PPSDP International Journal of Education
Volume 4 (2) (Special Issue) 5-7 November 2025, 1-16
3rd PPSDP International Conference on Educational Sciences (IConEds 2025)
E-ISSN 2829-5196, P-ISSN 2830-3229

Design-Based Learning in Undergraduate Engineering Education: A Systematic Conceptual Review of Implementation, Impact, and Challenges

Chen Fang[1,2], Gede Rasben Dantes[1], Kadek Rihendra Dantes[1], Dessy Seri Wahyuni[1]
[1]Universitas Pendidikan Ganesha, Bali, Indonesia, [2]Qingdao Hengxing University of Science and Technology, China

Corresponding author e-mail: chen.fang@student.undiksha.ac.id

Article History: Received on 8 September 2025, Revised on 6 October 2025,
Published on 17 November 2025

Abstract: This conceptual review synthesises and critically analyses recent literature on Design-Based Learning (DBL) in undergraduate engineering education. It examines how DBL is defined, how it is implemented and assessed, what strengths and recurring challenges are reported, and what these imply for teaching, programmes, and future research. A document-based search in Scopus, Web of Science, and Google Scholar identified English, peer-reviewed studies published between 2018 and 2024; a small number of earlier design-oriented works were retained to anchor key concepts. The review shows that DBL is characterised by iteration on an authentic design brief, structured reflection, and collaboration, and that when these elements and their assessment are explicit, DBL supports student engagement, problem solving, and the early formation of engineering identity. It also notes implementation problems across settings, especially heavy assessment load, limited opportunity for multiple iterations within fixed timetables, and team tasks that reproduce participation hierarchies. By isolating DBL's pedagogical identity from related approaches such as PBL and CBL, the review offers a balanced account and proposes an E–I–P–R alignment and a research agenda for longitudinal, multi-site, moderator-sensitive studies.

Keywords: Design-Based Learning, Engineering Education, Iterative Learning, Student Engagement, Team-Based Problem Solving

A. Introduction

Over the past two decades, undergraduate engineering programmes have been under pressure to move beyond predominantly lecture-centred delivery to approaches that engage students with authentic and complex tasks, because such approaches have been shown to improve achievement, retention, and participation in STEM fields (Prince, 2004; Freeman et al., 2014). This shift is not only pedagogical but also contextual. Contemporary engineering work is increasingly characterised by ill-structured problems, sustainability and digitalisation agendas, cross-disciplinary teams, and rapid cycles of prototyping. Graduates are therefore expected to integrate sound disciplinary knowledge with collaboration, design thinking, communication, and the capacity to tolerate and manage uncertainty. Traditional transmission models rarely provide repeated opportunities to practise these competences. As a result, engineering programmes have looked for pedagogical models that can make students work in ways that resemble professional engineering practice rather than simply learn about it.

Design-based learning (DBL) is one of the models that directly addresses this requirement. In DBL, students are asked to solve an engineering design task through successive cycles of framing the problem, generating alternative solutions, building and testing prototypes, and revising their designs. In other words, the iterative design cycle itself becomes the learning engine. This structure corresponds closely to the logic described in early design-rich science and engineering classrooms, where learning by designing proved effective in connecting abstract concepts with tangible artefacts (Dym et al., 2005). Because tasks are authentic and because the process is visible, DBL also creates natural points for feedback, reflection, and assessment of teamwork. These characteristics explain why DBL has been adopted in a variety of engineering courses to increase relevance and student engagement. What remains less clearly articulated in the literature is the precise position of DBL among the cluster of student-centred approaches already in use in engineering education. Course reports frequently mention problem-based learning, project-based learning, design thinking, and challenge-based learning; DBL is sometimes listed alongside them, and in some cases the labels are used interchangeably. Yet these approaches embody different logics. Problem-based learning is organised around systematic problem analysis and the guided application of prior knowledge. Design thinking places the focus on users, empathy, and creative divergence. Challenge-based learning foregrounds societal relevance and stakeholder engagement (Kohn Rådberg et al., 2020). DBL is distinctive because it requires students to engage with a design brief over several cycles and to make both the process and the product assessable. When DBL is blended with these neighbouring models without explanation, its unique contribution to undergraduate engineering becomes difficult to see, and curriculum designers cannot tell which elements are essential and which are optional.

The most recent empirical work provides a relatively coherent picture of DBL's strengths and limitations. Studies report that when DBL is built around authentic briefs and guided iteration, students show higher behavioural and cognitive engagement, are better able to integrate knowledge from different engineering subfields, and develop reflective habits that support lifelong learning (Weng et al., 2023; Wei et al., 2023). DBL has also been used to serve newer curriculum priorities—such as sustainability-oriented engineering tasks, interdisciplinary STEM integration, or the use of virtual/digital prototyping—indicating that the approach is adaptable to evolving programme goals (Lavado-Anguera et al., 2024). At the same time, the literature is consistent in pointing out frictions: assessing both process and artefact increases workload; team-based tasks do not automatically secure equitable participation; and staff report difficulty in accommodating iterative design within syllabi that are already dense with required topics (Borrego & Henderson, 2014). From an institutional point of view, DBL often depends on access to suitable spaces, materials, and staff preparation; where such conditions are absent, DBL tends to remain an isolated course-level innovation rather than a programme-level practice (Malmqvist et al., 2024). This combination of promise and constraint constitutes the state of the art. Although DBL is frequently mentioned together with problem-based learning, design thinking, or challenge-based learning, the boundaries of the construct in engineering education remain blurred. Much of the existing work describes attractive classroom activities but does not articulate which elements are indispensable for DBL and which are optional or context-dependent. Other papers report positive student responses but do not relate them to assessment structure or to institutional conditions, which makes replication in other programmes difficult. A further gap is that critical or mixed findings—such as single-cycle "DBL", unbalanced team contributions, or lack of staff readiness—are usually reported in isolation and not synthesised. The present review addresses these gaps by bringing together convergent evidence on what DBL does well and divergent evidence on where it fails, and by positioning DBL as an iteration-centred, assessment-aware pedagogy that is close to but not identical with PBL, design thinking, or CBL.

The novelty of the present review lies in taking DBL itself—rather than "design-oriented learning" in general—as the unit of analysis, and in doing so specifically for undergraduate engineering education. Previous mappings of design or design-thinking implementations in engineering have been valuable for showing overall trends, but by aggregating several pedagogies under broad labels they have not isolated what DBL adds to engineering programmes, especially in terms of iteration, authenticity, and assessability (Delen & Yüksel, 2022). By contrast, this review brings together peer-reviewed DBL studies published between 2018 and 2024 and anchors them in the small set of seminal design-based works, so that DBL's definition, characteristic elements, benefits, and recurrent challenges can be described without conceptual spillover.

The contribution of this article is twofold. Conceptually, it sharpens the profile of DBL by distinguishing its iterative, artefact-producing, and assessment-friendly nature from related active-learning models and by positioning it within contemporary experiential and constructivist thinking (Gómez Puente et al., 2013). Practically, it extracts from recent engineering-education reports those features that appear to be necessary for successful DBL implementation—authentic briefs, explicit explore–ideate–prototype–reflect structuring, collaborative arrangements, and rubric-based multimodal assessment—and relates them to the enabling institutional conditions reported in current practice. Guided by this rationale, the review addresses the following research question: What are the defining characteristics, strengths, and limitations of design-based learning in undergraduate engineering education, and under which curricular and institutional conditions can it contribute most effectively to student learning and professional preparation?

B. Methods

Because the study is documentary in nature, there were no human respondents and no field site. This study was carried out as a document-based, qualitative conceptual review. Such a design was chosen because the purpose of the article is to assemble and interpret published work on design-based learning (DBL) in undergraduate engineering education, not to collect new empirical data. The review followed the sequence for systematic library work described by George (2008) and the guidance on transparent qualitative reviews in education set out by Snyder (2019). Scopus and Web of Science were selected because they cover the leading journals in engineering education, educational technology, and higher education, and because they allow filtering by year and language, which was necessary to focus on the 2018‑2024 period. Google Scholar was added to capture conference papers and emerging DBL reports that may not yet be indexed in Scopus or Web of Science but are relevant to engineering practice. Studies were included when they explicitly used a design-based label, were situated in higher or engineering education, were peer reviewed, and provided sufficient methodological detail to judge the reported activity and outcomes. K ‑ 12 accounts, non-English publications, and conceptual papers without an implemented DBL activity were excluded. This justification makes the selection transparent and shows that the review sought breadth across venues but retained quality and relevance.

The initial search produced about 320 records. After automatic and manual removal of duplicates, 220 items remained. Titles and abstracts were screened against the inclusion conditions, with attention to education level, explicit mention of DBL, and adequacy of methodological description; this reduced the set to 80 publications. Full texts of these 80 items were then examined. Publications that did not describe the DBL activity, the higher-education context, or the outcomes clearly enough to permit comparison were set aside. The screening sequence resulted in a final corpus of 46 sources, consisting of 45 peer-reviewed journal articles and 1 monograph. The full sequence of identification, screening, eligibility checking, and inclusion is shown in Figure 1. Data from the 46 sources were recorded on a structured extraction sheet prepared for the review. For each publication, the sheet noted the author(s) and year, the educational and disciplinary context, the stated aim, the description of the DBL design (including iterative stages, authenticity of the task, and collaborative structure), the assessment approaches, and the main benefits or difficulties reported. Using the same extraction format for all items made it possible to compare studies on the same dimensions.

Analysis followed the thematic procedure proposed by Braun and Clarke (2006). The extracted notes were first read several times to gain familiarity. Repeated ideas–such as iteration as the core of DBL, the need for an authentic design brief, the use of rubric-based and multimodal assessment, problems of unequal participation in teams, and dependence on institutional support–were then coded. Related codes were grouped until four strands could be distinguished: (1) how DBL is defined in engineering education; (2) how it is commonly structured and assessed in courses; (3) what benefits are reported most often; and (4) what constraints appear repeatedly. Both favourable and critical reports were kept so that the picture of DBL would be complete. These steps produced a bounded and traceable set of 46 publications on which the subsequent analysis is based.

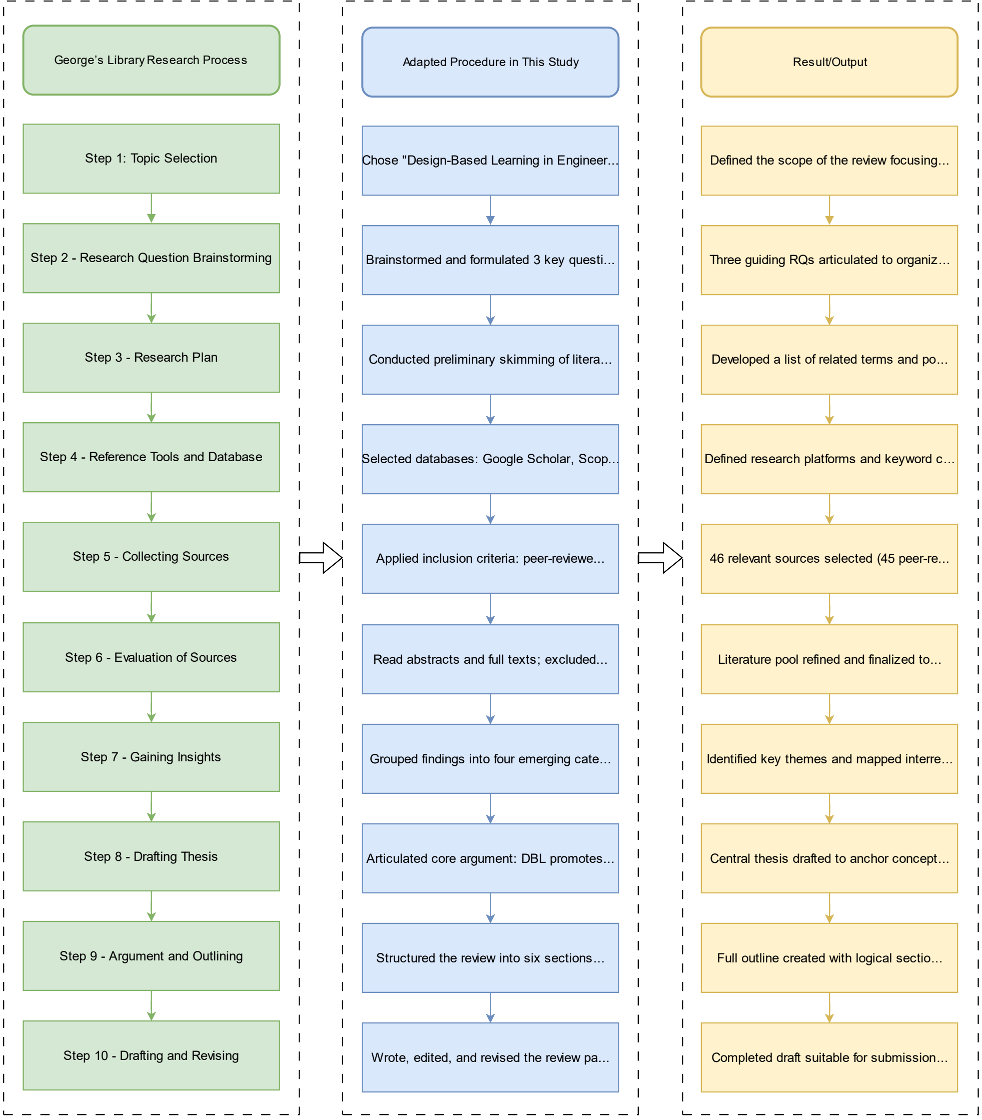

Figure 1. Adapted Library-Research Procedure (George, 2008)

C. Results and Discussion

Definition and Positioning of Design-Based Learning (DBL)

The sources reviewed converge on the view that design-based learning (DBL) is a pedagogy that makes the act of designing—not merely the design product—the central means through which students learn. The early design-rich studies in science and engineering classrooms showed that when students are asked to frame a problem, propose alternatives, build an artefact, test it, and improve it, they do not only produce a solution but also develop conceptual understanding in the process (Dym et al., 2005). Similar early evidence was reported in design-based science classrooms (Doppelt, 2003; Fortus et al., 2004). Later engineering-education work systematised this observation and described DBL through a small set of recurring features: tasks must be authentic, the work must be explicitly iterative, students must collaborate, and reflection must be built in (Gómez Puente et al., 2011, 2013; Gómez Puente, 2021). These four elements are the backbone of most DBL reports published after 2018.

Positioning DBL among neighbouring approaches is necessary because engineering programmes already use several forms of student-centred learning. Problem-based learning (PBL) typically organises learning around the analysis of an ill-structured problem and the self-directed acquisition of knowledge needed to solve it; once the problem is resolved, the instructional cycle ends. Design thinking stresses empathising with users and creative divergence, and challenge-based learning (CBL) in recent European curricula highlights societal relevance and stakeholder engagement (Kohn Rådberg et al., 2020; Lavado-Anguera et al., 2024; Malmqvist et al., 2024). DBL shares the emphasis on authenticity and collaboration with these models, but it is distinguished by one requirement: students must complete more than one design–test–redesign cycle, and both the process and the resulting artefact must be open to assessment. In other words, iteration is not an optional enrichment but the core of the pedagogy.

Recent reviews that map design-oriented practices in engineering confirm this reading. Delen and Yüksel (2022) show that studies labelled "design-based" consistently report cycles of ideation, prototyping and reflection, and that these cycles are the parts most strongly associated with gains in problem solving and persistence. Deng and Liu (2023), looking at design-thinking implementations in engineering, also note that when courses move beyond single-shot projects into iterated design, students' design thinking and integration of knowledge improve. DBL therefore represents the strand of design-oriented pedagogy that insists on iterative evidence of learning and that is easiest to align with rubric-based, multimodal assessment—an alignment several implementation studies identify as a practical advantage (Colmenares-Quintero et al., 2023).

On this basis, DBL can be defined for the purposes of this review as a design-centred, iterative, collaborative, and reflectively assessed pedagogy that brings the logic of engineering design into undergraduate courses. It is close enough to PBL, design thinking, and CBL to benefit from the same institutional push toward active learning, but sufficiently distinct—because of its non-negotiable iteration and its attention to both process and product—to warrant separate treatment in undergraduate engineering education.

Instructional Design and Implementation of DBL

Accounts of design-based learning (DBL) in undergraduate engineering published in the last few years describe a pattern that is recognisable across institutions, even when course aims and resources differ. The usual starting point is not a closed, single-answer exercise but an authentic engineering brief—something situated in a real or realistic socio-technical context that students must first make sense of before they can design. In Dutch and European reports this takes the form of campus or community challenges; in sustainability-oriented courses it may be a renewable-energy task or an efficiency problem drawn from industry (Gómez Puente et al., 2011; Colmenares-Quintero et al., 2023). Presenting the task in this way has two consequences that matter for DBL: it gives students a reason to stay engaged for several weeks, and it allows teachers to assess not only the artefact but also the way students framed the problem. Once the brief is in place, courses move students through the design cycle in teams. The sequence is usually some version of explore or analyse, generate alternatives, prototype, test, and then revisit the earlier decisions. This is the element that aligns current practice with the earlier design-rich work in engineering education, where learning was shown to improve when students had to produce and then improve an artefact (Dym et al., 2005). What is different in the 2018–2024 studies is that lecturers now ask students to make each iteration visible: teams are expected to record why they chose a particular solution, what feedback they received, and which aspects were revised in the next round (Gómez Puente, 2021). DBL has also been adapted to fully online or technology-rich environments, showing that the iterative logic can be preserved even when prototyping is virtual (Azizan & Abu Shamsi, 2022; Tsai, 2022). Courses that have access to digital prototyping or immersive tools report that these technologies shorten the build–test loop and make iterative work more feasible within a semester (Kandi et al., 2020). Recent reviews of design-oriented work in engineering note the same point: where iteration is explicit and recorded, the activity is consistently labelled DBL (Delen & Yüksel, 2022; Deng & Liu, 2023).

Collaboration is embedded rather than optional. Groups of three to six students are asked to distribute tasks, justify design decisions to one another, and integrate different strands of work—analysis, modelling, fabrication, documentation—into one coherent design. Several studies remark that this needs structuring; otherwise the familiar problems of team learning recur, with some students doing most of the work and others staying on the margins (Henderson, 2023). To prevent this, DBL courses often insert small devices at key stages: rotating roles, peer-feedback sheets, short reflective notes, or contribution statements in the final report (Gómez Puente, 2021; Guo et al., 2020). These devices do not change the basic design task, but they make the social process of designing easier to observe and, later, to assess. Work on equity in undergraduate design teams reaches a similar conclusion: facilitation is needed if all students are to benefit from team-based design (Turpen et al., 2018).

Assessment is the part of implementation that authors most often describe as demanding. A DBL course has to judge whether the artefact works, whether the path taken to reach it was appropriate, whether each student contributed, and whether the team learned from feedback. For that reason, instructors seldom rely on a single product. Instead they collect several kinds of evidence—design reports, prototype demonstrations, portfolios, peer assessments, and reflective writing—and bring them together with rubrics that name the stages of the design cycle (Borrego & Henderson, 2014; Gómez Puente et al., 2013). This approach fits DBL well, because it allows both process and product to count, but it also raises workload and reliability issues, especially in large cohorts. Programmes that already use project- or challenge-based modules report fewer difficulties here, because their assessment systems already accept multimodal work (Lavado-Anguera et al., 2024; Malmqvist et al., 2024).

Context makes a visible difference to how far DBL can be taken. Where the curriculum already contains design-intensive or capstone-style courses, and where students have access to labs or maker spaces, DBL can run two or three full iterations, involve external stakeholders, and use rich assessment (Kohn Rådberg et al., 2020; Malmqvist et al., 2024). Where timetables are tight, class sizes are large, or material resources are limited, lecturers use a reduced form—one iteration completed in class, a hypothetical second iteration described in writing, and fewer assessment artefacts. The core remains—authentic task, team-based design, attention to process—but the learning through redesign is weaker. Several authors make the same point in their conclusions: DBL is not difficult because students resist it, but because institutions have to give it time, space, and staff preparation if it is to be more than an isolated innovation (Borrego & Henderson, 2014; Gómez Puente, 2021). Taken together, these reports suggest that implementation of DBL in undergraduate engineering has settled into a fairly stable grammar: start from an authentic brief; ask students to work in teams; require at least one visible iteration; and assess with several forms of evidence tied to the stages of the design cycle (Colmenares-Quintero et al., 2023). What varies across institutions is not this grammar, but the depth to which it can be enacted.

Strengths of DBL in Undergraduate Engineering

Across the post-2018 studies reviewed in this article, the most consistent finding is that DBL sustains student engagement more effectively than lecture-centred teaching in engineering courses. When students are asked to design for an identifiable user, site, or problem, and when they know that their prototype will be shown and then improved, they report higher interest and a stronger sense of purpose (Wei et al., 2023; Weng et al., 2023). This confirms earlier evidence on active learning in STEM (Prince, 2004; Freeman et al., 2014) but adds a DBL-specific nuance: the object that students are building becomes the anchor for motivation, so that even ambiguous or messy problems can retain their attention. Several course reports note that the possibility of a second iteration was mentioned by students as the reason they stayed with the task (Gómez Puente, 2021; Colmenares-Quintero et al., 2023).

A second line of evidence concerns the way DBL makes students integrate disciplinary knowledge with design reasoning. Because a design must meet constraints, explain trade-offs, and sometimes address sustainability or stakeholder needs, students are obliged to draw on knowledge from mechanics, materials, computing, or energy systems and to justify why a given solution is acceptable. Reviews of design-oriented engineering education show that this movement between ideas and tests is the feature most closely associated with deeper learning (Delen & Yüksel, 2022; Deng & Liu, 2023). Courses that required students to document their redesign after testing reported clearer gains: students corrected misapplied formulas, simplified over-engineered solutions, or aligned their design better with user requirements once they had seen the results of the first attempt (Gómez Puente et al., 2013). In this sense DBL helps students move from “knowing the concept” to “using the concept in a realistic task”, which is one of the recurrent aims in undergraduate engineering curricula.

Team-based DBL also appears to develop communication and collaborative capacity without the need for a separate communication module. Because most DBL tasks are carried out in small groups, students must explain design choices, negotiate division of labour, and integrate partly independent pieces of work. Studies on design teams in higher education show that, when the process is lightly structured with tools such as role rotation, short reflection notes, or peer feedback, teams not only produce better artefacts but also report more peer learning and stronger classroom cohesion (Gómez Puente, 2021; Guo et al., 2020). This point matters for engineering programmes that want to foster professional competences but have limited room in the curriculum: DBL seems to “carry” communication, negotiation, and joint problem solving inside the design activity itself. It also helps address one of the classic weaknesses of project work, namely invisible contributions, because the iterative nature of DBL makes individual and group work more observable over time.

A further advantage reported in the 2019–2024 papers is curricular relevance. Programmes that are moving toward CDIO, challenge-based, or sustainability-oriented frameworks have found DBL useful because it can host several learning intentions at once: technical content, stakeholder awareness, teamwork, and documentation (Kohn Rådberg et al., 2020; Lavado-Anguera et al., 2024; Malmqvist et al., 2024). The energy-efficiency DBL projects described by Colmenares-Quintero et al. (2023) are a good illustration: within one design cycle students had to analyse a real problem, work in groups, present a prototype, and reflect on sustainability. This "multi-load" capacity makes DBL attractive in crowded engineering curricula where adding a new stand-alone course is difficult.

Finally, several authors note an effect on reflective and self-regulatory skills. Because DBL requires students to say what they changed and why, reflection is not an optional end-of-course activity but part of the design routine. In the Dutch engineering courses reported by Gómez Puente (2021), students became more explicit about weaknesses in their designs across iterations, and this was taken as an indicator of developing metacognitive awareness. Similar effects were reported in courses that used digital tools to document each stage of the design process (Kandi et al., 2020). This suggests that DBL does not only deliver on engagement and teamwork—two outcomes that many active approaches claim—but also on the ability to monitor one's own engineering work, which is central to professional growth.

Taken together, these findings answer the "what is gained by using DBL?" part of the research question. Compared with conventional delivery, DBL in undergraduate engineering generates sustained engagement around authentic tasks; it pushes students to mobilise disciplinary knowledge inside a design logic; it cultivates teamwork and communication through structured collaboration; and it fits well with current programme-level shifts toward design- and challenge-based curricula.

While the majority of studies reported positive effects on engagement, teamwork, and reflective practice, several accounts pointed to conditions under which these effects were weaker or did not appear. These observations foreshadow the more systematic set of challenges discussed in the next subsection. Large-enrolment courses often compressed the design cycle to a single iteration, which reduced opportunities for feedback and therefore for learning from redesign. Some first-year students experienced open-ended design tasks as anxiety inducing and preferred clearer outcome specifications, suggesting that DBL benefits may be moderated by students' self-regulation and task familiarity. A number of studies also showed that group-based DBL can reproduce existing hierarchies, so that the most confident members take over technical work while others remain peripheral (Turpen et al., 2018; Secules et al., 2018; Henderson, 2023). Bringing these less successful cases into the synthesis indicates that DBL's impact is conditional rather than automatic, and that iteration, assessment alignment, and equity-monitoring should be treated as design requirements rather than optional add-ons.

Learning Weaknesses and Challenges of DBL in Undergraduate Engineering

Although the literature is broadly positive about DBL, the same set of studies also makes it clear that the approach is demanding and not automatically successful. The difficulties that appear most frequently relate to assessment, teamwork, time and workload, and institutional conditions. These points come from papers that otherwise support active and design-oriented teaching, so they should be read as cautions rather than rejections (Borrego & Henderson, 2014; Turpen et al., 2018).

The first and most persistent problem is assessment. DBL asks lecturers to evaluate several things at once: the quality of the artefact, the appropriateness of the design process, the contribution of each student in a team, and the depth of reflection. Conventional examinations capture almost none of this. As a result, instructors turn to portfolios, design reports, peer assessment, prototype demonstrations, and reflective writing, usually tied together with a rubric that names the design stages (G ómez Puente et al., 2013). This aligns assessment with what DBL is trying to achieve, but it makes marking slower and raises questions about consistency across groups. Borrego and Henderson (2014) point out that, once class sizes grow, staff have to choose between maintaining alignment and keeping workload reasonable. That tension does not disappear even in well-designed courses.

A second set of difficulties comes from the social side of DBL. Teamwork is one of DBL’ s selling points, but the literature on undergraduate design teams shows that unequal participation is common unless instructors intervene. Turpen et al. (2018) document how peer educators in engineering sometimes miss inequities inside teams because they are watching the technical progress rather than the group dynamics. Secules et al. (2018) make a similar point from a classroom-culture perspective, showing that which students are recognised as “able” can shape who gets to contribute to technical work. Earlier work on group learning in technical subjects reported the same drift toward dominance by a few students (Henderson, 2023). DBL does provide more “checkpoints” than a one-off project—every iteration is a chance to look at how the team is functioning—but these checkpoints need to be used deliberately. Where peer evaluation, role rotation, or contribution statements are omitted, the risk is that the benefits of collaboration reported in C.3 will only accrue to the more confident or more vocal team members.

Time and curriculum space form a third constraint. Iteration takes time: students need to build something, test it, receive feedback, and revise it. In programmes where the semester is tightly scheduled or where courses are expected to cover a wide range of technical content, lecturers report difficulty in accommodating a full DBL cycle without sacrificing coverage. Some respond by compressing the cycle—one real iteration plus a “hypothetical” redesign described in writing—but this weakens DBL’ s distinctive promise of learning through redesign. Others move DBL into capstone or design-focused modules where time is more flexible, which improves the quality of implementation but limits the reach of DBL to a small part of the programme (Malmqvist et al., 2024). In both cases the message is the same: DBL is depth-oriented, and depth needs time.

Instructor readiness and workload are closely related to this. DBL shifts the teacher’s role from presenting content to coaching teams, giving formative feedback, and monitoring group processes. Several of the engineering-education papers note that this role is not yet familiar to all lecturers and that it takes time to design open tasks, build rubrics, and track several groups over multiple iterations (Gómez Puente, 2021). When staff already have heavy teaching loads, it is easier to run a conventional lab than to run a DBL sequence. Without professional development and timetable support, DBL risks being implemented in a partial way—students may do a project, but iteration and reflection are not really there.

A further limitation is linked to resources. Strong DBL courses often rely on access to lab space, prototyping equipment, or at least software that makes virtual prototyping possible. Where such facilities are limited, instructors scale down the DBL activity to what can be done on paper or at low fidelity. This preserves authenticity to some extent but does not expose students to the full design‑test‑redesign experience that the most successful cases report (Colmenares-Quintero et al., 2023). Institutional policies can add to this problem when they emphasise standardised tests or lecture-based delivery; in such settings DBL remains an “extra” rather than part of the core (Lavado-Anguera et al., 2024).

Finally, a small number of recent papers report that not all students experience DBL positively. When problems are very open and feedback is delayed, some students describe the activity as confusing or even unfair, especially if team contributions are not transparent (F. Zhang et al., 2022). This suggests that the ambiguity which is pedagogically valuable for creativity can also generate negative affect if it is not scaffolded.

Taken together, these findings provide the “not fully supportive” counterweight the journal expects in a results-and-discussion section. DBL remains a strong candidate pedagogy for undergraduate engineering, but its effectiveness depends on conditions that are outside the method itself: time to iterate, assessment systems that accept multimodal evidence, staff prepared to facilitate design work, and resources that let students build and test. Where these are in place, the positive results reported in the majority of studies are plausible; where they are not, the challenges reported by Borrego and Henderson (2014), Turpen et al. (2018), and Zhang et al. (2022) are the more realistic picture.

D. Conclusions

This review set out to answer four questions on DBL in undergraduate engineering: how it is defined, how it is implemented and assessed, what strengths and challenges recur in recent practice, and what these findings imply for future work. The synthesis shows that, in this field, DBL is best understood as an iteration-driven, collaboration-rich pedagogy that requires an authentic design brief, at least one visible redesign, structured reflection, and assessment that can see both process and product. This formulation differentiates DBL from PBL, design thinking, and challenge-based learning, which do not always demand an assessed iteration. At a theoretical level, the review contributes by making explicit the conditions under which DBL fails to deliver its promised benefits, namely when iteration is nominal, when assessment focuses only on the final artefact, and when team dynamics are not made visible. At a practical level, the review recommends aligning DBL courses with an E‑I‑P‑R sequence, adopting balanced assessment portfolios that include individual reflective work and peer-evaluated team contributions, and securing institutional support for space, tools, and teacher facilitation. Future research should prioritise longitudinal and multi-site designs to examine the durability and transferability of DBL effects, and conduct moderator analyses to test how learner characteristics, learning environments, or technology-enhanced prototyping influence outcomes. DBL can therefore be positioned not as a universal remedy but as a powerful pedagogy when its conceptual core and its implementation constraints are both acknowledged.

E. Acknowledgement

The authors gratefully acknowledge the guidance and encouragement of advisors whose comments and suggestions significantly improved the quality of this manuscript. The authors also thank the Educational Science Program, Postgraduate, Universitas Pendidikan Ganesha, for providing the academic setting and institutional support needed to complete this study. Constructive exchanges with peers and colleagues in the program are likewise appreciated, as they helped refine the conceptual focus and interpretation of the review.

References

Azizan, S. A., & Abu Shamsi, N. (2022). Design-based learning as a pedagogical approach in an online learning environment for science undergraduate students. Frontiers in Education, 7, 860097. https://doi.org/10.3389/feduc.2022.860097

Borrego, M., & Henderson, C. (2014). Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies. Journal of Engineering Education, 103(2), 220‑252. https://doi.org/10.1002/jee.20040

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77‑101. https://doi.org/10.1191/1478088706qp063oa

Colmenares-Quintero, R. F., Caicedo-Concha, D. M., Rojas, N., Stansfield, K. E., & Colmenares-Quintero, J. C. (2023). Problem-based learning and design thinking methodologies for teaching renewable energy in engineering programs:

Implementation in a Colombian university context. Cogent Engineering, 10(1), 2164442. https://doi.org/10.1080/23311916.2022.2164442

Delen, İ., & Yüksel, İ. (2022). Understanding trends in engineering design and design-based learning studies with a bibliometric approach. European Journal of Engineering Education, 47(6), 1099 - 1119. https://doi.org/10.1080/03043797.2022.2104695

Deng, Y., & Liu, W. (2023). Integrating design thinking into engineering education: A systematic review of learning outcomes. International Journal of Technology and Design Education, 33(5), 1873-1895. https://doi.org/10.1007/s10798-022-09732-7

Doppelt, Y. (2003). Implementation and assessment of project-based learning in a flexible environment. International Journal of Technology and Design Education, 13(3), 255-272. https://doi.org/10.1023/A:1026125427344

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. Journal of Engineering Education, 94(1), 103-120. https://doi.org/10.1002/j.2168-9830.2005.tb00832.x

Fortus, D., Dershimer, R. C., Krajcik, J., Marx, R. W., & Mamlok-Naaman, R. (2004). Design-based science and student learning. Journal of Research in Science Teaching, 41(10), 1081-1110. https://doi.org/10.1002/tea.20040

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences, 111(23), 8410-8415. https://doi.org/10.1073/pnas.1319030111

George, M. W. (2008). The elements of library research: What every student needs to know. Princeton University Press. https://doi.org/10.1515/9781400830411

Gómez Puente, S. M., van Eijck, M., & Jochems, W. (2011). Towards characterising design-based learning in engineering education: A review of the literature. European Journal of Engineering Education, 36(2), 137-149. https://doi.org/10.1080/03043797.2011.565116

Gómez Puente, S. M., van Eijck, M., & Jochems, W. (2013). A sampled literature review of design-based learning approaches: A search for key characteristics. International Journal of Technology and Design Education, 23(3), 717-732. https://doi.org/10.1007/s10798-012-9212-x

Gómez Puente, S. M. (2021). Design-based learning in engineering education. In I. Henze & M. J. de Vries (Eds.), Design-based concept learning in science and technology education (pp. 163-191). Brill|Sense. https://doi.org/10.1163/9789004450004_008

Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. International Journal of Educational Research, 102, 101586. https://doi.org/10.1016/j.ijer.2020.101586

Henderson, T. S. (2023). Understanding access to learning opportunities in collaborative projects: Gendered social hierarchies in student teams. Studies in Engineering Education, 4(1), 90–114. https://doi.org/10.21061/see.101

Kandi, V. R., Castronovo, F., Brittle, P., Mastrolembo Ventura, S., & Nikolic, D. (2020). Assessing the impact of a construction virtual reality game on design review skills of construction students. Journal of Architectural Engineering, 26(4), 04020035. https://doi.org/10.1061/(ASCE)AE.1943-5568.0000434

Kohn Rådberg, K., Lundqvist, U., Malmqvist, J., & Hagvall Svensson, O. (2020). From CDIO to challenge-based learning experiences: Expanding student learning as well as societal impact? European Journal of Engineering Education, 45(1), 22–37. https://doi.org/10.1080/03043797.2018.1441265

Lavado-Anguera, S., Velasco-Quintana, P. J., & Terrón-López, M. J. (2024). Project-based learning (PBL) as an experiential pedagogical methodology in engineering education: A review of the literature. Education Sciences, 14(6), 617. https://doi.org/10.3390/educsci14060617

Malmqvist, J., Kohn Rådberg, K., Lundqvist, U., & Svensson, O. H. (2024). Challenge-based learning implementation in engineering education: A systematic literature review. Journal of Engineering Education, 113(2), 289 – 313. https://doi.org/10.1002/jee.20588

Prince, M. J. (2004). Does active learning work? A review of the research. Journal of Engineering Education, 93(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Secules, S., Gupta, A., Elby, A., & Turpen, C. (2018). Zooming out from the struggling individual student: An account of the cultural construction of engineering ability in an undergraduate programming class. Journal of Engineering Education, 107(1), 56–86. https://doi.org/10.1002/jee.20191

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Tsai, C.-Y. (2022). Applying the design-based learning model to foster undergraduates' web design skills: The role of knowledge integration. International Journal of Educational Technology in Higher Education, 19, 3. https://doi.org/10.1186/s41239-021-00308-4

Turpen, C. A., Gupta, A., Radoff, J., Elby, A., Sabo, H., & Quan, G. M. (2018, June 24–27). Successes and challenges in supporting undergraduate peer educators to notice and respond to equity considerations within design teams. Proceedings of the 2018 ASEE Annual Conference & Exposition, Salt Lake City, UT, United States. https://doi.org/10.18260/1-2--31028

Wei, L., Zhang, W., & Lin, C. (2023). The study of the effectiveness of design-based engineering learning: The mediating role of cognitive engagement and the moderating role of modes of engagement. Frontiers in Psychology, 14, 1151610. https://doi.org/10.3389/fpsyg.2023.1151610

Weng, C., Chen, C., & Ai, X. (2023). A pedagogical study on promoting students' deep learning through design-based learning. International Journal of Technology and Design Education, 33, 1653‑1674. https://doi.org/10.1007/s10798-022-09789-4

Zhang, F., Markopoulos, P., Bekker, T., Paule-Ruíz, M., & Schüll, M. (2022). Understanding design-based learning context and the associated emotional experience. International Journal of Technology and Design Education, 32(2), 845‑882. https://doi.org/10.1007/s10798-020-09630-w