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Active Learning Approaches in Numerical Methods for Civil Engineering Students

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Abstract

The teaching of Numerical Methods within engineering mathematics curricula has long been dominated by lecture-based instruction focused on algorithmic exposition and formal mathematical derivations. While this approach ensures theoretical rigor, it frequently fails to convey the practical relevance of numerical techniques to civil engineering students, who often struggle to connect iterative computational procedures with the structural, geotechnical, and thermal problems they encounter in their professional training. This disconnect contributes to reduced student motivation, passive learning behaviors, and limited capacity to apply numerical tools independently in authentic engineering contexts. This paper presents the design, implementation, and evaluation of active learning strategies integrated into a Numerical Methods course delivered to civil engineering students at the Technical University of Civil Engineering Bucharest (UTCB). The central argument is that active learning methodologies, when carefully aligned with the mathematical content of numerical analysis and grounded in recognizable civil engineering applications, can significantly improve both conceptual understanding and student engagement. The study is grounded in constructivist and student-centered learning theory, which positions the learner as an active constructor of knowledge rather than a passive recipient of algorithmic procedures. Three active learning strategies were designed and implemented within the course structure. The first strategy applied project-based learning to core numerical topics including linear system solving, polynomial interpolation, and finite element approximations, using authentic problems drawn from structural analysis and materials resistance typical of civil engineering practice. Student teams were required to formulate the engineering problem mathematically, select and implement an appropriate numerical method, and interpret the results within realistic engineering constraints. The second strategy employed problem-based learning centered on numerical solutions of ordinary and partial differential equations, with applications in thermal conduction through building materials and soil settlement modeling. Students were presented with open-ended, ill-structured problems that required iterative refinement of both the mathematical model and the numerical approach. The third strategy integrated computational tools, specifically Python, MATLAB, and GeoGebra, as active exploration environments in which students could experiment with algorithm parameters, visualize convergence behavior, and compare the performance of alternative numerical schemes in real time. The implementation was carried out with two parallel student cohorts enrolled in the Numerical Methods course at UTCB. One cohort followed the conventional instructional model based on formal derivations and standard textbook exercises, while the second cohort engaged with the active learning strategies described above. Student performance was assessed through a common written evaluation covering problem formulation, method selection, computational accuracy, and result interpretation. A structured feedback questionnaire employing a five-point Likert scale was administered to both cohorts to measure perceptions of relevance, motivation, confidence, and conceptual clarity. Attendance rates across the intervention period were recorded as a supplementary indicator of engagement. The results indicate that students

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in the active learning cohort demonstrated stronger performance in problem formulation and result interpretation, while showing significantly higher levels of motivation and perceived relevance of numerical methods to civil engineering practice. Notably, these students exhibited greater flexibility in selecting and adapting numerical methods when problem conditions were varied, suggesting deeper procedural and conceptual understanding compared to the control cohort. These findings support the systematic integration of active learning strategies into Numerical Methods courses at technical universities, particularly when instructional design explicitly connects mathematical content to authentic engineering scenarios. The paper concludes with recommendations for mathematics educators and curriculum designers seeking to embed active learning into Numerical Methods teaching, and discusses the institutional and logistical conditions under which such approaches are most effective. Limitations of the present study and directions for future research, including the extension of active learning strategies to advanced topics such as finite difference methods, numerical optimization, and stochastic simulation, are also addressed.

***K*eywords** numerical methods · active learning · civil engineering education · project-based learning · computational tools · engineering mathematics

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