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Impact of project-based learning on inorganic chemistry laboratory practices in agricultural higher education

Impacto del aprendizaje basado en proyectos en las prácticas de laboratorio de química inorgánica en la educación superior agrícola

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Palabras claves: aprendizaje basado en proyectos; prácticas de laboratorio; educación superior; educación química; aprendizaje significativo; competencias científicas.	**Introducción:** la enseñanza tradicional de laboratorio en química inorgánica a nivel universitario suele priorizar el cumplimiento procedimental sobre la reflexión crítica, limitando la participación activa de los estudiantes y debilitando la integración de la teoría con la práctica profesional. **Objetivo:** este estudio evaluó la asociación entre una intervención de Aprendizaje Basado en Proyectos (PBL) y los cambios en la percepción de los estudiantes sobre las prácticas de laboratorio dentro del programa de Ingeniería Agrícola de la Universidad Politécnica Estatal de Carchi. **Metodología:** se implementó un diseño cuasi-experimental de pretest - post test con un enfoque predominantemente cuantitativo. Cincuenta y un estudiantes participaron en la fase diagnóstica y 35 completaron la intervención pedagógica organizada en equipos colaborativos. **Resultados:** los datos se recopilaron mediante encuestas estructuradas a escala Likert, complementadas con observación diagnóstica y análisis documental. Las respuestas se dicotomizaron y analizaron utilizando la prueba exacta de Fisher con ajuste de Holm para comparaciones múltiples. Los resultados posteriores a la intervención mostraron aumentos consistentes en las respuestas favorables en todos los indicadores evaluados. Se observaron mayores avances en competencias experimentales auto percibidas relacionadas con el equilibrio ácido-base y la interpretación crítica (+32,60 puntos porcentuales; RR = 1,55), participación activa e integración teoría–práctica (+31,54 pp; RR = 1,50), y la integración del trabajo en equipo (+29,58 pp; RR = 1,46). Cinco de los seis indicadores demostraron diferencias estadísticamente significativas ($p < 0{,}05$). **Conclusiones:** aunque la satisfacción general aumentó, la significación estadística no se mantuvo tras el ajuste. Estos hallazgos sugieren que la enseñanza contextualizada basada en PBL en laboratorio está asociada con mejoras en la implicación y en las competencias experimentales percibidas en los programas de ciencias aplicadas. **Área de estudio general:** Educación. **Área de estudio específica:** Aprendizaje Basado en Proyectos. **Tipo de artículo:** original.
Keywords: project-based learning; laboratory practices; higher education; chemical education; meaningful learning; scientific competencies.	**Introduction:** Traditional laboratory teaching in inorganic chemistry at the university level usually prioritizes procedural compliance over critical reflection, limiting the active participation of students and weakening the integration of theory with professional practice. **Objective:** This study evaluated the association between a Project-Based Learning (PBL) intervention and changes in students' perception of laboratory practices within the agricultural engineering program of the State Polytechnic University of Carchi. **Methodology:** A quasi-experimental pre-test - post-test design was implemented with a quantitative approach. Fifty-one students participated in the diagnostic phase and 35 completed the pedagogical intervention organized in collaborative teams. **Results:** Data were collected through structured Likert-scale surveys, complemented by diagnostic observation and documentary analysis. Responses were dichotomized and analyzed using Fisher's exact test with Holm adjustment for multiple comparisons. Post-intervention outcomes showed consistent increases in favorable responses across all indicators assessed. Greater advances were observed in self-perceived experimental competencies related to acid-base balance and critical interpretation (+32.60 percentage points; RR = 1.55), active participation and theory-practice integration (+31.54 pp; RR = 1.50), and the integration of teamwork (+29.58 pp; RR = 1.46). Five of the six indicators showed statistically significant differences ($p < 0.05$). **Conclusions:** although overall satisfaction increased, statistical significance was not maintained after adjustment. These findings suggest that PBL-based contextualized teaching in the laboratory is associated with improvements in perceived involvement and experimental competencies in applied science programs. **General Area of Study:** Education. **Specific area of study:** Project-Based Learning. **Type of article:** original.

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1. Introduction

Scientific and technological development in higher education institutions poses new challenges when preparing students with the knowledge and skills required to address complex professional problems (López, 2025; Ojeda et al., 2025; Núñez et al., 2025). Among these demands, there is a growing need to promote meaningful learning and strengthen the connection between theory and practice. At the same time, science education faces difficulties in chemistry instruction, where fundamental concepts such as atomic structure, chemical reactions, and thermodynamics present an elevated level of abstraction.

Laboratory practices play an essential role in student training, as they enable learners to apply procedures and reinforce theoretical knowledge through practical experience (Espinosa-Ríos et al., 2016; Muñoz & Ramirez, 2024). Nevertheless, in various educational settings, laboratory activities are often limited to procedural execution, with students following instructions without critically analyzing their purpose or relevance (Muñoz & Ramirez, 2024). As a result, a gap emerges between theory, experimentation, and professional performance, negatively affecting conceptual understanding and student motivation toward the subject.

In response to this situation, Project-Based Learning (PBL) has been consolidated as a strategy to promote problem-solving, inquiry, and collaborative work through the development of projects linked to real or contextualized situations (Ojeda et al., 2025; Ayala et al., 2020; Lucero & Velasteguí, 2018; Quiñónez et al., 2025). Several studies have shown that PBL enhances conceptual understanding, improves knowledge retention, and strengthens critical thinking skills (Montesdeoca et al., 2020; Freeman et al., 2014; Caizaluisa et al., 2024; Chica et al., 2022). In addition, this methodology contributes to the development of transversal competencies such as communication, time management, and decision-making skills, which are essential in contemporary professional training (Matilainen et al., 2021; Montaño et al., 2025). When implemented in laboratory settings, PBL transforms experimental activities into opportunities for inquiry and analysis, moving beyond the mere repetition of procedures (Laal & Ghodsi, 2012; Davidson et al., 2014; McKeachie, & Svinicki, 2010).

Furthermore, PBL enables students to critically evaluate results, contextualize different laboratory practices, and integrate them into a broader understanding of the subject while fostering collaboration among peers (Ayala et al., 2020).

The State Polytechnic University of Carchi (UPEC) has laboratories equipped with basic infrastructure and qualified technical-academic staff. However, the inorganic chemistry course within the agricultural engineering program lacks a pedagogical methodology that positions students as active protagonists in their own learning process.

For this reason, difficulties in the assimilation of experimental content have been identified in the teaching-learning process of chemistry at UPEC. Most laboratory practices are conducted under a traditional approach in which the instructor acts as the central source of knowledge, delivering pre-structured content to students rather than encouraging them to construct and appropriate knowledge according to their cognitive frameworks. This traditional system limits students' analysis to formulate questions, design experimental strategies, and critically analyze results, generating a disconnect between laboratory practice and real professional challenges.

The objective of this research was to design and implement an instructional guide

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based on Project Based Learning as a pedagogical methodology for inorganic chemistry laboratory practices at UPEC, aimed at improving self-directed learning, student motivation, conceptual understanding, and the integration of theory and practice.

2. Methodology

This study adopted a quasi-experimental pretest–posttest design with a quantitative approach, aiming to evaluate the impact of a pedagogical intervention based on Project-Based Learning (PBL) on inorganic chemistry laboratory practices in higher education. During the diagnostic phase, complementary qualitative techniques such as direct observation and document analysis were employed; however, the primary evaluation of the results was based on data obtained through surveys.

The study population consisted of 51 students enrolled in the first semester of the agricultural engineering program at the State Polytechnic University of Carchi (UPEC), who were taking the inorganic chemistry course during the 2023 academic period. A census sampling approach was applied during the diagnostic phase, including the entire group; subsequently, 35 students participated in the implementation of the pedagogical intervention and in the posttest assessment, organized into seven collaborative teams of five members each. Participation was voluntary, and confidentiality of the information was ensured strictly for academic purposes.

The reduction in posttest participation was primarily due to voluntary participation and academic scheduling constraints. No selective exclusion criteria were applied. Although individual-level matching was not conducted, the posttest group represented students who completed the full pedagogical intervention.

For data collection, three techniques were employed: direct observation, a structured survey, and document analysis. Direct observation was conducted during the diagnostic phase to record the development of laboratory practices under a traditional instructional approach, considering indicators such as student participation, clarity of procedures, understanding of objectives, and time management.

Likewise, a structured survey was administered, consisting of closed-ended questions using a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). The survey was applied before and after the intervention and was validated through expert judgment by three faculty members from the area. Finally, document analysis was conducted through the review of course syllabus, laboratory guides, and curricular guidelines.

2.1. Methodological procedure

The methodological procedure was structured according to the pedagogical intervention model based on Project-Based Learning (PBL) illustrated in Figure 1, which integrates three interrelated levels: thematic modules, experimental mini-projects, and implementation phases.

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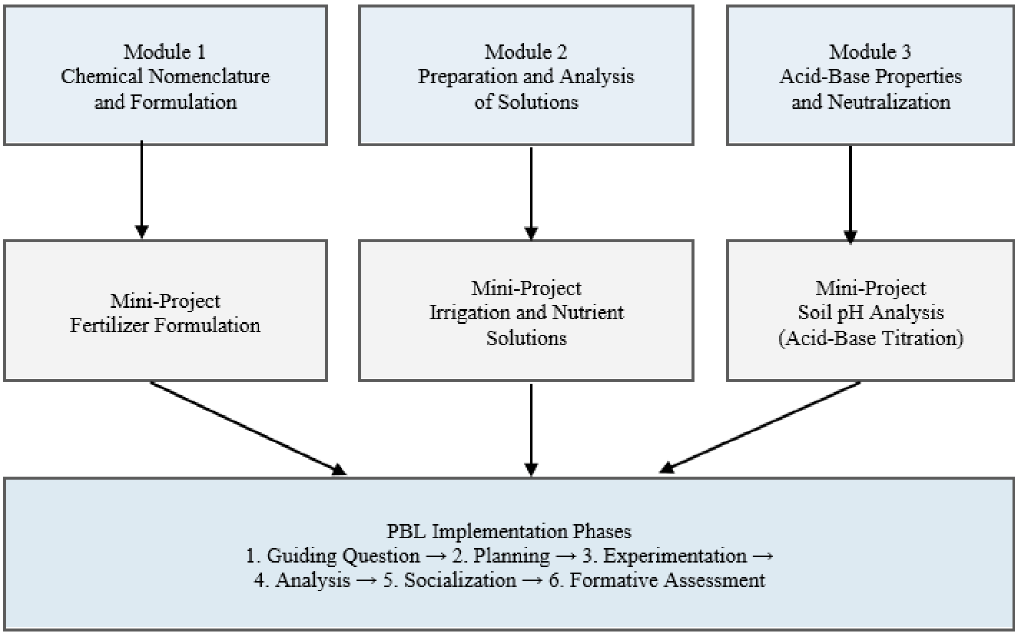
Figure 1

Conceptual model of the pedagogical intervention based on Project-Based Learning (PBL)



In the first stage, the course contents were organized into three thematic modules: (i) chemical nomenclature and formulation, (ii) preparation and analysis of solutions, and (iii) acid–base properties and neutralization processes. Each module was designed to address fundamental concepts of inorganic chemistry with emphasis on the agricultural engineering program.

In the second stage, each module was linked to an experimental mini-project related to the chemical formulation of fertilizers, preparation of irrigation and plant nutrition solutions, soil pH analysis, and acid–base titration. Finally, the Project-Based Learning approach was implemented through the formulation of a guiding question, project planning, experimentation, analysis of results, presentation of findings, and formative assessment, to ensure a progressive learning process and promote the integration of theory and practice.

2.2. Statistical analysis

Pre–post comparisons were conducted using aggregated survey data. Likert-scale items (1–5) were dichotomized into favorable responses (ratings 4–5) and non-favorable responses (ratings 1–3) to allow proportion-based analysis. Due to incomplete follow-up (pretest n = 51; posttest n = 35) and the absence of matched individual-level data, comparisons between pretest and posttest were analyzed as independent proportions. Differences in favorable response rates were evaluated using Fisher's exact test (two-sided), which is appropriate for categorical variables and unequal sample sizes. Effect sizes were reported as absolute percentage point differences (Δp = Post - Pre) with 95% confidence intervals calculated using the Newcombe/Wilson method, and risk ratios (RR) were computed to quantify the magnitude of change. To control multiple comparisons across indicators, p-values were ad-

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justed using the Holm procedure, with statistical significance established at $\alpha = 0.05$. All analyses were performed using Statgraphics Centurion (Version 16.1).

2.3. Ethical considerations

For this research, student participation was voluntary, and informed consent was obtained prior to data collection. The responses collected were anonymized and used exclusively for academic research purposes. The study was conducted in accordance with institutional guidelines for educational research and in compliance with confidentiality standards.

3. Results

Table 1 presents the comparison of responses before and after the implementation of the PBL-based instructional guide. At baseline (n = 51), favorable responses ranged between 58.82% and 84.31%. After the intervention (n = 35), these responses increased across all indicators, reaching values between 91.43% and 97.14%.

Table 1

Pre–Post comparison of favorable responses across indicators

Indicator	Pre (yes/n, %)	Post (yes/n, %)	Δp (Post/Pre)	95% CI Δp	p (Fisher)	p (Holm)	RR
Satisfaction with the laboratory's contribution to theoretical understanding	43/51 (84.31%)	34/35 (97.14%)	+12.83 pp	[-6.36; 27.50]	0.0765	0.0765	1.15
Laboratory guides promote reflection and experimental reasoning	39/51 (76.47%)	34/35 (97.14%)	+20.67 pp	[-0.53; 36.26]	0.0120	0.0360	1.27
Active participation and theory–practice integration	32/51 (62.75%)	33/35 (94.29%)	+31.54 pp	[6.71; 49.39]	0.0007	0.0044	1.50
Practical assessments facilitate the teaching–learning process	41/51 (80.39%)	34/35 (97.14%)	+16.75 pp	[-3.52; 31.95]	0.0243	0.0486	1.21
Theory–practice integration and teamwork	33/51 (64.71%)	33/35 (94.29%)	+29.58 pp	[5.03; 47.43]	0.0015	0.0059	1.46
Experimental competencies (acid–base equilibrium and critical interpretation)	30/51 (58.82%)	32/35 (91.43%)	+32.60 pp	[6.38; 51.88]	0.0012	0.0059	1.55

Note. Δp = percentage point difference (Post – Pre); CI = 95% confidence interval; RR = risk ratio. Fisherś exact test (two-sided) was used, with Holm correction for multiple comparisons. Favorable responses correspond to Likert 4–5.

The largest absolute improvement was observed in experimental competencies related to acid–base equilibrium and critical interpretation, which increased from 58.82% to 91.43% (Δp = +32.60 percentage points; 95% CI [6.38; 51.88]; p_adj = 0.0059; RR = 1.55). Similarly, active participation and theory–practice integration improved from 62.75% to 94.29% (Δp = +31.54 pp; 95% CI [6.71; 49.39]; p_adj = 0.0044; RR = 1.50), while integration of theory, practice, and teamwork increased from 64.71% to 94.29% (Δp = +29.58 pp; 95% CI [5.03; 47.43]; p_adj = 0.0059; RR = 1.46).

Improvements were also observed in students' perception that laboratory guides promoted reflection and experimental reasoning (Δp = +20.67 pp; p_adj = 0.0360; RR = 1.27) and those practical assessments

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facilitated the teaching–learning process (Δp = +16.75 pp; p_adj = 0.0486; RR = 1.21).

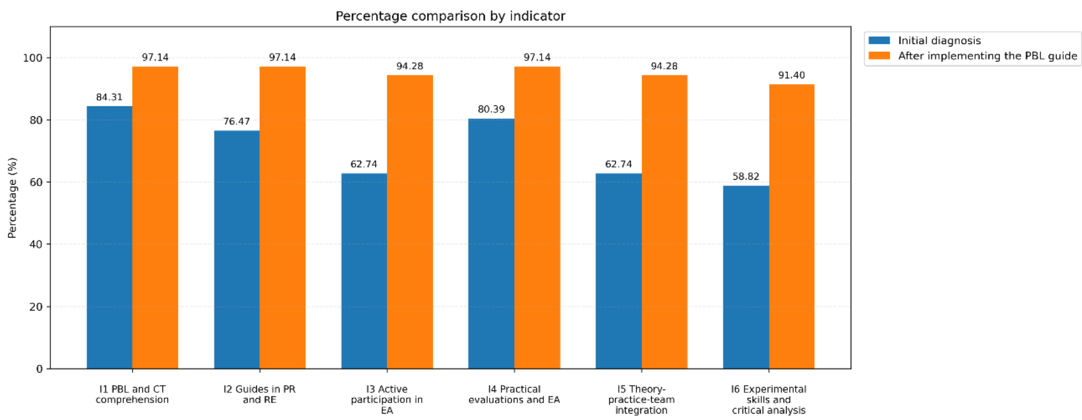
Although satisfaction with the contribution of laboratory practices to theoretical understanding increased from 84.31% to 97.14%, this change did not reach statistical significance after Holm adjustment (p_adj = 0.0765; RR = 1.15).

Overall, five out of six indicators showed statistically significant improvements following the intervention, indicating a consistent positive association between the PBL intervention and improvements in students' self-perceived experimental competencies and engagement indicators.

Figure 2 illustrates the comparison of favorable response percentages between pretest and posttest across the evaluated indicators. A consistent upward trend is observed in all variables following the implementation of the PBL-based instructional guide.

Figure 2

Comparison of pretest and posttest percentages for the evaluated variables before and after the PBL intervention



The most pronounced increases are evident in experimental competencies, active participation, and theory–practice integration, where posttest values exceed 90%, compared to baseline values below 65%. These visual differences correspond to the largest absolute percentage point gains identified in Figure 2.

Improvements are also observed in students' perception that laboratory guides promote reflection and that practical assessments facilitate learning, with posttest percentages approaching 97%. Although satisfaction with the contribution of laboratory practices was already high at baseline (84.3%), it increased further to 97.1% in the posttest, though this difference did not reach statistical significance after adjustment.

Overall, the graphical representation confirms the substantial improvement in favorable perceptions following the pedagogical intervention.

4. Discussion

The results of this study show a consistent and statistically supported improvement in most of the evaluated indicators following the implementation of the PBL-based instructional guide. Five out of six variables demonstrated statistically significant increases after Holm correction, suggesting a strong positive association between the intervention and students' self-perceived experimental competencies and engagement levels. These findings are con-

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sistent with previous research indicating that PBL promotes deeper conceptual understanding and meaningful learning in science education contexts (Ayala et al., 2020; Montesdeoca et al., 2020; Freeman et al., 2014; Chacón-Cueva et al., 2023).

The most pronounced improvement was observed in experimental competencies related to acid–base equilibrium and critical interpretation (Δp = +32.60 pp; p_adj = 0.0059; RR = 1.55). This substantial increase indicates that students not only perceived greater mastery of laboratory procedures but also reported enhanced analytical abilities in interpreting experimental results. This outcome aligns with studies showing that project-based methodologies strengthen scientific reasoning and analytical capacity in experimental environments (Ayala et al., 2020; García et al., 2022; Sosa et al., 2025). The confidence interval [6.38; 51.88] further supports the consistency of this improvement, reinforcing the pedagogical relevance of contextualized experimentation within PBL.

Similarly, active participation and theory–practice integration increased from 62.75% to 94.29% (Δp = +31.54 pp; p_adj = 0.0044; RR = 1.50). This result suggests that the intervention contributed to shifting students from passive procedural execution toward more engaged and reflective laboratory involvement. This finding is consistent with research criticizing traditional laboratory approaches centered on mechanical replication of procedures, which tend to limit reflective reasoning and meaningful learning (Ayala et al., 2020; Acosta et al., 2019). A comparable pattern was observed in theory–practice integration and teamwork (Δp = +29.58 pp; p_adj = 0.0059; RR = 1.46), highlighting the collaborative dimension of the mini-projects and their contribution to strengthening collective problem-solving processes, in line with project-based and collaborative learning models (Davidson et al., 2014; Mera et al., 2026).

Moderate but statistically significant improvements were also identified in students' perception that laboratory guides promoted reflection and experimental reasoning (Δp = +20.67 pp; p_adj = 0.0360; RR = 1.27) and that practical assessments facilitated the teaching–learning process (Δp = +16.75 pp; p_adj = 0.0486; RR = 1.21). These results support prior research emphasizing that inquiry-based and contextualized laboratory experiences enhance scientific competence development (García et al., 2022; Sosa et al., 2025; Guanotasig et al., 2025).

Although overall satisfaction with the laboratory's contribution to theoretical understanding increased numerically (Δp = +12.83 pp), this difference did not reach statistical significance after correction for multiple comparisons (p_adj = 0.0765). This outcome may reflect a ceiling effect, given that baseline satisfaction was already high (84.31%). When initial values approach upper limits, statistical capacity to detect additional improvements becomes restricted. Therefore, the absence of statistical significance in this variable does not necessarily imply a lack of pedagogical benefit but rather limited variability within the sample.

Figure 2 reinforces these interpretations. Post test percentages exceeded 90% across all indicators, while several baseline values were below 65%. This consistent upward trend confirms the internal coherence and magnitude of the observed improvements.

From a theoretical perspective, the strongest gains were concentrated in higher-order cognitive dimensions: analysis, integration, and application rather than general satisfaction. This pattern is consistent with constructivist and experiential learning frameworks, which posit that knowledge is consolidated when learn-

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ers actively engage in authentic problem-solving situations (Díaz & Hernández, 2003; Morales, 2009). Furthermore, the strengthened integration between theory and practice observed in this study supports prior evidence identifying contextualization as a key determinant of meaningful learning in chemistry education (Baque-Reyes & Portilla-Faican, 2021; López, 2025; Carchipulla & Guevara, 2022).

The observed increase in active participation and teamwork is also consistent with studies indicating that PBL fosters transversal competencies such as communication, collaboration, and decision-making (Vázquez et al., 2025; Laal & Ghodsi, 2012). These competencies are essential in contemporary professional training and applied scientific environments.

Nevertheless, due to the quasi-experimental design and the absence of a control group, the findings should be interpreted as associative rather than definitive causal evidence. The reduction in posttest sample size (n = 35) and reliance on self-reported perceptions also limit generalizability. Future research incorporating objective performance indicators, more rigorous experimental designs, and longitudinal follow-up would strengthen the empirical evidence.

Overall, the magnitude of the observed changes—particularly in experimental competencies (RR = 1.55), active participation (RR = 1.50), and theory–practice integration (RR = 1.46)—suggests that contextualized laboratory PBL may contribute to transforming laboratory environments from predominantly procedural settings into competence-oriented learning ecosystems in applied higher education contexts (Statgraphics.com, 2013).

5. Conclusions

- The design and implementation of a Project-Based Learning (PBL) based instructional guide in inorganic chemistry laboratory practices at the State Polytechnic University of Carchi was associated with improvements in students' active participation, motivation, and theory–practice integration.
- The organization of laboratory activities into thematic modules and mini-projects strengthened conceptual understanding, particularly in acid–base equilibrium analysis. In addition, it facilitated the transfer of knowledge to real-world agricultural applications, promoting the development of scientific and interdisciplinary competencies.
- Finally, the intervention contributed to redefining the roles of both faculty and technical staff, shifting from a content-centered approach toward facilitation, mediation, and collaborative guidance, thereby consolidating an active and interdisciplinary learning environment focused on the development of professional and transversal competencies.

6. Conflict of Interest

The authors declare that there is no conflict of interest regarding the submitted article.

7. Authors' Contribution Statement

All authors made significant contributions to the preparation of this article.

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9. References

Internal links to figures and tables: Figure 1; Table 1; Figure 2.

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Acosta, D. E., Ramírez, N. E., Villanueva, B. M., Zamora, S.E. (2019) Desarrollo de una experiencia de transversalidad: del laboratorio a la planta piloto [V Jornadas de Innovación Educativa de la Facultad de Ingeniería, Universidad Nacional de Jujuy]. https://ri.conicet.gov.ar/handle/11336/226885

Ayala Cabrera, J., Pérez Ràfols, C., Núñez Burcio, O., & Serrano i Plana, N. (2020). Implementación del aprendizaje basado en proyectos en laboratorios de química analítica del grado de química. Avances en Ciencias e Ingeniería, 11(2), 31-40. https://diposit.ub.edu/items/09d47fbc-4987-436d-830c-ac251a6245d3

Baque-Reyes, G. R., & Portilla-Faican, G. I. (2021) El aprendizaje significativo como estrategia didáctica para la enseñanza–aprendizaje. Polo del Conocimiento, 6(5), 75–86. https://dialnet.unirioja.es/servlet/articulo?codigo=7927035

Caizaluisa Calahorrano, L. V., Sumba Agila, V. J., & Recalde García, F. A. (2024). Aprendizaje basado en proyectos en el desarrollo de la comprensión lectora del inglés. Conciencia Digital, 7(4), 6-28. https://doi.org/10.33262/concienciadigital.v7i4.3209

Carchipulla Altamirano, C. L., & Guevara Vizcaíno, C. F. (2022). Laboratorios virtuales para fortalecer el aprendizaje de la química en segundo de bachillerato. Ciencia Digital, 6(4), 137-154. https://doi.org/10.33262/cienciadigital.v6i4.2340

Chacón-Cueva, J. J., Duran-Llaro, K. L., Chacón-Cueva, G. M., & Bustamante-Castrejón, D. C. (2023). Aprendizaje basado en problemas para desarrollar el pensamiento crítico en estudiantes de secundaria - 2023. Revista Arbitrada Interdisciplinaria Koinonía, 8(Supl. 2), 350-370. https://doi.org/10.35381/r.k.v8i2.2880

Chica Sánchez, M. J., Herrera Pérez , M. I., & Cisneros Quintanilla, P. F. (2022). Aprendizaje basado en proyectos como estrategia innovadora para el fortalecimiento de la lectura comprensiva. Conciencia Digital, 5(4), 56-72. https://doi.org/10.33262/concienciadigital.v5i4.2352

Davidson, N., Howell Major, C., & Michaelsen, L. (2014). Small-group learning in higher education cooperative, collaborative, problem-based, and team-based learning: An introduction by the guest editors. Journal on Excellence in College Teaching, 25(3 & 4). https://celt.miamioh.edu/index.php/JECT/article/view/451

Díaz Arcero, F. D., & Hernández Rojas, G. (2003). Estrategias docentes para un aprendizaje significativo: una interpretación constructivista. McGraw-Hill. https://books.google.com.ec/books/about/Estrategias_docentes_para_un_aprendizaje.html?hl=es&id=vAd6AAAACAAJ&redir_esc=y

Espinosa-Ríos, E. A., González-López, K. D., & Hernández-Ramírez, L. T. (2016). Las prácticas de laboratorio: una estrategia didáctica en la construcción de conocimiento científico escolar. Entramado, 12(1), 266–281. https://dialnet.unirioja.es/servlet/articulo?codigo=5755305

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences of the United States of America, 111(23), 8410–8415. https://pubmed.ncbi.nlm.nih.gov/24821756/

García, L. O., García, I. S., Monasterio, R., Rodríguez, P. R., & Pancorbo, A.

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C. (2022). Implementación del aprendizaje basado en proyectos en la enseñanza de química analítica: un caso práctico. Educar para transformar: Innovación pedagógica, calidad y TIC en contextos formativos, 2836–2846. https://dialnet.unirioja.es/servlet/articulo?codigo=8876633

Guanotasig Cambizaca, C. M., Jaramillo Rivadeneira, L. F., Lasso Poveda, E. V., & Samaniego Loja, J. M. (2025). Aprendizaje basado en proyectos en la educación inicial: una didáctica activa para la formación integral desde territorio. Ciencia Latina Revista Científica Multidisciplinar, 9(5), 14166-14177. https://doi.org/10.37811/cl_rcm.v9i5.20572

Laal, M., & Ghodsi, S. M. (2012). Benefits of collaborative learning. Procedia, Social and Behavioral Sciences, 31, 486–490. https://www.sciencedirect.com/science/article/pii/S1877042811030205

López González, W. O. (2025). Química y futuro: los grandes retos científicos que la educación superior debe enfrentar. Páginas Brillantes Ecuador. https://www.paginasbrillantesecuador.com/editorial/public/detail/54

Lucero Borja, N., & Velasteguí López, L. E. (2018). Aprendizaje basado en proyectos y el rendimiento académico de los estudiantes de la Unidad Educativa Pasa. Ciencia Digital, 1(2), 52-65. https://doi.org/10.33262/cienciadigital.v1i2.57

Matilainen, R., Nuora, P. & Valto, P. (2021). Student experiences of project-based learning in an analytical chemistry laboratory course in higher education. Chemistry Teacher International, 3(3), 229-238. https://doi.org/10.1515/cti-2020-0032

McKeachie, W., & Svinicki, M. (2010). McKeachie's teaching tips: strategies, research, and theory for college and university teachers. Cengage Learning, 2010 https://books.google.com.ec/books?id=TRgFAAAAQBAJ&printsec=frontcover&source=gbs_atb

Mera Nevárez, E. del S., Cedeño Cedeño, A. J., Quispe Guanoluisa, V. M., Ramírez Maldonado, L. A., Jaramillo Quezada, M. E., & Barre Moreira, J. J. (2026). Aprendizaje basado en proyectos (Abp): una estrategia para conectar el aula con la vida real. Revista Científica Multidisciplinaria Tsafiki, 1(1), 12–22. https://revista-tsafiki.org/index.php/revista/article/view/72

Montaño Sevillano, J. O., Peña Reascos, B. F., Velasteguí López, E., & Tapia Batidas, T. (2025). Aprendizaje basado en proyectos con Genially mediante la creación de contenidos para estudiantes de bachillerato. Explorador Digital, 9(4), 6-24. https://doi.org/10.33262/exploradordigital.v9i4.3543

Montesdeoca Esponda, S., Santana Viera, S., Guerra Santana, M. F., Rodríguez Pulido, J., & García Giménez, P. (2020). Aula invertida y aprendizaje basado en proyectos para aprender química: aplicación en prácticas de laboratorio del grado en ciencias del mar. Tendencias Metodológicas en Innovación Educativa / David de la Cruz Sánchez Rodríguez (coord.), Capítulo 6, 123-143. https://accedacris.ulpgc.es/handle/10553/74568

Morales Bueno, P. (2009). Uso de la metodología de aprendizaje basado en problemas (ABP) para el aprendizaje del concepto de periodicidad química en un curso de química general. Revista de la Sociedad Química del Perú, 75(1), 130–139. https://dialnet.unirioja.es/servlet/articulo?codigo=9565403

Muñoz Beriguete, I., & Ramírez Navarro, H. M. (2024) Diseño y aplicación de prácticas de laboratorio para la construcción del conocimiento de la

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química en educación secundaria [Tesis de pregrado, Universidad Nacional Pedro Henríquez Ureña, Santo Domingo, República Domenicana]. https://repositorio.unphu.edu.do/handle/123456789/6195

Núñez De Luca, J. M., Gallegos Robles, J. M., Suárez Ibujés, M. O., & Santillán Tasigchana, M. A. (2025). Optimización del aprendizaje conceptual y práctico en matemáticas, física y química mediante la implementación de tecnologías digitales y estrategias de gamificación en la educación superior. Revista Social Fronteriza, 5(3). https://doi.org/10.59814/resofro.2025.5(3)707

Ojeda Salvatierra, R. D. R., Guiñanzaca Vaca, J. E., Medina Navarro, A. M., López Becerra, E., & Wong Dillon, A. I. (2025). Innovaciones en la enseñanza de la química en educación media: integración de realidad aumentada y aprendizaje basado en proyectos para mejorar la comprensión y el interés estudiantil. Revista Iberoamericana de la Educación, 9(2), 118–140. https://doi.org/10.31876/rie.v9i2.308

Quiñónez Barrezueta, J. E., Pozo Hurtado, E. O., Jácome Encalada, S. H., & Reigosa Lara, A. (2025). Problem-based learning for teaching process through the Chamilo platform. Ciencia Digital, 9(2), 111-127. https://doi.org/10.33262/cienciadigital.v9i2.3483

Sosa Cortez, K. R., Tenorio Ordóñez, D. J., Pico Holguín , B. M., Yuquilema Carrillo, S. T., & Benalcázar Samaniego, L. G. (2025). El aprendizaje basado en proyectos (Abp) como herramienta para el desarrollo de habilidades del siglo XXI. Ciencia Latina Revista Científica Multidisciplinar, 9(1), 6133-6148. https://doi.org/10.37811/cl_rcm.v9i1.16329

Statgraphics.com. (2013). Downloads: Statgraphics Centurion XVI. https://www.statgraphics.com/download-statgraphics-centurion-xvi

Vázquez Arango, M. de L., Martínez, R., Ramírez Castillo, E. A., & Parraga Mendoza, R. R. (2025). Desarrollo de la comunicación efectiva, el trabajo colaborativo y la capacidad para la resolución de problemas, a través del aprendizaje basado en proyectos, como estrategia para fortalecer las competencias transversales en estudiantes de educación superior. Reincisol, 4(7), 3846–3869. https://doi.org/10.59282/reincisol.V4(7)3846-3869

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