medical education. It addresses the challenge medical students face in managing uncertainty during their transition from classroom learning to clinical environments. Using a DBR approach, the researchers designed and tested DEERs as a learning tool, guided by the Community of Inquiry (CoI) framework. Data were collected through a mixed-methods approach, including focus groups, gameplay observations, and questionnaires. The results showed that DEERs significantly supported students' ability to manage uncertainty and provided evidence of CoI's applicability in this learning context. The study proposed a set of design principles for DEERs to enhance learning in clinical education.

To provide a more precise comparison, Table 2 summarizes the key elements of each DBR study, including the problem addressed, research focus, methods, intervention, and practical contributions.

Table 2*Comparison of three DBR sample studies*

Element	Ustun & Tracey (2021)	Coenraad et al. (2022)	Moffett et al. (2023)
Problem Addressed	Novice educator designing and delivering blended learning (BL) in higher education	Lack of teacher familiarity with computational thinking (CT) in elementary science	Transition challenges and uncertainty in clinical placements for medical students
Research Focus	Identify design practices to support effective BL course delivery	Develop and evaluate CT integration in teacher education and PD	Explore DEER as a tool to support uncertainty management in medical education
Methodology	Mixed methods: observations, interviews, surveys, and document analysis	Qualitative: focus groups, lesson plans, meeting notes	Mixed methods: focus groups, gameplay observations, questionnaires
Intervention Developed	Course Blackboard site as BL platform	Dual-track CT design: embedded coursework and PD	Digital Educational Escape Room (DEER)
Implementation & Spread	Iterative, flexible BL course design with guidance on tool selection and pedagogy	Key design insights for CT curriculum and instruction across teacher education programs	Design principles for DEER integration in medical education and clinical preparation

These case studies highlight the adaptability and value of DBR in addressing practical educational challenges. Across diverse contexts, including blended learning, computational thinking, and medical education, DBR has enabled the development of effective, theory-informed interventions. Each study demonstrates how iterative design can inform practice while contributing to broader educational understanding, reinforcing DBR's relevance in shaping meaningful and scalable innovations.

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