International Journal of Evaluation and Research in Education (IJERE)
Vol. 15, No. 1, February 2026, pp. 607~615
ISSN: 2252-8822, DOI: 10.11591/ijere.v15i1.37803

Profiles of design-based learning experiences among undergraduate engineering students in an application-oriented Chinese university

Fang Chen[1,2], Gede Rasben Dantes[3], Kadek Rihendra Dantes[4], Dessy Seri Wahyuni[5]
[1]Doctoral Program in Education, Universitas Pendidikan Ganesha, Buleleng, Indonesia
[2]Qingdao Hengxing University of Science and Technology, Qingdao, China
[3]Department of Information System, Faculty of Engineering and Vocational Studies, Universitas Pendidikan Ganesha, Buleleng, Indonesia
[4]Department of Mechanical Engineering Education, Faculty of Engineering and Vocational Studies, Universitas Pendidikan Ganesha, Buleleng, Indonesia
[5]Department of Informatics Education, Faculty of Engineering and Vocational Studies Universitas Pendidikan Ganesha, Buleleng, Indonesia

Article Info

Article history:

Received Oct 21, 2025
Revised Jan 13, 2026
Accepted Jan 20, 2026

Keywords:

Cluster analysis
Design-based learning
Engineering education
Profile analysis
Student experience

ABSTRACT

Design-based learning (DBL) is widely promoted in engineering education, yet there is limited evidence on how students experience DBL when a common framework is implemented across multiple programs. This study examined support for four DBL phases—problem exploration (PE), design generation (DG), prototype iteration (PI), and reflection and evaluation (RE)—in undergraduate engineering programs at an application-oriented university in China. A 12-item DBL phases scale was developed from this framework and prior work in design-oriented engineering education and was completed by 407 students who had taken at least one DBL-based course in 12 programs. Partial least squares confirmatory factor analysis supported a four-factor structure with satisfactory reliability and convergent validity. To capture heterogeneity that is often obscured by average scores, a person-centered profiling approach was adopted. K-means cluster analysis of the four phase scores yielded three DBL experience profiles—high, moderate, and low intensity—that differed mainly in level rather than in shape across phases and were distributed across all programs and year levels. Grounded in engineering design and experiential learning perspectives, the phase-based scale and profiles offer a pragmatic tool for monitoring DBL implementation and for targeting professional development where students most often report low-intensity DBL.

Corresponding Author:

Fang Chen
Doctoral Program in Education, Universitas Pendidikan Ganesha
Udayana Street No. 11, Singaraja, 81116 Buleleng, Bali, Indonesia
Email: chen.fang@student.undiksha.ac.id

1. INTRODUCTION

Engineering graduates are now expected to tackle open-ended problems, work in interdisciplinary teams, and design solutions that address real-world needs [1], [2]. Traditional lecture-based instruction, which often separates theoretical exposition from authentic practice, has struggled to develop these capabilities [2], [3]. In response, many universities have turned to design-based learning (DBL) as a core strategy in engineering education, in which students work on iterative projects that involve exploring

problems, generating and testing solutions, and reflecting on the outcomes of their work, thereby bringing university learning closer to engineering practice [4]–[11].

Empirical studies report a range of positive effects of DBL and related project-based approaches in higher education. DBL has been used to foster sustainability-related competencies [12], [13], to enhance students' motivation, creativity, and design skills [14], [15], and to support the development of complex engineering competencies through authentic, project-based tasks [4], [7], [9], [16], [17]. Variable-centered analyses such as regression and structural equation modeling typically show that higher levels of perceived DBL support are associated with stronger cognitive engagement and better learning outcomes [18], while conceptual work in engineering education argues that design- and project-based approaches are central to contemporary professional preparation [1], [2]. Much of this literature, however, focuses on single courses or short interventions rather than on institution-wide implementation of DBL [4]–[6].

In many institutions, DBL has been organized around staged models of the design process. The four-phase framework used in this study—problem exploration (PE), design generation (DG), prototype iteration (PI), and reflection and evaluation (RE)—builds on prior work on DBL and engineering design education [3]–[6], [15]. The first three phases correspond to widely described engineering design cycles in which problems are framed, alternative solutions are proposed, and prototypes are developed and refined [1], [19], [20]. The final phase of RE links DBL to traditions of experiential learning and reflective practice [3], [15]: students review their design process, evaluate outcomes, and articulate lessons for future projects. Systematic reflection is thus treated as a core feature of mature DBL practice rather than an optional add-on, because it helps transform concrete project experience into reusable knowledge.

When DBL is scaled across multiple programs, implementation rarely remains uniform. Even under a shared framework, individual instructors may place different emphasis on problem framing, ideation, prototyping, and reflection, so that some students experience coherent design cycles while others encounter only isolated project elements [13]. Evaluation tools are therefore needed that capture the intensity and balance of DBL implementation at the level of students' lived experiences, not only in course documentation. Most existing studies use variable-centered analyses and provide limited insight into how students cluster into groups with consistently high, moderate, or low DBL experiences [21], [22]. In other areas of education and health professions research, person-centered approaches such as cluster analysis and latent profile analysis have been used to reveal heterogeneous profiles of motivation, engagement, and learning strategies that are obscured by average scores [23]–[26], yet such methods have rarely been applied to students' DBL experiences.

The present study addresses this gap in the context of an application-oriented university in China that adopted the four-phase DBL framework as a reference model for course design in 12 undergraduate engineering programs [3]–[6], [15]. Program leaders and instructors were encouraged to embed DBL-based projects into core courses, yet it remains unclear how strongly students perceive each phase of the DBL cycle and whether distinct levels of implementation intensity have emerged. To provide an institution-level view of DBL implementation, we use a brief phase-based scale to capture students' perceived support across the four phases and apply a person-centered clustering approach to identify profiles of DBL experiences and examine their distribution across programs and years of study [21]–[23]. A schematic representation of the four-phase DBL cycle used in this study is presented in Figure 1.

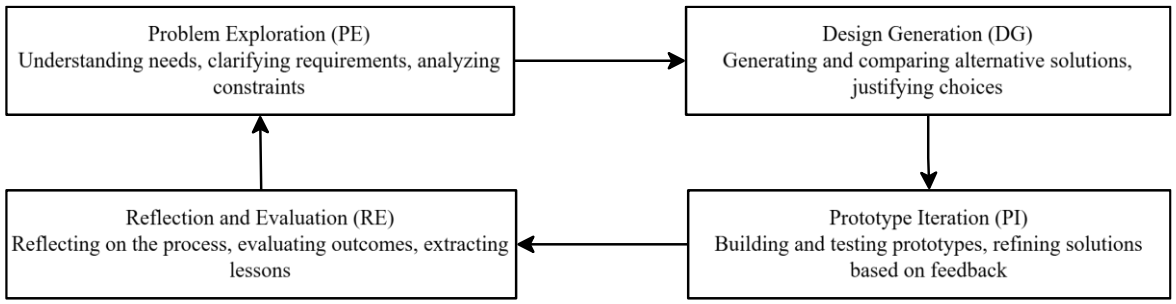

Figure 1. Four-phase institutional DBL framework used in this study

Specifically, the study addresses the following research questions (RQ):

- What is the overall level of students' perceived support in the four DBL phases (PE, DG, PI, and RE) across the 12 engineering programs? (RQ1)

- What distinct profiles of DBL phase experiences can be identified using a person-centered clustering approach? (RQ2)
- How do these profiles differ in their mean levels of perceived support across the four DBL phases? (RQ3)
- How are the DBL experience profiles distributed across programs and years of study? (RQ4)

The study provides an institution-level analysis of how DBL is experienced across multiple engineering programs and offers an initial demonstration of a simple, student-based phase profiling approach that can be used to monitor DBL implementation and inform targeted professional development for engineering educators in an application-oriented university context [10], [27].

2. METHOD

2.1. Research design and sampling

This study adopted a quantitative, cross-sectional survey design with a person-centered profiling approach [28], [29]. The aim was to describe patterns in students' DBL experiences and to examine how these patterns were distributed across undergraduate engineering programs that had adopted a common four-phase DBL framework—PE, DG, PI, and RE—as a reference for course design [3]–[6], [15]. The research took place at an application-oriented university in eastern China. The 12 undergraduate engineering programs that had integrated DBL projects into core courses were included: Electrical Engineering and Automation, Mechanical Engineering, Vehicle Engineering, Automotive Service Engineering, Robotics Engineering, Intelligent Manufacturing Engineering, Software Engineering, Network Engineering, Artificial Intelligence, Engineering Cost, Civil Engineering, and Printing Engineering.

A two-stage sampling strategy was used. In the first stage, purposive sampling was applied to identify students with substantive DBL experience. Program coordinators provided official enrolment lists and indicated which students had completed at least one course or project module explicitly structured around the institutional four-phase DBL framework. Only these students were kept in the sampling frame so that responses reflected actual DBL practice rather than hypothetical opinions. In the second stage, proportionate stratified random sampling was conducted within each of the 12 programs. The number of students drawn from each program was proportional to its total enrolment, and individual students were randomly selected within each stratum.

In total, 420 students were invited to complete the survey during regular class sessions of DBL-based courses; 415 accessed the online questionnaire. All items were compulsory, so there were no missing responses. Cases with implausibly short completion times or invariant response patterns were removed, leaving 407 valid cases for analysis [28], [30]. The final sample comprised 244 male students (59.95%) and 163 female students (40.05%). With respect to age, 20 students (4.91%) were under 18, 100 (24.57%) were 18–19, 150 (36.86%) were 20–21, 90 (22.11%) were 22–23, and 47 (11.55%) were 24 or older, indicating that most respondents were traditional-age undergraduates. Students from all four-year levels and all 12 programs were represented. Participation was voluntary and anonymous, and students were informed that their responses would be used only for research and course improvement.

2.2. Instrument

Students' DBL experiences were measured using a 12-item DBL phases scale developed for this project. The scale was grounded in the institutional four-phase DBL framework and informed by prior work on DBL and engineering design education [7]–[9]. The intention was to construct a brief instrument suitable for routine monitoring while still capturing the core experiential and reflective components of the DBL cycle [3], [15].

The scale comprises four subscales with three items each. The PE subscale assesses support for understanding real-world needs, clarifying requirements, and analyzing constraints at the start of the project. The DG subscale reflects opportunities to generate multiple ideas, compare alternative solutions, and justify design choices. The PI subscale captures hands-on prototyping, testing designs, and revising solutions based on feedback. The RE subscale focuses on structured opportunities to review the design process, evaluate outcomes, and identify lessons for future projects [7]. Sample items for each subscale are reported in Table 1.

All items were rated on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Subscale scores were calculated as the mean of the three items for each phase, with higher scores indicating stronger perceived support in that phase. Item wording was reviewed by three engineering educators with DBL experience to check clarity, relevance, and alignment with classroom practice; minor revisions were made based on their comments, following recommended procedures for content validation in education and psychology [30].

To examine the internal structure of the scale, a four-factor model corresponding to the four DBL phases was tested using partial least squares confirmatory factor analysis. The expected structure was

supported: standardized loadings ranged from 0.849 to 0.902 on their intended factors, with no substantial cross-loadings. Composite reliability (CR) values ranged from 0.897 to 0.919 and average variance extracted (AVE) values from 0.745 to 0.792, indicating satisfactory convergent validity. In the present sample (N=407), Cronbach's alpha values were 0.868 (PE), 0.829 (DG), 0.829 (PI), and 0.842 (RE), all above the commonly recommended threshold of 0.70 for research instruments [30]–[32]. Given its brevity, reliability, and acceptable convergent validity, the scale is best viewed as a practical monitoring tool for profiling DBL implementation rather than a comprehensive diagnostic of all aspects of DBL.

Table 1. Overview and reliability of the DBL phases scale

Phase (code)	Focus in DBL cycle	Sample item	Number of items	Cronbach's α	CR	AVE
PE	Understanding needs, clarifying requirements, analyzing constraints	"I can effectively understand the background and requirements of the engineering problem before starting the project."	3	0.868	0.919	0.792
DG	Generating and comparing solution ideas, justifying choices	"I can propose several different engineering design solutions."	3	0.829	0.897	0.745
PI	Building and testing prototypes, refining solutions based on feedback	"I can revise my prototype repeatedly based on feedback."	3	0.829	0.898	0.745
RE	Reflecting on the process, evaluating outcomes, extracting lessons	"I can reflect on the strengths and weaknesses of the entire engineering design process."	3	0.842	0.905	0.760

2.3. Data analysis

Data analysis was conducted in SPSS 27.0. First, descriptive statistics (means and standard deviations) and Cronbach's alpha coefficients were computed for the four DBL phase subscales to address RQ1 and to assess basic measurement properties [31], [32]. Second, a person-centered profiling strategy was used to identify groups of students with similar DBL experience patterns. Phase scores were standardized (z-scores), and K-means cluster analysis was applied to the four standardized phase variables, following recommendations for person-centered analyses in education and health professions research [24]. Cluster solutions with two to four groups were examined. The three-cluster solution was retained because it produced clearly differentiated profiles, avoided very small clusters, and yielded substantial between-cluster differences on all four phases. Elbow plots of within-cluster sums of squares and inspection of cluster cohesion and separation supported the choice of three clusters.

K-means was chosen over model-based approaches such as latent profile analysis because the primary aim was exploratory and applied—to derive a simple classification that can be reproduced by program leaders using widely available software with a small set of subscale scores—rather than to estimate a fully specified latent profile model. The minimal distributional assumptions and computational simplicity of K-means make it a pragmatic choice for this initial institutional profiling study [21], [24]. Third, cross-tabulations and Pearson chi-square tests were used to examine how DBL profiles were distributed across engineering programs and years of study (RQ4), with the significance level set at 0.05 [28]. Descriptive information on the sample's demographic characteristics and program distribution is reported in the results section.

3. RESULTS AND DISCUSSION

3.1. Design-based learning phase scores

On the 5-point scale, mean scores for PE, DG, PI, and RE were all close to the midpoint (around 3.0), with standard deviations of about 1.2. This pattern suggests that students, on average, perceived a moderate level of support in each phase of the DBL cycle, with considerable variation across the sample. Similar combinations of mid-range means and wide dispersion have been reported in studies of design-based and project-based learning in higher education, where reforms often lead to uneven implementation across courses and instructors [7]–[9]. This pattern also echoes work on student motivation and engagement showing that mid-range average scores can mask important differences between more and less supported subgroups [25], [26], [33], [34].

3.2. Design-based learning experience profiles

K-means cluster analysis was applied to the standardized scores for the four DBL phases (PE, DG, PI, and RE) to identify groups of students with similar patterns of DBL experiences. Solutions with two to four clusters were examined. The three-cluster solution was retained because it yielded clearly interpretable

profiles, avoided very small groups (n=133, 159, and 115), and produced clear differences between clusters on all four phases. An elbow plot of within-cluster sums of squares showed a marked improvement when moving from two to three clusters and only marginal gains thereafter, consistent with recommendations for evaluating cluster solutions in educational profiling studies [21]–[24]. The pattern for the high-DBL profile, with consistently strong support across all phases, echoes DBL and design-based science studies in which coherent design cycles are associated with higher levels of conceptual understanding, creativity, and achievement [16], [17], [19], [35].

Table 2 and Figure 2 summarize the three profiles. Profile 1 (high-DBL) is characterized by consistently high scores, close to "agree" or above, indicating that these students experienced a coherent and well-supported design cycle from PE through reflection. Profile 2 (moderate-DBL) shows scores slightly below the scale midpoint on all four phases, suggesting that DBL elements were present but not strongly emphasized. Profile 3 (low-DBL) has uniformly low scores, with students reporting little DBL-related support in any phase. The three profile lines across PE, DG, PI, and RE shown in Figure 2 are almost parallel, which indicates that profiles differ mainly in overall intensity rather than in qualitatively different shapes. Such level-difference patterns are common in person-centered analyses of motivation and engagement, where groups differ mainly in how strongly they experience the same underlying dimensions rather than in how those dimensions are configured [21]–[23].

Within the high-DBL profile, scores for RE are slightly higher than those for the other phases. Although the difference is modest, it suggests that structured opportunities to review the design process and draw lessons for future work may be a hallmark of stronger DBL implementation in this setting. This aligns with experiential learning perspectives, which treat reflection as the point at which concrete experience is transformed into learning [3], and with accounts of reflective practice that place systematic review of action at the center of professional competence [15]. For institutions seeking to monitor design-oriented reforms, the prominence of RE in the high-intensity profile highlights reflective activities as a useful indicator of more mature DBL practice rather than a peripheral add-on.

Table 2. Mean scores on DBL phases by profile (K-means clusters)

Profile	n	PE mean	DG mean	PI mean	RE mean
Profile 1 (high-DBL)	133	4.30	4.29	4.28	4.34
Profile 2 (moderate-DBL)	159	2.92	2.91	2.90	2.84
Profile 3 (low-DBL)	115	1.64	1.66	1.70	1.70

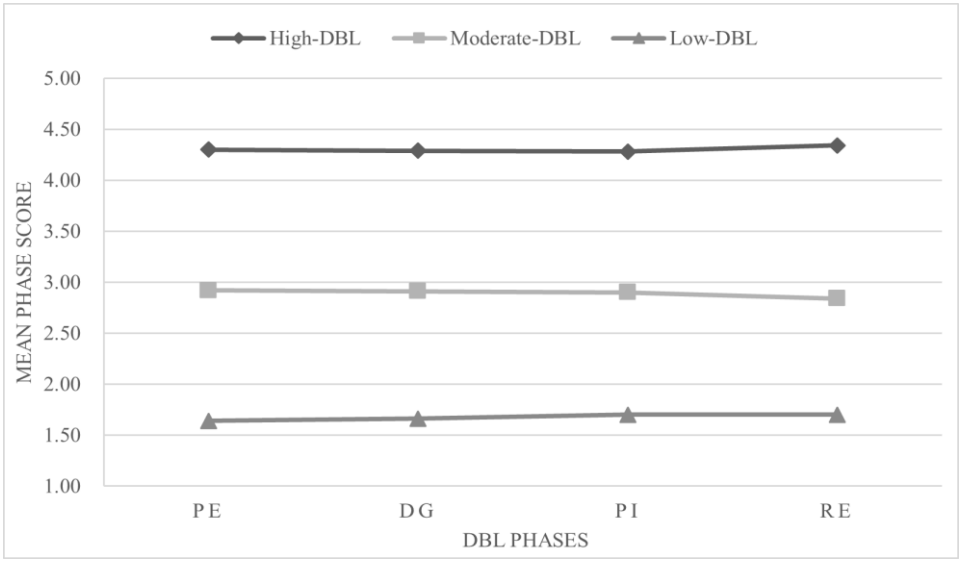

Figure 2. Profiles of mean DBL phase scores across the four DBL phases

3.3. Distribution of design-based learning profiles by program and year level

To address the fourth research question, the distribution of DBL profiles across engineering programs and year levels was examined using cross-tabulations and chi-square tests. As shown in Table 3, all 12 programs contained students in each of the three profiles. Within programs, the moderate-DBL profile generally accounted for the largest share of students, whereas the high- and low-DBL profiles each

represented sizable minorities. The association between program and DBL profile membership was not statistically significant, $\chi^2(22, N=407)=9.217$, $p=0.992$, indicating that the three experience profiles were spread across disciplines rather than concentrated in particular programs.

Table 3. Distribution of DBL profiles by program (N=407)

Program	Profile 1 (high-DBL) n (%)	Profile 2 (moderate-DBL) n (%)	Profile 3 (low-DBL) n (%)
Electrical Engineering and Automation	16 (36.4%)	16 (36.4%)	12 (27.3%)
Mechanical Engineering	12 (28.6%)	16 (38.1%)	14 (33.3%)
Vehicle Engineering	11 (33.3%)	12 (36.4%)	10 (30.3%)
Automotive Service Engineering	8 (29.6%)	12 (44.4%)	7 (25.9%)
Robotics Engineering	10 (32.3%)	12 (38.7%)	9 (29.0%)
Intelligent Manufacturing Engineering	13 (39.4%)	11 (33.3%)	9 (27.3%)
Software Engineering	20 (35.7%)	22 (39.3%)	14 (25.0%)
Network Engineering	15 (39.5%)	12 (31.6%)	11 (28.9%)
Artificial Intelligence	9 (25.0%)	16 (44.4%)	11 (30.6%)
Engineering Cost	7 (28.0%)	13 (52.0%)	5 (20.0%)
Civil Engineering	6 (24.0%)	9 (36.0%)	10 (40.0%)
Printing Engineering	6 (35.3%)	8 (47.1%)	3 (17.6%)
Total	133 (32.7%)	159 (39.1%)	115 (28.3%)

A similar pattern emerged when DBL profiles were cross-tabulated with year of study, as shown in Table 4. At every year level, students were distributed across all three profiles, with the moderate-DBL group again slightly more prevalent and the high- and low-DBL groups each accounting for roughly one quarter to one third of students. The Chi-square test showed no significant association between year level and DBL profile membership, χ^2 (6, N=407)=3.019, p=0.806.

Table 4. Distribution of DBL profiles by year level (N=407)

Year of study	Profile 1 – high-DBL n (%)	Profile 2 – moderate-DBL n (%)	Profile 3 – low-DBL n (%)
Year 1	28 (29.5%)	40 (42.1%)	27 (28.4%)
Year 2	47 (32.4%)	59 (40.7%)	39 (26.9%)
Year 3	43 (37.4%)	38 (33.0%)	34 (29.6%)
Year 4	15 (28.8%)	22 (42.3%)	15 (28.8%)
Total	133 (32.7%)	159 (39.1%)	115 (28.3%)

These results suggest that differences in DBL intensity arise more within programs and cohorts than between them. Under the same institutional framework, some students encounter strong and coherent DBL experiences while others encounter only weak or fragmented forms, regardless of their program or year. This is consistent with work showing that design-oriented reforms are often enacted unevenly at the level of individual courses and instructors rather than at the level of formal program structures [11]. At the same time, the present study did not link profile membership to specific course characteristics, instructor training, or subsequent learning outcomes, so the mechanisms behind these within-program differences remain unclear. Future research could combine profiling with data on course design and instructional practices to identify which features of DBL implementation are most closely associated with membership in the high-DBL profile.

4. CONCLUSION

This study described how the key phases of DBL are supported in undergraduate engineering programs at an application-oriented university, using a brief four-phase DBL scale and a person-centered profiling approach. Students reported mid-range average support for PE, DG, PI, and RE, with substantial within-sample variation. Combined with the acceptable reliability and convergent validity of the phase subscales, these findings indicate that the institutional DBL framework has been translated into classroom practice to a moderate extent, while leaving scope to strengthen how design problems are framed, how ideas are developed and tested, and how students are guided to reflect on their projects.

The profiling analysis identified three patterns of DBL experience—high-, moderate-, and low-intensity profiles—that differed mainly in overall level rather than in qualitatively different shapes across the four phases. Students in the high-DBL profile perceived consistently strong support throughout the design cycle, with slightly higher scores for RE, pointing to structured reflection as a feature of more mature DBL implementation in this setting. Students in the low-DBL profile reported limited support in any phase,

suggesting that DBL elements in their courses were weak or fragmented. Profile membership was distributed across all 12 engineering programs and all year levels, and there were no significant associations between profiles and either discipline or year of study. Differences in DBL intensity therefore appear to arise within programs and cohorts rather than between them, which shifts attention from formal program structures to variation in how individual courses and instructors enact DBL.

Practically, the 12-item DBL phases scale and the three profile categories offer a simple tool that program leaders and teaching teams can use to monitor how students experience DBL over time. Repeated administrations could track changes in the proportions of high-, moderate-, and low-DBL profiles as reforms progress and identify courses or teaching contexts in which students are concentrated in the low-intensity group. At the course level, profile information can help instructors check whether students experience a full design cycle—from PE through reflection—or mainly isolated project components, and can inform adjustments to project design, scaffolding, and reflective activities.

The study has several limitations. It was conducted at a single institution, relied on cross-sectional self-report data, and did not link DBL profiles to subsequent learning outcomes, which restricts both causal interpretation and generalizability. The profiling focused on students' perceptions of DBL support rather than direct observations of classroom practice, and potential explanatory factors such as course design characteristics or instructor preparation were not analyzed. Future research could relate DBL profiles to outcomes such as student engagement and engineering thinking, combine the DBL phases scale with observational or performance-based measures, and follow cohorts longitudinally as DBL initiatives are scaled up. Studies that incorporate information on course structures, assessment tasks, and teacher professional development would also help clarify which features of DBL implementation are most strongly associated with membership in the high-intensity profile and how phase-based profiles can be used to guide engineering education reforms more directly.

FUNDING INFORMATION

Authors state no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Fang Chen	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	
Gede Rasben Dantes	✓	✓								✓		✓		
Kadek Rihendra Dantes		✓								✓		✓		
Dessy Seri Wahyuni		✓								✓		✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We obtained informed consent from all participants before data collection.

ETHICAL APPROVAL

The research involving human participants complied with relevant national regulations and institutional policies and adhered to the tenets of the Helsinki Declaration. As the study used anonymous, minimal-risk course evaluation data, it was exempt from formal review by a separate institutional ethics committee under the institution's guidelines for educational research.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [FC], upon reasonable request.

REFERENCES

[1] A. Kolmos and E. D. Graaff, "Problem-based and project-based learning in engineering education," in *Cambridge Handbook of Engineering Education Research*, A. Johri and B. M. Olds, Eds. Cambridge, UK: Cambridge University Press, 2014, pp. 141–161.

[2] S. D. Sheppard, K. Macatangay, A. Colby, and W. M. Sullivan, *Educating engineers: designing for the future of the field*. San Francisco, CA: Jossey-Bass, 2008.

[3] D. A. Kolb, *Experiential learning: experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice-Hall, 1984.

[4] S. M. G. Puente, M. van Eijck, and W. Jochems, "Towards characterising design-based learning in engineering education: a review of the literature," *European Journal of Engineering Education*, vol. 36, no. 2, pp. 137–149, May 2011, doi: 10.1080/03043797.2011.565116.

[5] S. M. G. Puente, M. van Eijck, and W. Jochems, "A sampled literature review of design-based learning approaches: a search for key characteristics," *International Journal of Technology and Design Education*, vol. 23, no. 3, pp. 717–732, Aug. 2013, doi: 10.1007/s10798-012-9212-x.

[6] S. M. G. Puente, "Design-based learning in engineering education," in *Design-Based Concept Learning in Science and Technology Education*, I. Henze and M. J. de Vries, Eds., Leiden: BRILL, 2021, pp. 163–191, doi: 10.1163/9789004450004_008.

[7] D. Fortus, R. C. Dershimer, J. Krajcik, R. W. Marx, and R. Mamlok-Naaman, "Design-based science and student learning," *Journal of Research in Science Teaching*, vol. 41, no. 10, pp. 1081–1110, Dec. 2004, doi: 10.1002/tea.20040.

[8] Y. Doppelt, "Implementation and assessment of project-based learning in a flexible environment," *International Journal of Technology and Design Education*, vol. 13, no. 3, pp. 255–272, Oct. 2003, doi: 10.1023/A:1026125427344.

[9] S. M. G. Puente, M. van Eijck, and W. Jochems, "Empirical validation of characteristics of design-based learning in higher education," *International Journal of Engineering Education*, vol. 29, no. 2, pp. 491–503, 2013.

[10] S. Chandrasekaran, A. Stojcevski, G. Littlefair, and M. Joordens, "Project-oriented design-based learning: aligning students' views with industry needs," *International Journal of Engineering Education*, vol. 29, no. 5, pp. 1109–1118, 2013.

[11] X. Zhang, Y. Ma, Z. Jiang, S. Chandrasekaran, Y. Wang, and R. F. Fofou, "Application of design-based learning and outcome-based education in basic industrial engineering teaching: a new teaching method," *Sustainability*, vol. 13, no. 5, p. 2632, Mar. 2021, doi: 10.3390/su13052632.

[12] G. Geitz, J. de Geus, and L. Tinoca, "Design-based education, sustainable teaching, and learning," *Cogent Education*, vol. 6, no. 1, p. 1647919, Jan. 2019, doi: 10.1080/2331186X.2019.1647919.

[13] Z. Huang, A. Peng, T. Yang, S. Deng, and Y. He, "A design-based learning approach for fostering sustainability competency in engineering education," *Sustainability*, vol. 12, no. 7, p. 2958, Apr. 2020, doi: 10.3390/su12072958.

[14] T. Z. Oo, T. Kadyirov, L. Kadyjrova, and K. Józsa, "Design-based learning in higher education: its effects on students' motivation, creativity and design skills," *Thinking Skills and Creativity*, vol. 53, Sep. 2024, doi: 10.1016/j.tsc.2024.101621.

[15] D. A. Schon, *The reflective practitioner: how professionals think in action*. New York: Basic Books, 1983.

[16] Y. Doppelt, M. M. Mehalik, C. D. Schunn, E. Silk, and D. Krysinski, "Engagement and achievements: a case study of design-based learning in a science context," *Journal of Technology Education*, vol. 19, no. 2, pp. 22–39, 2008.

[17] M. M. Mehalik, Y. Doppelt, and C. D. Schuun, "Middle-school science through design-based learning versus scripted inquiry: better overall science concept learning and equity gap reduction," *Journal of Engineering Education*, vol. 97, no. 1, pp. 71–85, Jan. 2008, doi: 10.1002/j.2168-9830.2008.tb00955.x.

[18] L. Wei, W. Zhang, and C. Lin, "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*, vol. 14, p. 1151610, May 2023, doi: 10.3389/fpsyg.2023.1151610.

[19] C. E. Hmelo, D. L. Holton, and J. L. Kolodner, "Designing to learn about complex systems," *Journal of the Learning Sciences*, vol. 9, no. 3, pp. 247–298, Jul. 2000, doi: 10.1207/S15327809JLS0903_2.

[20] C. L. Dym, A. M. Agogino, O. Eris, D. D. Frey, and L. J. Leifer, "Engineering design thinking, teaching, and learning," *Journal of Engineering Education*, vol. 94, no. 1, pp. 103–120, Jan. 2005, doi: 10.1002/j.2168-9830.2005.tb00832.x.

[21] R. A. Kusurkar *et al.*, "'One size does not fit all': the value of person-centred analysis in health professions education research," *Perspectives on Medical Education*, vol. 10, no. 4, pp. 245–251, Dec. 2020, doi: 10.1007/S40037-020-00633-w.

[22] D. A. Pastor, K. E. Barron, B. J. Miller, and S. L. Davis, "A latent profile analysis of college students' achievement goal orientation," *Contemporary Educational Psychology*, vol. 32, no. 1, pp. 8–47, Jan. 2007, doi: 10.1016/j.cedpsych.2006.10.003.

[23] N. P. von der Embse, A. D. Mata, N. Segool, and E.-C. Scott, "Latent profile analyses of test anxiety," *Journal of Psychoeducational Assessment*, vol. 32, no. 2, pp. 165–172, Apr. 2014, doi: 10.1177/0734282913504541.

[24] L. Kaufman and P. J. Rousseeuw, *Finding groups in data: an introduction to cluster analysis*. New York: Wiley, 1990, doi: 10.1002/9780470316801.

[25] G. M. Sinatra, B. C. Heddy, and D. Lombardi, "The challenges of defining and measuring student engagement in science," *Educational Psychologist*, vol. 50, no. 1, pp. 1–13, Jan. 2015, doi: 10.1080/00461520.2014.1002924.

[26] K. A. Smith, S. D. Sheppard, D. W. Johnson, and R. T. Johnson, "Pedagogies of engagement: classroom-based practices," *Journal of Engineering Education*, vol. 94, no. 1, pp. 87–101, Jan. 2005, doi: 10.1002/j.2168-9830.2005.tb00831.x.

[27] I. G. Astawan, I. M. Suarjana, B. R. Werang, S. I. Asaloei, M. Sianturi, and E. C. Elele, "STEM-based scientific learning and its impact on students' critical and creative thinking skills: an empirical study," *Jurnal Pendidikan IPA Indonesia*, vol. 12, no. 3, pp. 482–492, Sep. 2023, doi: 10.15294/jpii.v12i3.46882.

[28] J. R. Fraenkel, N. E. Wallen, and H. H. Hyun, *How to design and evaluate research in education*, 8th ed. New York: McGraw-Hill, 2012.

[29] L. Cohen, L. Manion, and K. Morrison, *Research methods in education*, 8th ed. London: Routledge, 2018, doi: 10.4324/9781315456539.

[30] R. F. DeVellis, *Scale development: theory and applications*, 4th ed. Thousand Oaks, CA: SAGE Publications, Inc., 2017.

[31] L. J. Cronbach, "Coefficient alpha and the internal structure of tests," *Psychometrika*, vol. 16, no. 3, pp. 297–334, Sep. 1951, doi: 10.1007/BF02310555.
[32] K. S. Taber, "The use of Cronbach's alpha when developing and reporting Research instruments in science education," *Research in Science Education*, vol. 48, no. 6, pp. 1273–1296, Dec. 2018, doi: 10.1007/s11165-016-9602-2.
[33] J. A. Fredricks, P. C. Blumenfeld, and A. H. Paris, "School engagement: potential of the concept, state of the evidence," *Review of Educational Research*, vol. 74, no. 1, pp. 59–109, Mar. 2004, doi: 10.3102/00346543074001059.
[34] D. Fortus and D. Vedder-Weiss, "Measuring students' continuing motivation for science learning," *Journal of Research in Science Teaching*, vol. 51, no. 4, pp. 497–522, Apr. 2014, doi: 10.1002/tea.21136.
[35] Y. Doppelt, "Assessing creative thinking in design-based learning," *International Journal of Technology and Design Education*, vol. 19, no. 1, pp. 55–65, Mar. 2009, doi: 10.1007/s10798-006-9008-y.

BIOGRAPHIES OF AUTHORS

Fang Chen is a lecturer at Qingdao Hengxing University of Science and Technology, Qingdao, China, and a Ph.D. candidate in the Doctoral Program in Education at Universitas Pendidikan Ganesha, Indonesia. Her work explores curriculum innovation and instructional improvement in undergraduate engineering education, with particular interest in digital tools that enhance design learning and evidence-based assessment. She has participated in teaching and curriculum reform projects that integrate authentic design tasks, digital learning resources, and industry-oriented practice. She can be contacted at email: chen.fang@student.undiksha.ac.id.

Gede Rasben Dantes is a lecturer in the Information Systems Undergraduate Program and the Computer Science Postgraduate Program at Universitas Pendidikan Ganesha. He has more than 20 years of teaching experience in the field of information systems. His areas of interest include enterprise resource planning systems, enterprise systems, and online learning. He can be contacted at email: rasben.dantes@undiksha.ac.id.

Kadek Rihendra Dantes is a lecturer and researcher at Universitas Pendidikan Ganesha, Bali, Indonesia. He holds degrees in Mechanical Engineering and Educational Management, and his work focuses on the integration of engineering and education in teaching and research. He can be contacted at email: rihendra-dantes@undiksha.ac.id.

Dessy Seri Wahyuni is a lecturer and researcher at the Informatics Education Study Program, Engineering and Vocational Faculty, Universitas Pendidikan Ganesha, Bali, Indonesia. Her main duties are teaching, researching, and providing community services. She accomplished her doctoral at Vocational Education Joint Degree Program Technische Universität Dresden Germany and Yogyakarta State University. She teaches in the undergraduate and postgraduate programs in the university, in which several of the courses is in related with Praxis Instructional Design and Strategy in Vocational High School, Link and Match Curriculum Design in Vocational High School and The Learner Development by Cognitive and Practical Skills. She can be contacted at email: seri.wahyuni@undiksha.ac.id.