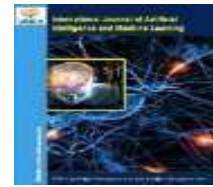




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Active Pedagogical Strategies in the Training of Civil Engineers: A Systematic Review

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ABSTRACT

Civil engineering education for public works projects faces pedagogical and curricular challenges. Given this context, this study aims to analyze active pedagogical strategies in civil engineering education through a systematic review. Methodologically, this study employs a qualitative approach with a documentary research methodology based on the guidelines established by the PRISMA systematic review protocols. Nineteen research studies were selected for the sample. The results show that active methodologies improve academic performance. It is concluded that active strategies are superior, but their impact is contingent upon comprehensive curricular reforms that update the content.

Keywords: Strategies, pedagogy, training, engineers, teaching.

1. Introduction

Among all engineering disciplines, civil engineering is one of the most important for civilization, since it provides the theoretical and practical foundation needed to build housing, buildings, bridges, roads, and other infrastructure. However, despite its importance, its teaching remains anchored in encyclopedism and memorization, which creates difficulties in developing practical competencies and solving complex problems in real infrastructure contexts. In this regard, Araya et al. (2023) indicate that many civil engineering students have difficulty relating theory to real situations, owing to the predominance of traditional methodologies centered on memorization rather than active learning. For Buffa et al. (2021), the traditional conceptions held by some instructors limit pedagogical innovation in engineering, affecting meaningful learning and the development of critical thinking among students. In addition, Salas et al. (2021) note that academic programs still have limitations in adequately assessing professional competencies.

In a constantly evolving society, where emerging technologies such as artificial intelligence are setting the professional standard, universities must stay at the forefront and equip students with competencies that allow them to make decisions in the workplace. On the other hand, Zhang et al. (2021) note that civil engineering schools face difficulties incorporating emerging technologies such as artificial intelligence and intelligent systems into students' professional training. It should be noted that, according to Domínguez et al. (2021), equipping students with technological competencies strengthens the teaching-learning process in civil engineering, because technology allows problems to be solved with greater precision—for example, through computational simulations it is possible to introduce variables such as wind, temperature, humidity, and tectonic faults, among others, and to anticipate how infrastructure will behave under the simulated conditions.

In order to achieve these changes, universities are called upon to update curricula that in many cases date back to the last century; although these curricula met the challenges of their historical moment, they have become outdated in the face of current changes. In this regard, Salinas (2022) argues that civil engineering education faces barriers related to educational quality, the lack of curricular updating, and weaknesses in the ethical and professional training of future engineers. Quintero et al. (2022) point out that civil engineering teaching still relies on pedagogical practices poorly adapted to the new professional demands of the construction sector. Given this reality, the present study aims to analyze active pedagogical strategies in the training of civil engineers through a systematic review. Civil engineering teaching related specifically to road construction was selected, because research on the teaching of this discipline and area of study is scarce, and the aim is therefore to analyze the findings identified.

Moreover, students' weaknesses are not limited to curricular design: according to Echazarreta & Haudemand (2009), many civil engineering students have difficulties in basic courses such as Physics owing to poorly contextualized methodologies that are far removed from the profession's real problems. Given this context, Gutiérrez (2023) states that one of the current challenges in civil engineering education is integrating cross-cutting competencies, collaborative work, and complex thinking into university educational processes. Building on these requirements, Andrić et al. (2026) note that strategies such as problem-based learning increase the motivation, engagement, and academic results of civil engineering students, especially in international and technological contexts. On the other hand, Ortiz (2021) states that active learning strategies improve spatial visualization, structural analysis, and the practical understanding of content, fostering a more applied and meaningful education for future engineers.

Guaranda et al. (2023) explain that the teaching-learning process in civil engineering requires interdisciplinary approaches and contextualized didactic strategies that respond to current professional needs. In this sense, González (2024) argues that civil engineering students' spatial understanding and critical thinking can be achieved by improving the application of technical knowledge in real contexts.

Hence the importance of maintaining the theory-practice relationship. Among other strategies, Miller et al. (2024) indicate that methodologies such as project-based learning and the flipped classroom increase academic performance and develop fundamental professional competencies in civil engineering. However, these strategies will have no impact on student education unless instructors integrate learning theories and currents such as meaningful learning and constructivism into the classroom, because, for Das (2021), constructive alignment fosters deep learning among civil engineering students by appropriately integrating learning objectives, didactic strategies, and formative assessments. Meaningful learning, in turn, allows the student to participate in learning through anchoring ideas, starting from a familiar environment or concept to build new knowledge. For Novkovic et al. (2026), learning in higher education is called upon to improve student engagement, conceptual understanding, and the development of the analytical skills needed for professional practice. Given these requirements, the question arises: what are the active pedagogical strategies in the training of civil engineers from a systematic review?

2. Methodology

This study is framed within a qualitative approach using a documentary research design, following the guidelines established for systematic reviews as explained by Higgins et al. (2023), who describe a systematic review as a type of scientific study that uses systematic and explicit methods to identify, select, and critically appraise all research relevant to a given question, with the aim of providing a complete, unbiased, and reproducible synthesis of the available evidence, based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocols, which consist of a checklist of minimum items designed to help authors prepare and report the protocol of a systematic review or meta-analysis in a structured and complete manner (Estarli et al., 2016). Based on the PRISMA protocols, the following phases were established:

Identification phase

This initial stage involves searching for and compiling all potentially relevant literature, in this case related to road construction. The sources consisted of two main types: records from academic databases—an initial total of 260 records were located from scientific platforms—and records from other sources, with an additional 40 records identified from gray literature and other alternative platforms such as university repositories, theses, and specialized journals published between 2021 and 2026. As a result of this phase, an initial pool of 300 total records was identified.

Screening phase

In this phase, duplicates were removed and a quick review of titles and abstracts was conducted to discard clearly irrelevant studies. This phase applies a first, coarse filter to eliminate duplicate works and those that clearly did not match the topic. Of the 300 initial records, 52 duplicate records were detected and excluded, leaving a total of 248 unique records to be assessed. Title-and-abstract filter: these 248 records were assessed by reading only their titles and abstracts. Following this reading, 168 records were excluded because they fell outside the road-construction area or the required pedagogical focus. Phase result: a total of 80 articles passed this filter and moved on to the next stage for full-text review.

Eligibility phase

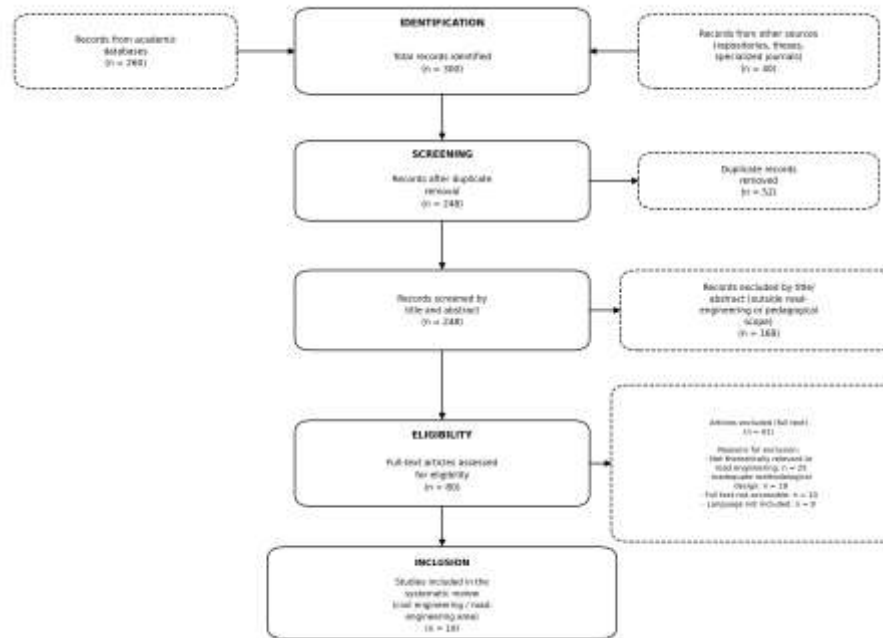
The full text of the articles was assessed to determine whether they met the inclusion criteria established for the review. That is, a much deeper and more critical analysis was conducted on the studies that survived screening, assessing the full articles against rigorous inclusion and exclusion criteria. The 80 full-text articles were subjected to eligibility assessment. After careful reading, 61 articles were discarded

for specific methodological and theoretical reasons: 18 studies did not meet the expected scientific rigor or design, 10 records could not be retrieved in full for reading, and 8 articles were published in languages not considered under the review's criteria (language not included).

Inclusion phase

At this stage, the studies that passed all previous phases were finally included in the systematic review; it was determined that 19 studies fully met all the criteria.

Figure 1. Sample resulting from the execution of the PRISMA protocols



3. Results

Table 1. Findings identified in the sample selected using the PRISMA protocols

Author(s)	Title	Type of research	Findings (Summary for Excel)
Boza & Silva (2024)	Methodological considerations for developing the road design project in the Civil Engineering program. University of Holguín, Cuba	Article	Project-based learning improves competent professional performance in construction companies.
Valdés et al. (2024)	Continuing education of civil engineers in the road-engineering track	Article	Learning is limited by the dispersion of content and outdated bibliography in the road-engineering field.
Páez (2023)	The teaching of bridge engineering in engineering schools. A critical perspective	Article	The Bridges course is usually an elective; it is mandatory in fewer than 5% of accredited institutions.
Valdés et al. (2025)	Study material for asphalt mix design in road construction	Article	Teaching aids and pedagogical foundations stimulate self-directed learning in road structures.
Herrera (2024)	Pedagogical Competencies and Meaningful Learning among students of the Faculty of Civil Engineering of the National University of Engineering – Lima, 2022	Article	There is a positive relationship between teaching competencies and the increase in students' meaningful learning.
Horna (2024)	Methodological strategy to improve the academic performance of students in the construction course of the Civil	Article	A four-phase strategy (from introduction to assessment) improves performance in construction courses.

Author(s)	Title	Type of research	Findings (Summary for Excel)
	Engineering program at a university in Huacho		
Aguilar (2024)	Influence of problem-based learning on the development of the experimentation-and-testing competency in the Soil Mechanics I course among civil engineering students, Lima, 2024	Thesis	PBL positively influences the development of experimentation competencies in Soil Mechanics.
García (2025)	Improving civil engineering education through innovative STEM-based prototypes: a comparative study of physical models and board games in road geometric design	Article	The use of physical models and board games highlights the value of creativity and teamwork in road design.
García (2021)	Active learning techniques in remote learning: a case study in road design courses in Ecuador	—	Remote active learning reduces the failure rate and improves the learning experience (grade > 8.9).
Vargas et al. (2022)	Strategies for University Teaching in Civil Engineering Applying PBL for Better Academic Performance	Article	PBL increased the pass rate from 58% to 73% compared with the traditional method.
Goncharova (2024)	Educational and professional potential of advanced training courses in the field of road construction	Article	The potential of the professional education system to create advanced training courses in road engineering was identified.
Edmondson & Sherratt (2022)	Engineering judgment in undergraduate structural design education: enhancing learning with failure case studies	Article	The use of structural failure cases deepens students' inquiry and critical judgment.
Oller et al. (2024)	Effectiveness of project-based learning in a civil engineering reinforced concrete course	Article	Applying the PBL strategy directly increases motivation and summative assessment results.
Almeida et al. (2024)	Incorporating building information modeling into the construction field: a case within an undergraduate civil engineering program	Article	A six-mechanism methodology was established for implementing BIM, including faculty training and projects.
Norashikin et al. (2025)	Mapping ESD competencies in civil engineering: a scoping review	Article	A clear mapping framework aligns the curriculum with sustainability and improves graduates' readiness.
Torres et al. (2022)	Didactic attributes of rubrics in civil engineering education: a perspective from Statics	Article	Rubrics must articulate theoretical and sociocultural elements to fulfill their formative function in Statics.
Batista et al. (2023)	Didactic Strategy to Foster the Development of Research Competency in Civil Engineers	Article	The didactic strategy is feasible and fosters the development of student performance across various assessment stages.
Gutiérrez (2023)	Developmental Competency-Based Learning in Civil Engineering: Addressing Complexity and Cross-Cutting Themes	Article	It is crucial to address cross-cutting themes and complexity to prepare engineers for future challenges.
Quinan & Sierra (2024)	Active learning methods for BIM in construction management and parameters for its implementation: a systematic review	Article	The most common combination of active methods for teaching construction management through BIM was identified.

Source: Own elaboration

The literature review reveals a clear trend toward active, contextualized teaching methodologies in civil engineering education, particularly applicable to the public construction sector. Project-based learning (PBL) and problem-based learning emerge as the most effective and recurrent strategies. Boza & Silva (2024) and Oller et al. (2024) agree that PBL improves both competent professional performance and motivation and summative results, while Vargas et al. (2022) quantify an increase in pass rates from 58% to 73% compared with traditional methods. Along the same lines, Aguilar (2024) confirms the positive

influence of PBL on experimental competencies in Soil Mechanics, a key course for public works. The incorporation of technologies such as BIM also shows promising results: Almeida et al. (2024) propose a six-mechanism methodology that includes faculty training and integrative projects, and Quinan & Sierra (2024) identify combinations of active methods for teaching construction management through BIM. Nevertheless, structural limitations persist. Valdés et al. (2024) warn that the dispersion of content and outdated bibliography restrict learning in the road-engineering field, and Páez (2023) reports that bridge-engineering instruction is an elective in more than 95% of accredited institutions, creating a critical gap for public infrastructure. In response, complementary strategies such as the use of prototypes and board games (García, 2025), remote active learning that reduces failure rates (García, 2021), and the study of structural failure cases (Edmondson & Sherratt, 2022) prove effective for developing critical judgment and creativity. At the pedagogical level, Herrera (2024) establishes a positive relationship between teaching competencies and meaningful learning, while Horna (2024) proposes a strategy structured in four phases (from introduction to assessment) that improves performance in construction courses. In addition, Torres et al. (2022) point out that rubrics must articulate theoretical and sociocultural elements to fulfill their formative function, and Batista et al. (2023) validate a didactic strategy to foster research competency. Finally, Gutiérrez (2023) and Norashikin et al. (2025) emphasize the need to address cross-cutting themes, complexity, and sustainability in the curriculum, aligning education with the real challenges of public construction. Taken together, the findings indicate that civil engineering education requires a decisive shift toward active, flexible methodologies, with ongoing content updates, pedagogical training for faculty, and the integration of BIM technologies, since only in this way will graduates be competent to design, build, and maintain quality public infrastructure.

Table 2. Thematic distribution of studies on civil engineering education

No.	Thematic category	Studies addressing it	Description
1	Project- and problem-based learning (PBL)	1, 7, 10, 13	Analyze how PBL strengthens practical learning, problem-solving, and academic performance in civil engineering.
2	Pedagogical innovation and active learning	8, 9, 12, 17	The studies highlight active methodologies, physical models, case studies, and dynamic tools to improve road-engineering learning.
3	Professional competencies and meaningful learning	2, 5, 11, 18	Focus on the development of professional competencies, critical thinking, and meaningful learning among civil engineering students.
4	Technological integration and BIM	14, 19	Highlight the incorporation of BIM and digital tools as modern teaching strategies in construction and project management.
5	Faculty training and curricular updating	2, 3, 15	Point to curricular limitations, outdated content, and the need for ongoing faculty training in the road-engineering field.
6	Assessment and didactic strategies	6, 16, 17	Analyze rubrics, methodological strategies, and pedagogical resources that foster academic performance and well-rounded education.
7	Sustainability and curricular cross-cutting themes	15, 18	Propose integrating sustainability, cross-cutting themes, and global competencies into civil engineering education.
8	Road engineering education and transport structures	3, 4, 8, 12	Address specialized content such as bridges, asphalt mixes, geometric design, and road structures.

Source: Own elaboration

The table compiles the studies (mostly articles, one thesis) focused on teaching-learning strategies for civil engineering, with an implicit emphasis on public construction (roads, bridges, structures, road engineering). The findings show clear effectiveness of active methodologies: Project-Based Learning (PBL) emerges as the most validated strategy. Boza & Silva (2024) report improved competent professional performance; Oller et al. (2024) associate PBL with greater motivation and better summative results; Vargas et al. (2022) quantify an increase in pass rates from 58% to 73% compared with the traditional method. Problem-Based Learning also has a positive influence on experimental competencies (Aguilar, 2024, in Soil Mechanics). These convergent findings reinforce that active learning, centered on real public-infrastructure problems, is superior to traditional lecture-based teaching.

However, important structural limitations are identified. Valdés et al. (2024) report content dispersion and outdated bibliography in the road-engineering field, which hinders learning. Páez (2023) highlights a critical finding: the Bridges course is an elective in more than 95% of accredited institutions, creating a dangerous gap in public-construction training. This suggests that pedagogical innovations collide with rigid, outdated curricula.

Other complementary strategies show promising results. García (2025) demonstrates that physical prototypes and board games in road design foster creativity and teamwork. García (2021) reports that remote active learning reduces the failure rate and achieves grades above 8.9. Edmondson & Sherratt (2022) point out that the study of structural failure cases deepens critical judgment. The incorporation of BIM (Building Information Modeling) is another relevant axis: Almeida et al. (2024) propose a six-mechanism methodology (including faculty training and integrative projects), and Quinan & Sierra (2024) identify combinations of active methods for teaching construction management with BIM.

At the pedagogical level, Herrera (2024) finds a positive relationship between teaching competencies and meaningful learning. Horna (2024) proposes a four-phase strategy (from introduction to assessment) that improves performance in construction courses. Torres et al. (2022) point out that rubrics must articulate theoretical and sociocultural elements to be formative. Batista et al. (2023) validate a didactic strategy for research competency. Finally, Gutiérrez (2023) and Norashikin et al. (2025) emphasize the need for cross-cutting themes, complexity, and sustainability in the civil engineering curriculum, aligning it with the real challenges of public construction.

Taken together, the analysis reveals a dual reality: effective, validated strategies exist (PBL, BIM, remote active learning, board games, failure case studies), but their effective implementation is limited by curricular factors (elective status of key courses, outdated bibliography, lack of faculty pedagogical training). Public construction demands engineers capable of solving complex problems, with critical judgment and command of technologies such as BIM; the results indicate that active methodologies are the way forward, but they require systemic change within engineering schools.

4. Conclusions

The evidence consistently reviewed across both analyses supports the conclusion that teaching-learning strategies based on active, contextualized methodologies are unequivocally superior for civil engineering education oriented toward public construction. Project-Based Learning, Problem-Based Learning, the use of prototypes, board games, structural failure case studies, and remote active learning have all been shown to improve academic performance, motivation, critical judgment, teamwork, and professional competencies. The incorporation of BIM and curricular sustainability emerge as urgent, non-deferrable needs.

However, the conclusions must also point to a worrying structural barrier: the persistent outdatedness of content, curricular dispersion, and the elective status of fundamental courses (such as Bridges) in more than 95% of accredited institutions. This indicates that pedagogical innovations alone are not enough unless accompanied by profound curricular reform, ongoing bibliographic updating, pedagogical training for faculty, and institutional policies that make competencies critical to public infrastructure mandatory. The final recommendation is therefore twofold: to massively adopt active methodologies (PBL, problem-based learning, integrated BIM, assessment with formative rubrics) and, simultaneously, to revise curricula to eliminate fragmentation, update references, mainstream sustainability, and ensure that courses that are key to public construction (bridges, road engineering, soil mechanics, structures) are made mandatory. Only a combination of innovative didactic strategies and a coherent, up-to-date curriculum will produce graduates competent to face the real challenges of public construction in the 21st century.

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