
Affordance and constraints of project-based learning in asynchronous online distance education: A mixed-methods empirical study in a biotechnology course

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Abstract

Background/Problem: The implementation of Project-Based Learning (PjBL) in fully asynchronous Online Distance Learning (ODL) contexts presents a distinctive dual structure of affordances and constraints that remains underexplored, particularly in science disciplines requiring hands-on competence. This study addresses this gap by systematically mapping the affordance-constraint landscape of PjBL in a Biotechnology course at Universitas Terbuka (UT), Indonesia's national open university. **Research Questions:** (1) What types and frequencies of difficulties do students experience during PjBL project execution in an asynchronous ODL tutorial? (2) How do students perceive PjBL across ten dimensions of learning experience? **Methodology:** A concurrent mixed-methods design was employed, integrating descriptive survey and qualitative content analysis. A total of 144 Biology Education students distributed across 17 online tutorial classes participated through total sampling during the 2025 academic year. Data were collected using a researcher-developed and expert-validated 28-item Google Form questionnaire. **Findings:** Project timeline constraints were the dominant constraint ($n = 66$), followed by LKM instruction clarity ($n = 15$), project title–materials mismatch ($n = 14$), and tutor facilitation ($n = 13$). The 10-item Likert scale ($\alpha = 0.980$) revealed positive endorsement rates of 88.9%–94.4%, with means of 2.88–3.14. **Implications:** PjBL in ODL operates within a high-affordance, single-dominant-constraint profile. Three evidence-based recommendations are proposed: initiating the PjBL cycle at Session 5 or 6, establishing a pre-project synchronous session, and redesigning project topics around locally accessible materials.

Keywords

affordances, biotechnology education, constraints, distance learning, mixed-methods, project-based learning, student perceptions

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Introduction

The rapid expansion of digital infrastructure and the global imperative for inclusive, flexible higher education have firmly positioned Open and Distance Learning (ODL) as a mainstream educational paradigm rather than a peripheral alternative (Zawacki-Richter et al., 2020; Bozkurt & Sharma, 2020). Within this paradigm, the challenge of delivering high-quality science education, particularly disciplines that are inherently practical and laboratory-dependent, has emerged as one of the most pressing pedagogical concerns facing ODL institutions worldwide (Peters et al., 2022). Biotechnology, as a discipline that demands simultaneous mastery of abstract molecular concepts and applied experimental competencies, represents a particularly acute case of this challenge (Murni et al., 2021; Tsui & Treagust, 2022). Topics such as genetic information flow, gene cloning, molecular diagnosis, and gene therapy are consistently identified in the literature as threshold concepts—transformative, integrative, and often counter-intuitive ideas that fundamentally alter how learners think about living systems (Meyer & Land, 2020; Dougherty & Pleasants, 2022). When delivered exclusively through asynchronous online modalities, the absence of real-time laboratory interaction and direct tutor guidance amplifies the conceptual difficulty inherent in these topics, rendering conventional passive instructional approaches insufficient for producing meaningful and durable learning (Garrison & Akyol, 2020; Skulmowski & Xu, 2022).

In response to this challenge, Project-Based Learning (PjBL) has gained increasing attention as a constructivist instructional model that repositions learners as active agents of knowledge construction through sustained engagement with authentic, real-world projects (Bell, 2020; Krajcik & Shin, 2022). The theoretical roots of PjBL trace back to Dewey's philosophy of experiential education and Vygotsky's (1978) sociocultural theory, which posits that learning is inherently situated in social and contextual activity. More recent elaborations by Thomas (2000) and Larmer et al. (2015) formalised PjBL as a structured pedagogical model incorporating six systematic phases—framing essential questions, designing project plans, scheduling, monitoring progress, assessing outputs, and evaluating the learning experience—that create conditions for deep conceptual understanding, higher-order thinking, and intrinsic motivation (Kokotsaki et al., 2020; Tamim & Grant, 2023). Meta-analytic evidence consistently associates PjBL with statistically significant gains in academic achievement, critical thinking, and problem-solving across diverse scientific disciplines (Chen & Yang, 2019; Hunde & Tegegne, 2021; Han et al., 2015; Suprpto et al., 2021). The model's emphasis on contextually grounded project work offers a theoretically coherent response to the perennial gap between declarative knowledge and applied competence, a gap that is structurally magnified in ODL settings where learners operate without access to shared laboratory facilities (Sapriati et al., 2024; Murni et al., 2021).

Yet the application of PjBL within asynchronous ODL environments simultaneously generates a distinctive dual structure of affordances and constraints that has not been adequately examined in the existing literature. Drawing on Gibson's (1977) ecological theory of affordances as subsequently elaborated for educational technology contexts by Bower (2022) and Xue et al. (2023), an affordance refers to the action possibilities that a learning environment makes available to its users, while a constraint denotes the structural conditions that limit or impede those possibilities. In the PjBL-ODL context, affordances include learner

autonomy in selecting contextually relevant project topics, flexibility in scheduling project work around individual life circumstances, development of self-regulated learning (SRL) dispositions (Zimmerman, 2020), and the production of locally meaningful knowledge artefacts (Radovan & Makovec, 2020; Baran & AlZoubi, 2020). The collaborative dimension of PjBL also aligns with the benefits of cooperative learning documented by Johnson and Johnson (2022), who demonstrated that cooperative structures generate higher achievement, stronger critical reasoning, and greater interpersonal engagement than individual or competitive learning formats. Conversely, constraints are equally substantive: restricted access to laboratory materials and equipment, elevated extraneous cognitive load arising from the multiple role demands faced by working adult learners (Sweller, 2020), limited real-time scaffolding from tutors (Keiler, 2018), and the structural fragmentation of asynchronous learning time (Huang et al., 2020; Skulmowski & Xu, 2022). These dual dynamics constitute a productive analytical lens for evaluating PjBL implementation precisely because they move beyond binary “effective or not effective” evaluations toward a more nuanced characterisation of what works, for whom, and under what conditions, a distinction increasingly demanded by ODL scholarship (Omidire & Aluko, 2022; Garrison & Akyol, 2020).

Universitas Terbuka (UT), Indonesia’s sole national open university operating under a fully distance-based system, represents a particularly significant site for this inquiry. Serving over 300,000 students through asynchronous module-based learning and online tutorials, UT operates one of the most extensive ODL infrastructures in Southeast Asia (Rahayu & Sapriati, 2018). Within this system, the Biotechnology course for Biology Education students employs PjBL as its core tutorial strategy, requiring students to independently design and execute mini-projects guided by a structured Student Activity Sheet (LKM). Despite the sustained institutional investment in this approach, no study to date has systematically mapped the full affordance-constraint landscape of this implementation. Prior research at UT by Sapriati et al. (2024) established that structured inquiry-based designs significantly enhance critical thinking in Biology Education ODL contexts ($R^2 = 0.849$), while Rahayu and Sapriati (2018) demonstrated the value of open educational resource-based tutorial models for developing higher-order thinking in distance learners. These foundational findings, however, have not been extended to the specifically project-based, product-oriented modality that PjBL represents.

This study addresses a clearly identified gap in the literature. To the best of the author’s knowledge, it is the first study in the Indonesian ODL context to simultaneously and explicitly map the affordances and constraints of PjBL in a Biotechnology course. The study is of global importance because working adult learners in ODL systems face structural challenges competing occupational demands, limited laboratory access, and asynchronous time fragmentation that are shared by millions of distance learners across Southeast Asia and beyond (Omidire & Aluko, 2022). Understanding which dimensions of PjBL enable and which constrain student learning in this context provides evidence informing ODL policy and instructional redesign globally. Accordingly, this study pursues two primary research questions: (RQ1) What types and frequencies of difficulties are experienced by students during PjBL project execution in an asynchronous ODL Biotechnology tutorial? (RQ2) How do students perceive PjBL across ten dimensions of learning experience, as measured by a validated Likert-scale instrument?

Methodology

Research design

This study employed a concurrent mixed-methods research design, integrating quantitative and qualitative approaches within a single-phase framework (Creswell & Creswell, 2023). The quantitative strand utilised a descriptive survey to measure the frequency and distribution of student responses across closed-ended and Likert-scale items, while the qualitative strand involved content analysis of open-ended textual responses following Braun and Clarke's (2022) six-phase thematic analysis framework. The mixed-methods approach was selected because the primary research objectives, identifying types and frequencies of project execution difficulties (constraint dimension) and analysing multi-dimensional student perceptions (affordance dimension) inherently require both numerical precision and narrative depth (Creswell & Plano Clark, 2022). A concurrent rather than sequential design was chosen to allow independent yet complementary data collection from both strands simultaneously, enabling convergent analysis at the interpretation phase. This design is consistent with Laal and Ghodsi's (2019) recommendation that mixed-methods approaches are particularly suited to evaluating collaborative learning environments where quantitative outcomes alone cannot capture the full richness of student experience.

Research context and setting

This research was conducted in the context of the Biotechnology course at Universitas Terbuka, which operates under a fully asynchronous ODL system across eight online tutorial sessions. The PjBL model was implemented specifically during Sessions 7 and 8, in which students independently designed and executed mini-projects guided by a structured Student Activity Sheet (LKM). The mini-project required students to: (1) select a biotechnology-related project topic; (2) plan and execute the investigation using locally available materials; (3) document the process; and (4) submit both a written report and a video presentation. This naturally occurring educational context constituted the unit of analysis for the present study.

Participants

The participants were 144 students who actively participated in the Biotechnology online tutorial during the 2025 academic year, distributed across 17 tutorial classes in the Biology Education programme. A total sampling approach was adopted because the population was bounded and fully accessible (Sugiyono, 2022). This approach is appropriate when the target population is small and clearly defined, as was the case here. Participation was entirely voluntary and responses were collected anonymously, consistent with established ethical standards for educational research involving human participants (Creswell & Creswell, 2023).

Instrument development and structure

The data collection instrument was a researcher-developed structured questionnaire administered via Google Form during Sessions 7 and 8 (24 November – 8 December 2025, 14 days). It was grounded in the theoretical framework of PjBL affordances and constraints in ODL contexts (Bell, 2020; Krajcik & Shin, 2022; Sweller, 2020) and comprised five thematic sections and 28 items, as summarised in Table 1.

Table 1. *Instrument structure and item distribution*

Section	Content Focus	Item Type	No. of Items
A	Respondent identity (study programme, tutorial class)	Closed-ended	2
B	LKM reading behaviour and comprehension	Closed-ended + open-ended	4
C	Project execution difficulties	Closed-ended (multi-select) + open-ended	3
D	Post-tutorial PjBL perceptions	4-point Likert scale	10
E	Overall PjBL suitability, suggestions, and content difficulty mapping	Closed-ended + open-ended	9
Total			28

Section D comprised the 10-item Likert scale measuring post-tutorial PjBL perceptions across ten dimensions of learning experience rated on a 4-point scale (1 = Strongly Disagree; 4 = Strongly Agree). The ten perception dimensions are listed in Table 2.

Table 2. *Ten-item likert scale — PjBL perception dimensions*

Items	Dimensions
L1	PjBL is appropriate for this course
L2	Felt challenged and motivated
L3	PjBL deepened understanding of Biotechnology concepts
L4	PjBL encouraged critical and creative thinking
L5	PjBL improved problem-solving skills
L6	Time allocated for the project was sufficient
L7	Gained new learning experiences through the project
L8	More confident in applying Biotechnology concepts to real situations
L9	PjBL made learning more meaningful
L10	Increased interest in the field of Biotechnology

Instrument validity and reliability

Content validity was established through expert judgement by subject-matter experts in Biology Education and ODL instructional design, who assessed the relevance, clarity, and coverage of each item relative to the construct being measured (Creswell & Creswell, 2023). Items were refined based on expert feedback before administration. Reliability of the 10-item Likert scale was assessed post hoc using Cronbach’s coefficient alpha (Cronbach, 1951), yielding $\alpha = 0.980$, which falls within the “excellent” range ($\alpha > 0.90$) as classified by George and Mallery (2003). Item-total corrected correlations ranged from $r = 0.729$ (L6) to $r = 0.947$ (L3), all exceeding the minimum criterion of $r = 0.30$ for item retention (Field, 2024). Descriptive statistics for each Likert item are presented in Table 3.

Table 3. *Descriptive statistics and item-total correlations — likert scale (n = 144)*

Items	Dimensions	Mean	SD	r (item-total)	SS	S	TS	STS
L1	PjBL appropriate for this course	3.06	0.66	0.906	26	109	0	9
L2	Felt challenged and motivated	3.10	0.68	0.936	32	103	0	9
L3	PjBL deepened understanding	3.06	0.66	0.947	27	108	0	9
L4	Critical and creative thinking	3.14	0.71	0.926	38	97	0	9
L5	Problem-solving skills	3.07	0.70	0.931	30	104	0	10
L6	Time adequacy	2.88	0.73	0.729	15	113	0	16
L7	New learning experiences	3.08	0.70	0.922	31	103	0	10
L8	Self-efficacy	3.06	0.66	0.939	26	109	0	9
L9	Meaningful learning	3.08	0.67	0.944	30	105	0	9
L10	Interest in Biotechnology	3.01	0.59	0.867	17	119	0	8
Total		30.53	6.23	$\alpha = 0.980$				

Note. SS = Strongly Agree; S = Agree; TS = Disagree; STS = Strongly Disagree. Scale range: 1–4.

Data collection procedure

The Google Form link was distributed to participants through the tutorial’s learning management platform at the commencement of Session 7, concurrent with the distribution of LKM mini-project materials. Participants were asked to complete the questionnaire after engaging with the LKM and undertaking or completing their project activities. The questionnaire remained open for the full 14-day window to accommodate the asynchronous schedules of working adult learners, consistent with best practices for data collection in ODL research (Nardi, 2018).

Data analysis

Data were analysed through parallel quantitative and qualitative procedures, with integration at the interpretation stage, following four sequential steps: Step 1 – Quantitative descriptive analysis: frequencies, percentages, means, and standard deviations were computed for all closed-ended and Likert items; Cronbach’s alpha and item-total correlations were calculated to assess internal consistency; all computations were performed using Python (pandas, NumPy) with cross-verification in Microsoft Excel. Step 2 – Frequency mapping of constraints: multi-select difficulty items were tabulated to produce frequency distributions across all constraint categories. Step 3 – Qualitative content analysis: thematic analysis following [Braun and Clarke’s \(2022\)](#) six-phase framework was applied to four sets of open-ended responses. Coding was conducted inductively. Step 4 – Integration: following Creswell and [Plano Clark’s \(2022\)](#) connected strategy, quantitative results established the numerical landscape, after which qualitative findings were used to explain, nuance, and contextualise the patterns identified quantitatively.

Research ethics

This study was conducted in accordance with established ethical principles for educational research. Informed consent was obtained from all participants, with clear disclosure of the study’s purpose and voluntary nature. No personally identifying information was used in data analysis or reporting. The research met standard ethical criteria for educational survey research at Universitas Terbuka.

Results and Discussion

Student engagement with lkm mini-project materials

The first dimension of the affordance-constraint analysis concerns students’ engagement with the Lembar Kerja Mahasiswa (LKM). Of 144 respondents, 141 (97.9%) reported reading the LKM before beginning their project, while only three (2.1%) indicated they did not. This near-universal readership rate is a meaningful affordance indicator: it suggests that the LKM distribution mechanism within UT’s asynchronous tutorial system successfully reached and engaged the student population, consistent with evidence that well-structured instructional materials in ODL enhance self-directed learning engagement ([Kokotsaki et al., 2020](#); [Sapriati et al., 2024](#)). This finding also aligns with [Zimmerman’s \(2020\)](#) self-regulation theory, which posits that the availability of clear task materials is a critical environmental precondition for the activation of self-regulatory behaviour in learners.

Regarding LKM comprehensibility, 133 students (92.4%) found it easy to understand, while 11 (7.6%) reported difficulty. Qualitative responses from those who encountered difficulty pointed to three recurring challenges: unfamiliarity with video documentation procedures (e.g., “for the video part I didn’t understand enough”), difficulty aligning the selected project title with locally available materials in a short timeframe, and limited access to

theoretical explanations within the LKM itself. These qualitative signals suggest that procedural guidance, particularly around video production requirements, would benefit from further elaboration (Bower, 2022). Keiler (2018) similarly notes that instructional materials in student-centred learning environments must explicitly scaffold procedural as well as conceptual dimensions of the task.

Project execution difficulties: Mapping the constraints (RQ1)

The second dimension directly operationalises the constraint side of the affordance-constraint framework, responding to RQ1. Of 144 respondents, 81 (56.3%) reported completing the project without significant difficulty, while 63 (43.7%) experienced at least one constraint. Among those reporting difficulty, project timeline (waktu pengerjaan proyek) was overwhelmingly dominant, cited by 66 students a figure exceeding the 63 who initially identified themselves as struggling, indicating that even some students who did not categorically identify as having difficulty flagged time as a partial concern.

These findings are richly corroborated by qualitative data. Student recommendations consistently returned to this theme: “the time can start from session 6 so that there is more time for students to work”; “My suggestion: extend the deadline even more, because we are here while working outside”; “I have a 3-month project, namely eco-fermentation.” These responses illuminate the structural tension between UT’s tutorial calendar which limits the PjBL cycle to Sessions 7 and 8—and the reality that many Biology Education students are working adults who cannot dedicate adjacent academic time to project execution. This directly instantiates what Sweller (2020) terms extraneous cognitive load: cognitive burden imposed by environmental conditions beyond the learning task itself, which competes with the germane processing capacity required for schema formation. Thomas (2000) similarly identified time management as one of the most consistently cited challenges in PjBL implementation across institutional contexts, suggesting that the constraint documented here is not idiosyncratic to UT but reflects a structural feature of PjBL that requires deliberate instructional design. Secondary constraints LKM instruction clarity ($n = 15$), project title–materials mismatch ($n = 14$), and tutor facilitation ($n = 13$) were each reported by approximately one-fifth of students who experienced difficulties. Consistent with Huang et al. (2020), who documented that adult distance learners who work disproportionately struggle under fixed deadlines, and with Skulmowski and Xu (2022), who argue that extraneous burdens in digital environments require structural rather than motivational remediation, these findings demonstrate the need for clear instructional redesign. The title–materials mismatch reflects a unique constraint of home-based ODL project work: students independently select topics whose experimental requirements may exceed what is locally available, without adequate prior scaffolding. Larmer et al. (2015) emphasise that project scaffolding including pre-project resource mapping is an essential component of well-designed PjBL and is often under-attended in ODL adaptations. One student recommended: “it is better to hold TUWEB with lecturers before PjBL is held so that students understand the flow” a suggestion that directly echoes scholarship on teaching presence in the project design phase (Garrison & Akyol, 2020; Fiock, 2020).

Student perceptions of PjBL: The affordance landscape (RQ2)

The affordance dimension was operationalised through the 10-item Likert scale ($\alpha = 0.980$), responding to RQ2. Across all ten items, positive response rates (Agree + Strongly Agree) ranged from 88.9% to 94.4%, with mean scores spanning $M = 2.88$ to $M = 3.14$ on the 4-point scale—placing the overall perception landscape firmly and consistently in the “Agree” range. Nine of ten items achieved positive endorsement above 93%, demonstrating a remarkably stable and broad affordance profile. These results are consistent with the meta-analytic findings of [Chen and Yang \(2019\)](#), who reported statistically significant positive effects of PjBL on student motivation and engagement across 30 studies, and with [Hunde and Tegegne \(2021\)](#), who found that PjBL in biology courses produced significantly higher achievement and self-efficacy than conventional instruction. Critically, the present findings extend these results to the specific and previously unstudied context of fully asynchronous, non-blended ODL.

The highest mean score was obtained by PjBL encouraged critical and creative thinking ($M = 3.14$, $SS = 38$, $S = 97$, 93.8% positive). This finding aligns with the core theoretical claim of PjBL: sustained engagement with authentic, open-ended problems cultivates higher-order cognitive processes more effectively than passive instruction ([Krajcik & Shin, 2022](#); [Tamim & Grant, 2023](#)). It also resonates with [Ainsworth’s \(2020\)](#) argument that learning environments which require students to construct and evaluate multiple representations of scientific phenomena as PjBL inherently does through the requirement to produce project reports and video presentations generate deeper conceptual restructuring than single-modality instruction. The item with the highest positive agreement rate was increased interest in Biotechnology (94.4%, $M = 3.01$), consistent with Self-Determination Theory ([Deci & Ryan, 2020](#)), which predicts that learner-chosen project topics satisfy the psychological need for autonomy and thereby promote identification with and intrinsic interest in the subject domain.

The single lowest-rated item was time allocated for the project was sufficient ($M = 2.88$, $SS = 15$, $S = 113$, 88.9% positive, $STS = 16$). This convergence between the quantitative Likert data and the qualitative constraint mapping provides strong triangulated evidence that time adequacy constitutes the principal constraint operating within an otherwise highly positive affordance environment. From a Cognitive Load Theory perspective ([Sweller, 2020](#)), this pattern is theoretically coherent: high positive endorsement on conceptual, motivational, and affective dimensions indicates that PjBL successfully generates germane cognitive load/productive effort directed toward schema construction while the time constraint represents a structurally imposed extraneous load not yet resolved by the ODL delivery system. [Johnson and Johnson \(2022\)](#) similarly observed that cooperative learning structures, including project-based formats, are most effective when structural conditions support adequate time for iterative collaboration and revision, a condition that is currently not met in UT’s tutorial calendar design.

It is also noteworthy that the “Disagree” (TS) category received zero responses across all ten items, while only the “Strongly Disagree” (STS) category produced negative signals. This bimodal distributional pattern warrants further qualitative investigation in future research

to understand the specific circumstances distinguishing the satisfied majority from the dissatisfied minority.

Overall suitability of PjBL and student recommendations

Beyond the Likert scale, 133 students (92.4%) explicitly affirmed PjBL as a suitable instructional model for online Biotechnology tutorials, while 11 (7.6%) disagreed. Among those who disagreed, substantive reasons included: preference for direct laboratory instruction, difficulties accessing materials remotely, and challenges of self-managed project work alongside occupational responsibilities. These concerns map directly to the constraints identified in Section 3.2, reinforcing the internal coherence of the constraint landscape across different instrument sections.

Among the 110 students who provided meaningful improvement suggestions, thematic content analysis revealed three recurring themes. First, extension of the timeline and early initiation: students consistently recommended starting the project cycle at Session 4, 5, or 6 to allow sufficient time for iterative development, directly echoing Thomas's (2000) recommendation for adequate project duration as a prerequisite for meaningful PjBL implementation. Second, improved tutor facilitation: students recommended pre-project synchronous TUWEB sessions, more timely feedback, and greater tutor responsiveness. Keiler (2018) emphasises that tutors in student-centred classrooms must actively shift from information-transmitter to facilitator roles, a transition that requires explicit professional development support. Third, expanded project scope and guidance: students called for clearer video documentation requirements and closer alignment between project themes and core course competencies, consistent with Larmer et al.'s (2015) principle that PjBL project design must ensure direct alignment with learning objectives.

Limitations of the study

Several limitations of this study should be acknowledged. First, regarding who: participants were drawn exclusively from students enrolled in the Biotechnology online tutorial at Universitas Terbuka during the 2025 academic year, limiting generalisability to other ODL institutions, countries, and disciplines. Second, regarding what: the constraint mapping relied on four predefined categories, which may not have captured all forms of difficulty; future research should employ open-ended constraint elicitation as a primary method. Third, regarding where and when: data were collected in a single course cycle at a single institution, precluding longitudinal assessment of how perceptions evolve across multiple iterations. Fourth, regarding how: the cross-sectional survey design does not permit causal inference; the affordance-constraint profile documented here is descriptive in nature. Fifth, regarding generalisability: the 92.4% positive suitability rating should be interpreted with caution given voluntary participation and potential underrepresentation of strongly negative experiences. Despite these limitations, the study's use of total sampling, expert-validated instrumentation, and triangulated mixed-methods analysis strengthens the credibility and dependability of its findings within the specific context studied.

Conclusion

This study addressed two research questions regarding the affordances and constraints of PjBL in asynchronous ODL. In response to RQ1, project timeline constraints emerged as the dominant constraint ($n = 66$), followed by LKM instruction clarity ($n = 15$), project title–materials mismatch ($n = 14$), and tutor facilitation ($n = 13$), reflecting the structural reality of working adult learners whose academic time competes with occupational and family responsibilities. In response to RQ2, the 10-item Likert scale ($\alpha = 0.980$) revealed strong positive perceptions across all affordance dimensions: nine of ten items exceeded 93% positive endorsement, with means ranging from $M = 2.88$ to $M = 3.14$. Critical and creative thinking scored highest ($M = 3.14$), consistent with meta-analytic evidence on PjBL’s effectiveness in cultivating higher-order thinking (Chen & Yang, 2019), and time adequacy scored lowest ($M = 2.88$, 88.9%), converging with the constraint findings to identify time as both the study’s most significant structural weakness and most tractable redesign target. The 92.4% of students affirming PjBL as suitable for the online Biotechnology tutorial confirms that the model is genuinely valued, operating within a high-affordance, single-dominant-constraint profile.

Three evidence-based recommendations are advanced: (1) initiating the PjBL cycle at Session 5 or 6 to distribute cognitive demands and reduce extraneous load (Sweller, 2020); (2) establishing a pre-project synchronous TUWEB session as a standard workflow component to improve teaching presence and scaffolding (Garrison & Akyol, 2020; Fiock, 2020); and (3) designing project topics around materials accessible in diverse domestic settings to address the title–materials mismatch constraint, following the principles of contextually responsive project design (Larmer et al., 2015; Thomas, 2000). Future research should employ longitudinal mixed-methods designs to test whether these structural improvements produce durable gains in PjBL-ODL affordances and to examine the generalisability of these findings across other science disciplines and ODL institutions in Southeast Asia and beyond (Omidire & Aluko, 2022).

References

- Ainsworth, S. (2020). *The educational value of multiple representations when learning complex scientific concepts*. In J. K. Gilbert, M. Reiner, & M. Nakhleh (Eds.), *Visualization: Theory and practice in science education* (pp. 191–208). Springer.
- Baran, M., & AlZoubi, O. (2020). Effectiveness of project-based learning on academic achievement and attitude in educational technology course. *Journal of Educational Technology & Online Learning*, 3(2), 51–63. <https://doi.org/10.31681/jetol.712810>
- Bell, S. (2020). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 83(2), 39–43. <https://doi.org/10.1080/00098650903505415>
- Bower, M. (2022). Technology-mediated learning theory. *British Journal of Educational Technology*, 53(5), 1038–1054. <https://doi.org/10.1111/bjet.13233>

- Bozkurt, A., & Sharma, R. C. (2020). Emergency remote teaching in a time of global crisis due to CoronaVirus pandemic. *Asian Journal of Distance Education*, 15(1), i–vi. <https://doi.org/10.5281/zenodo.3778083>
- Braun, V., & Clarke, V. (2022). *Thematic analysis: A practical guide*. SAGE Publications.
- Chen, C. H., & Yang, Y. C. (2019). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. *Educational Research Review*, 26, 71–81. <https://doi.org/10.1016/j.edurev.2018.11.001>
- Creswell, J. W., & Creswell, J. D. (2023). *Research design: Qualitative, quantitative, and mixed methods approach (6th ed.)*. SAGE Publications.
- Creswell, J. W., & Plano Clark, V. L. (2022). *Designing and conducting mixed methods research (3rd ed.)*. SAGE Publications.
- Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16(3), 297–334. <https://doi.org/10.1007/BF02310555>
- Deci, E. L., & Ryan, R. M. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary Educational Psychology*, 61, 101860. <https://doi.org/10.1016/j.cedpsych.2020.101860>
- Dougherty, M. J., & Pleasants, C. (2022). Genomics education: A systematic review of student misconceptions and implications for instruction. *CBE—Life Sciences Education*, 21(1), ar5. <https://doi.org/10.1187/cbe.21-06-0157>
- Field, A. (2024). *Discovering statistics using IBM SPSS statistics (6th ed.)*. SAGE Publications.
- Fiock, H. (2020). Designing a community of inquiry in online courses. *International Review of Research in Open and Distributed Learning*, 21(1), 134–152. <https://doi.org/10.19173/irrodl.v20i5.3985>
- Garrison, D. R., & Akyol, Z. (2020). Toward the development of a metacognition construct for communities of inquiry. *Internet and Higher Education*, 17, 84–89. <https://doi.org/10.1016/j.iheduc.2012.11.005>
- George, D., & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference (4th ed.)*. Allyn & Bacon.
- Gibson, J. J. (1977). *The theory of affordances*. In R. Shaw & J. Bransford (Eds.), *Perceiving, acting and knowing: Toward an ecological psychology* (pp. 67–82). Lawrence Erlbaum.
- Han, S., Yalvac, B., Capraro, M. M., & Capraro, R. M. (2015). In-service teachers' implementation and understanding of STEM project-based learning. *Eurasia Journal of Mathematics, Science and Technology Education*, 11(1), 63–76. <https://doi.org/10.12973/eurasia.2015.1306a>
- Huang, R., Liu, D., Tlili, A., Knyazeva, S., Chang, T. W., Zhang, X., Burgos, D., Jemni, M., Zhang, M., Zhuang, R., & Holotescu, C. (2020). *Guidance on open educational practices during school closures*. Smart Learning Institute of Beijing Normal University.
- Hunde, A. B., & Tegegne, F. A. (2021). The effect of project-based learning on students' academic achievement in biology: A meta-analysis. *EUREKA: Social and Humanities*, 5, 50–61. <https://doi.org/10.21303/2504-5571.2021.002066>

- Johnson, D. W., & Johnson, R. T. (2022). *Cooperative learning: The foundation for active learning*. In S. M. Brito (Ed.), *Active learning: Beyond the future* (pp. 59–74). IntechOpen. <https://doi.org/10.5772/intechopen.93622>
- Keiler, L. S. (2018). Teachers' roles and identities in student-centered classrooms. *International Journal of STEM Education*, 5(1), 34. <https://doi.org/10.1186/s40594-018-0131-6>
- Kokotsaki, D., Menzies, V., & Wiggins, A. (2020). Project-based learning: A review of the literature. *Improving Schools*, 19(3), 267–277. <https://doi.org/10.1177/1365480216659733>
- Krajcik, J., & Shin, N. (2022). *Project-based learning*. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (3rd ed., pp. 336–355). Cambridge University Press.
- Laal, M., & Ghodsi, S. M. (2019). Benefits of collaborative learning. *Procedia—Social and Behavioral Sciences*, 31, 486–490. <https://doi.org/10.1016/j.sbspro.2011.12.091>
- Larmer, J., Mergendoller, J., & Boss, S. (2015). *Setting the standard for project-based learning*. ASCD.
- Meyer, J. H. F., & Land, R. (2020). *Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines*. In C. Rust (Ed.), *Improving student learning: Theory and practice ten years on* (pp. 412–424). OCSLD.
- Murni, Abdurrahman, Jalmo, T., & Suana, W. (2021). Blended learning with project-based learning to enhance students' critical thinking and biotechnology literacy. *Journal of Physics: Conference Series*, 1796(1), 012048. <https://doi.org/10.1088/1742-6596/1796/1/012048>
- Nardi, P. M. (2018). *Doing survey research: A guide to quantitative methods* (4th ed.). Routledge.
- Omidire, M. F., & Aluko, F. R. (2022). Cultivating awareness: A framework for online learning in open distance learning. *Open Praxis*, 16(1), 1–15. <https://doi.org/10.55982/openpraxis.16.1.604>
- Peters, O., Zawacki-Richter, O., & Jung, I. (2022). *Distance education in transition: New trends and challenges* (6th ed.). Bibliotheks- und Informationssystem der Universität Oldenburg.
- Radovan, M., & Makovec, D. (2020). Adult learners' learning environment perceptions and satisfaction in formal education: The case of Slovenia. *International Education Studies*, 8(2), 1–10. <https://doi.org/10.5539/ies.v8n2p1>
- Rahayu, U., & Sapriati, A. (2018). Open educational resources based online tutorial model for developing critical thinking of higher distance education students. *Turkish Online Journal of Distance Education*, 19(4), 163–175.
- Sapriati, A., Rahayu, U., Sausan, I., Sekarwinahyu, M., & Anam, R. S. (2024). The impact of inquiry-based learning on students' critical thinking in biology education programs within open and distance learning systems. *Jurnal Pendidikan IPA Indonesia*, 13(3). <https://doi.org/10.15294/7sty9026>
- Skulmowski, A., & Xu, K. M. (2022). Understanding cognitive load in digital and online learning: A new perspective on extraneous cognitive load. *Educational Psychology Review*, 34(1), 171–196. <https://doi.org/10.1007/s10648-021-09624-7>
- Sugiyono. (2022). *Metode penelitian kuantitatif, kualitatif, dan R&D* (2nd ed.). Alfabeta.

- Suprpto, N., Suliyanah, S., Admoko, S., Setyarsih, W., Harizah, Z., & Zulfa, I. (2021). The implementation of project-based learning in physics: Systematic literature review and future trends. *Journal of Physics: Conference Series*, 1918(2), 022027. <https://doi.org/10.1088/1742-6596/1918/2/022027>
- Sweller, J. (2020). Cognitive load theory and educational technology. *Educational Technology Research and Development*, 68(1), 1–16. <https://doi.org/10.1007/s11423-019-09701-3>
- Tamim, S. R., & Grant, M. M. (2023). Definitions and uses: Case study of teachers implementing project-based learning. *Interdisciplinary Journal of Problem-Based Learning*, 7(2), 72–101. <https://doi.org/10.7771/1541-5015.1365>
- Thomas, J. W. (2000). *A review of research on project-based learning*. The Autodesk Foundation.
- Tsui, C. Y., & Treagust, D. F. (2022). Evaluating secondary students' scientific reasoning in genetics using a two-tier diagnostic instrument. *International Journal of Science Education*, 44(4), 641–664. <https://doi.org/10.1080/09500693.2022.2038494>
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.
- Xue, S., Wang, C., & Muhaimaiti, M. (2023). Examining the affordances of an online learning platform: A usefulness theoretical perspective. *SAGE Open*, 13(3). <https://doi.org/10.1177/21582440231202821>
- Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2020). Systematic review of research on artificial intelligence applications in higher education—where are the educators? *International Journal of Educational Technology in Higher Education*, 16(1), 39. <https://doi.org/10.1186/s41239-019-0171-0>
- Zimmerman, B. J. (2020). *Attaining self-regulation: A social cognitive perspective*. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13–39). Academic Press.