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Engaging Students through Project-Based Learning during Biology Instruction in Selected Day Lower Secondary Schools in Gasabo District, Rwanda

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Abstract: This study examined how Biology teachers engage students through Project-Based Learning (PBL) in six-day lower secondary schools in Gasabo District, Rwanda, guided by three objectives: teachers' understanding of PBL, their design and implementation of PBL activities, and PBL's contribution to students' motivation. A convergent parallel mixed-methods design was adopted within the pragmatic paradigm, with all 30 Biology teachers in the six schools included through census sampling. Data were collected using a questionnaire, a semi-structured interview guide, and a classroom observation checklist, and triangulated across the three sources; quantitative data were analyzed in SPSS Version 26 using descriptive statistics and multiple regression, while qualitative data were analyzed thematically. Teachers showed a strong theoretical understanding of PBL (M = 4.00–4.13) but a comparatively weaker command of implementation and assessment procedures (M = 3.70–3.73), a gap attributed to limited time, large classes, and insufficient materials rather than to any deficit in conceptual knowledge. Effective PBL activities were curriculum-aligned, collaborative, inquiry-based, and teacher-facilitated. Authentic, real-life projects emerged as the strongest predictor of behavioral, emotional, and cognitive engagement, with the largest effect on cognitive engagement ($\beta = 0.451$, $p = .001$). PBL is an effective, learner-centred approach for engaging Biology students, and its full potential is currently constrained more by institutional and resource conditions than by teachers' understanding of, or commitment to, the approach. Strengthening teacher capacity in PBL implementation and assessment, and providing adequate instructional time and materials, is recommended.

Keywords: *Project-Based Learning, Student engagement, Biology instruction, Secondary schools, Rwanda*

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1. Introduction

Education systems worldwide are shifting from teacher-centred instruction toward learner-centred pedagogies that promote active engagement, critical thinking, and the application of knowledge to real-life situations (Allayarova, 2025). In biology education specifically, this shift responds to the need to develop learners' scientific inquiry skills, problem-solving ability, and lifelong learning competencies (Bell, 2010). Project-Based Learning (PBL), grounded in constructivist and experiential learning traditions (Reese, 2011; Waite-Stupiansky, 2022), positions students as active investigators of authentic, curriculum-aligned biological questions rather than passive recipients of content (Krajcik

& Shin, 2014). Contextually relevant biology projects have been associated with deeper conceptual understanding, stronger engagement, and improved scientific reasoning (Tsaniyah, 2025).

Student engagement is conceptualized here as the behavioural, cognitive, and emotional investment learners bring to academic tasks (Nizeyimana, 2013; Wong & Liem, 2022). In Rwanda's Competence-Based Curriculum, which explicitly encourages learner-centred approaches (Rwanda Basic Education Board [REB], 2020), PBL offers a natural vehicle for cultivating this engagement in Biology classrooms. Yet the adoption of PBL does not automatically translate into meaningful engagement: prior work indicates that projects are sometimes reduced to supplementary tasks or teacher-dominated assignments, undermining the active participation PBL is meant to foster (Sánchez-García & Reyes-de-Cózar, 2025; Schnell, 2025). Much of the existing literature has also focused on academic achievement outcomes rather than on the process by which engagement is generated during project work (Krajcik & Shin, 2014), and studies frequently report that limited pedagogical training, large class sizes, time constraints, and inadequate instructional materials weaken PBL implementation (Aldabbus, 2018; Larmer, 2015).

This gap between the theoretical promise of PBL and its classroom realization motivated the present study, which was guided by three objectives: (i) to assess the extent to which Biology teachers understand PBL and its relevance to student engagement; (ii) to analyze how teachers design and implement PBL activities that engage students; and (iii) to determine how PBL use improves students' motivation. The corresponding research questions asked to what extent Biology teachers understand PBL and its relevance to engagement, how teachers design and implement engaging PBL activities, and how PBL use improves students' motivation.

2. Literature Review

2.1 Theoretical Foundations of Student Engagement

Student engagement is widely treated as a multidimensional construct spanning cognitive, emotional, and behavioural components that jointly shape learning depth and persistence (Wong & Liem, 2022). Cognitive engagement concerns investment in understanding complex ideas, emotional engagement concerns interest and perceived relevance, and behavioural engagement concerns active participation in tasks (Huang, 2023). The ICAP (Interactive, Constructive, Active, Passive) framework offers a useful lens for analyzing engagement within PBL, since biology projects that require students to design investigations and interpret data align with its higher, more constructive and interactive modes (Chi & Wylie, 2014; Herliyanti & Usman, 2024). Nonetheless, several reviews caution that engagement in PBL is often assumed rather than directly examined, particularly within subject-specific contexts such as biology (Budiarti, 2025).

2.2 PBL as a Pedagogical Approach in Biology

PBL is defined as a learner-centred approach in which students follow sustained inquiry into authentic problems and produce tangible outcomes (Nghiem, 2025). Biology is particularly well suited to this approach because biological knowledge connects directly to real-world issues such as health, sustainability, and biodiversity (Tsaniyah, 2025). Its effectiveness depends on core design features — authentic driving questions, learner autonomy, collaboration, and reflection (Sánchez-García & Reyes-de-Cózar, 2025) — which, when embedded well, foster greater ownership of learning (Khatter & Blyth, 2024), though implementation quality varies considerably across classrooms (Rehman, 2024).

2.3 Empirical Evidence and Real-World Relevance

Empirical studies confirm that PBL is associated with higher participation, creativity, and inquiry behaviour in biology classrooms relative to traditional instruction (Herliyanti & Usman, 2024), and meta-analytic evidence reports considerable learning gains from PBL across science subjects, though engagement outcomes vary with project structure and facilitation quality (Balemen & Keskin, 2018; Tirado-Morueta, 2024). Projects addressing community health, environmental conservation, or other locally relevant issues have been linked to stronger emotional engagement and intrinsic motivation (Cardinal & Oxley, 2022), although authenticity alone is insufficient without adequate scaffolding and reflection (George, 2023).

2.4 Teacher Facilitation and Implementation Challenges

Teacher facilitation , guiding reflection, questioning, and feedback , is central to sustaining engagement across the project cycle (Agustina, 2025; Salinas-Navarro, 2024). At the same time, limited instructional time, insufficient professional training, and pressure to cover dense curricula frequently push teachers toward simplified projects that privilege final products over process, constraining engagement (Udin & Arfanaldy, 2025).

2.5 Research Gap

Across this literature, three gaps stand out: a persistent emphasis on outcomes rather than on how engagement develops during projects (Dzaiy & Abdullah, 2024); limited analysis of which specific design features (autonomy, authenticity, collaboration) drive which dimensions of engagement (Indriati et al., 2020); and few studies that examine teacher facilitation as a mediator between project design and engagement, particularly in African secondary-school biology classrooms (Akram & Li, 2024; Uwizeyimana, 2018). This study addresses these gaps within the Gasabo District context.

2.6 Theoretical and Conceptual Framework

The study is grounded in Constructivist Learning Theory and Self-Determination Theory (SDT). Constructivism holds that learners build knowledge through inquiry, collaboration, and real-life experience (Mishra, 2023), consistent with Rwanda's competence-based curriculum (REB, 2020). SDT explains the motivational mechanism: engagement rises when learning supports autonomy, competence, and relatedness (Deci & Ryan, 2000; Guay, 2022), needs that PBL addresses through student choice, mastery of inquiry skills, and teamwork (Tang, 2024). The conceptual framework accordingly positions PBL as the independent variable acting on student engagement (behavioural, cognitive, emotional) through the mediating processes of motivation, collaboration, and cognitive effort, moderated by teacher preparedness, class size, instructional time, and resource availability (Tirado-Morueta, 2024).

3. Methodology

3.1 Research design

The study adopted a convergent parallel mixed-methods design within the pragmatic paradigm (Creswell & Clark, 2023; Tashakkori & Teddlie, 2010), collecting quantitative and qualitative data concurrently, analyzing them separately, and integrating them at the interpretation stage.

3.2 Study Area, Population, and Sampling

The study was conducted in six-day lower secondary schools in Gasabo District, Kigali City: G.S. Ntora, G.S. Gisozi II, G.S. Agateko, G.S. Gatunga, G.S. Kagarama, and G.S. Gikumba, selected for their implementation of the Competence-Based Curriculum. All 30 Biology teachers in these schools were included through census sampling, eliminating sampling bias.

3.3 Data Collection Instruments

Three instruments were used: a structured questionnaire measuring teachers' understanding of PBL, its perceived relevance to engagement, implementation practices, and influence on motivation, using a five-point Likert scale; a semi-structured interview guide exploring teachers' experiences and challenges; and a classroom observation checklist recording facilitation practices and student participation. The instruments were reviewed by the supervisor and subject experts for content validity and piloted in one comparable school outside the study area; Cronbach's alpha for the questionnaire, interview guide, and observation checklist was 0.78, 0.81, and 0.83 respectively, all above the 0.70 threshold.

3.4 Data Collection Procedure

Following ethical clearance and school-level authorization, the questionnaire was administered to all 30 teachers, semi-structured interviews were conducted with a subset of respondents (coded R1–R30 to protect identity while preserving traceability across themes), and classroom observations were carried out during ongoing Biology lessons using the checklist to record facilitation practices and student participation as they occurred.

3.5 Data Analysis

Quantitative data were analyzed in SPSS Version 26 using descriptive statistics (frequencies, percentages, means, standard deviations) and multiple regression, with significance set at .05. Qualitative data from interviews and observations were analyzed thematically and integrated with the quantitative findings at the interpretation stage.

3.6 Ethical Considerations.

The study received ethical approval and research permission from the relevant university and district education authorities before data collection began. All teacher participants gave informed consent after being briefed on the study's purpose, procedures, and their right to decline participation or withdraw at any time without penalty. Students were not directly involved as research subjects. Confidentiality was maintained by coding respondents rather than using names, and all data were stored securely and used solely for academic purposes.

4. Results and Discussion

4.1 Participant Profile

Half of the 30 respondents (50%) were aged 25–34 and 40% were 35 or older; 56.7% were female and 43.3% male.

Most held a Bachelor's degree (83.3%), and 60% had five or more years of teaching experience, indicating a body of respondents well positioned to report credibly on PBL practice.

4.2 Teachers' Understanding of PBL and its Relevance to Engagement

Teachers reported high understanding of PBL's concept and purpose (M = 4.13), its underlying principles of inquiry, collaboration, and learner autonomy (M = 4.00), and the redefined roles of teacher and learner (M = 4.10 and 4.07). Understanding of implementation procedures (M = 3.73) and assessment approaches (M = 3.70) was comparatively lower — moderately high rather than high — and interview and observation evidence linked this specifically to limited lesson time, large class sizes, and the difficulty of fairly assessing group-based project work, rather than to a gap in conceptual knowledge. Teachers rated PBL's contribution to engagement highly across all seven indicators examined (M = 4.10–4.40), with the highest scores for collaboration and critical thinking/problem-solving (M = 4.40 each).

4.3 Design and Implementation of Engaging PBL Activities

Teachers rated alignment of projects with curriculum objectives (M = 4.13) and with real-life biology problems (M = 4.00) highly, citing topics such as osmosis and food-component identification. Collaboration recorded the highest design-related mean (M = 4.27), and practical application of biology concepts was also rated highly (M = 4.20). Across interviews and observation, however, the same structural constraint persisted: limited time, large classes, and insufficient materials restricted how fully every project stage could be implemented.

4.4 Contribution of Project-Based Learning to Students' Motivation and Engagement

PBL's contribution to students' interest and enthusiasm was rated highly (M = 4.23), as was its contribution to active participation (M = 4.37, the highest motivation-related mean), independent exploration (M = 4.13), and persistence in completing tasks (M = 4.10). Multiple regression analysis (Table 1) showed that real-life biology projects were the strongest predictor across all three engagement dimensions, with the largest coefficient in the entire analysis on cognitive engagement (β = 0.451, p = .001). Inquiry-based activity likewise contributed more strongly to cognitive engagement (β = 0.397) than to behavioural or emotional engagement (β = 0.295 each), while group collaboration and teacher facilitation contributed comparably across the more visible, participatory dimensions.

Table 1: Contribution of PBL Practices to Behavioural, Emotional, and Cognitive Engagement

PBL Practice (Predictor)	Behavioural β (Sig.)	Emotional β (Sig.)	Cognitive β (Sig.)
Real-life Biology projects	0.386 (.006)	0.386 (.006)	0.451 (.001)
Group collaboration	0.334 (.019)	0.334 (.019)	0.368 (.007)
Inquiry-based activities	0.295 (.021)	0.295 (.021)	0.397 (.003)
Teacher facilitation	0.278 (.026)	0.278 (.026)	—

4.5 Discussion

The findings indicate a two-speed understanding of PBL among Gasabo District Biology teachers: strong conceptual clarity about what PBL is and why it matters, paired with weaker confidence in carrying its stages through under real classroom conditions. This reframes the practical problem: teachers do not need to be persuaded of PBL's value, but need continued, practical support to implement and assess it, consistent with Rehman's (2024) observation that theoretical understanding of PBL does not automatically translate into consistent implementation without adequate professional preparation.

The consistently high ratings of PBL's contribution to behavioural, emotional, and cognitive engagement, corroborated by interview and observation evidence, empirically support Herliyanti and Usman's (2024) finding that PBL learners participate more than conventionally taught students, and align with Wong and Liem's (2022) tridimensional model of engagement. That all three dimensions scored highly, rather than only one, suggests PBL's relevance in this context is broad: projects appear to simultaneously draw students into participating, caring about the subject, and thinking more deeply about it.

Teachers' design practice , aligning projects with curriculum objectives and real-life context, and structuring them around collaboration and inquiry rather than direct

instruction , supports Tsaniyah's (2025) claim that biology is inherently suited to contextualized project work and Khatter and Blyth's (2024) argument that well-designed PBL builds ownership of learning through authentic, investigative tasks. Yet the same resource and time constraints surfaced independently across teachers' accounts of understanding, implementation, and design, indicating a structural, institutional-level barrier rather than an isolated complaint, and pointing to where intervention would have the broadest effect (Udin & Arfanaldy, 2025).

The regression results suggest two distinct mechanisms at work: authentic, real-life projects and structured inquiry appear to deepen students' thinking more than they simply increase visible activity, whereas collaboration and facilitation appear to sustain day-to-day participation and confidence. Self-Determination Theory (Guay, 2022) accounts for the motivational gains, since PBL affords autonomy through student-led investigation, competence through problem-solving success, and relatedness through collaboration, while Constructivist Learning Theory accounts for the behavioural and cognitive gains through active involvement and reflection. Together these support Tirado-Morueta's (2024) claim that PBL strengthens behavioural, emotional, and cognitive engagement as an interconnected whole. Consistent with Uwizeyimana (2018), the benefits documented here are real but conditional: they depend on teachers being able to run projects that are genuinely authentic and inquiry-driven, which in turn depends on adequate time, class size, and materials.

5. Conclusion and Recommendations

5.1 Conclusion

This study set out to assess Biology teachers' understanding of PBL, examine how they design and implement PBL activities, and determine PBL's contribution to students' motivation and engagement. On the first objective, teachers in the selected day lower secondary schools of Gasabo District understand PBL conceptually and theoretically to a high degree and correctly perceive it as relevant to promoting behavioural, emotional, and cognitive engagement; their understanding of day-to-day implementation and assessment, while adequate, is comparatively weaker and represents the area most in need of continued support. On the second objective, teachers design PBL activities well aligned with curriculum objectives and students' real-life environment, structured around collaboration, inquiry, and facilitation, but the effectiveness of this design work is limited in practice by insufficient instructional time, large class sizes, and inadequate materials. On the third objective, PBL measurably improves students' motivation and engagement across all three dimensions examined, with authentic, real-life projects and structured inquiry exerting the strongest influence, particularly on critical thinking and depth of understanding. Overall, PBL is an effective and contextually relevant approach for engaging Biology students in Gasabo District, and its benefits are not yet fully realized because of institutional and resource constraints rather than any deficiency in teachers' understanding of, or commitment to, the approach.

5.2 Recommendations

Based on the findings, the following recommendations are made:

Biology teachers should:

- Continue and deepen the use of authentic, real-life, curriculum-aligned projects, which showed the strongest influence on engagement.
- Strengthen practical skills in project planning, group monitoring, and formative assessment through tools such as rubrics and peer assessment, to address the comparatively weaker implementation and assessment scores.

School leaders should:

- Support flexible allocation of lesson time for project stages that require sustained investigation.
- Assist teachers with manageable group sizes within large classes.
- Mobilize basic project materials locally to reduce resource constraints on implementation.

The Rwanda Basic Education Board and the Ministry of Education should:

- Incorporate practical guidance on PBL implementation and assessment into in-service teacher training.
- Review Biology lesson time allocation to allow adequate time for project-based activities.
- Support schools with essential materials for inquiry-based projects.

Teacher training institutions should:

- Strengthen pre-service preparation in inquiry-based pedagogy and authentic assessment.

Curriculum developers should:

- Embed locally relevant real-life problems and sample project briefs within syllabus guidance.

Future researchers should:

- Employ a larger, multi-district sample and a longitudinal design to establish whether these patterns, particularly the strong influence of authentic projects on cognitive engagement, generalize beyond Gasabo District and persist over an academic year.

5.3 Limitations of the Study

The study was limited to day lower secondary schools in one district and a sample of 30 Biology teachers; findings should therefore be interpreted as context-specific rather than automatically generalizable to other districts or school types.

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