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Methodological teaching-learning experiments applied to Geotechnical Engineering

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Article

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Abstract

The use of problem-based and project-based learning is beneficial. The teaching-learning process requires the development of a critical, objective, and rational mind. This paper analyzes methodological experiments from the teaching-learning process carried out in the geotechnical area of the civil engineering program at three universities in the state of Pernambuco, Brazil, for more than 40 years. Three integrated experiments are presented. In the first experiment, undergraduate students in geotechnical engineering courses interacted with companies operating in the area, conducting laboratory and field tests and geotechnical instrumentation. The second experiment integrated students and teachers from different areas of the civil engineering program around a multidisciplinary project, while the third brought together undergraduate and graduate (master and doctoral) student research activities into a single project that extends from the development and construction of geotechnical equipment and applications of new soil improvement techniques to land use planning and occupation. This study shows the use of teaching-learning experiences carried out in geotechnical engineering, contributing to the development of technical skills and professional competencies of civil engineers. It contributed to the advancement of knowledge in the development of new equipment, soil improvement, testing techniques and in the use, planning and occupation of soils. The interaction between the university, society and government institutions in problem solving also contributed.

1. Introduction

The soil formations found in the city of Recife, the capital of the state of Pernambuco, Brazil, are the result of several geological events that gave rise to a morphology composed of two distinct topographic sets: the basins or plains that occupy the central-eastern portion and the contiguous hills that dominate the northern portion and surround the city to the west and south (Ferreira, 1982; Alheiros et al., 1990). The central urban core sits on a fluvial-marine alluvial plain around which rises, to the north, south, and west, the Barrier Formation, forming a semicircle. To the east, the oceanic coastline develops, which, protected by coral reefs, provides favorable conditions for the establishment of commercial ports (Ferreira, 1982; Gusmão Filho, 1990).

The fluvio-marine sedimentary process was responsible for the creation of the plain resulted in a considerable diversity of heterogeneous soft clay soil profiles (Souza et al., 2017; Ferreira et al., 2022; Dias et al., 2022), which can reach thicknesses of over thirty meters and are generally saturated due to their low elevation above sea level, when sandy (Oliveira et al., 2016). Peat soils (Cadete, 2016; Barbosa, 2018) and deposits of coral fragments (Oliveira, 2012) are also found.

The northern portion of the hilly area is less dissected, with more continuous plateaus and a fluvial network embedded in vertical valleys, while the central, western and southern portions are intensely dissected into isolated hills of different geological units (sediments, crystalline basement, etc.). In the northern portion, the tops of the hills have elevations of around 100 m, dropping to approximately 30 m near the lower basin areas (Alheiros et al., 1990).

On hillsides and slopes in Recife, the anthropic component is the most important trigger of landslide hazard situations (Gusmão Filho, 1990; Gusmão Filho et al., 1997). The destabilization of the environment is mainly due to cuts and embankments on slopes from low-income housing construction, following random invasions and lacking any land use or land occupation planning. Erodible, dispersive soils (Quental & Ferreira, 2008; Portela et al., 2021) and expansive, collapsible soils (Ferreira et al., 2020; Maior & Ferreira, 2022) are found on the slopes.

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Associated with this, the city of Recife has the second smallest urban area among Brazilian state capitals and a high population density, factors that lead to increasingly verticalized construction on soils that often lack sufficient support conditions and can excessively deform (Fonte et al., 2005; Oliveira et al., 2016). The current foundation construction practices are strongly governed by the subsoil characteristics, although other factors may influence the choice. In light of this complexity, it is also important to note that the monitoring of building performance becomes even more relevant because projects do not often take into account the mechanism of soil-structure interaction, which can cause a series of effects on the buildings.

The city of Recife is a challenging and motivating experimental field for the development of soil mechanics and geotechnical engineering. Investigating and understanding hydro-geomechanical behavior, analyzing and proposing solutions, and planning soil use and occupation are all goals in the formation of the geotechnical engineer and the development of his or her skills and competencies.

Teaching-learning in the educational system is a process of interaction between teachers and learners, to change behavior and develop new attitudes and skills. The Constructivist-Freirian perspective (Freire, 1997) promotes learning that is not based only on the transfer of knowledge but adds experimentation and research based on prior knowledge that people have to contribute to the teaching-learning process. Perception and understanding are fundamental for the development of learning, education and teaching activity (Kubo & Botomé, 2005; Muggler et al., 2006).

The learner's motivation is directly related to the incentive provided by the teacher. With objectives and content selection appropriate to each subject, they will interact so that the objectives are achieved, using strategies that can be applied to the universe of the learners. The learners will be more interested and therefore more likely to perform well, contributing to self-fulfillment, generating new incentives and new motivations as needed.

Each phase of the teaching-learning process is extremely important in ensuring its effectiveness. The evaluation, not only of the learners, but of the entire process, is fundamental for planning and executing new stages, aiming to correct failures, mitigate weak points, and identify and strengthen the positive points of each phase. Good pedagogical practice is guided by these principles.

This paper presents and analyses methodological experiments of the teaching-learning process conducted in geotechnical engineering educational system (undergraduate and graduate studies) at three universities in the state of Pernambuco, Brazil, two of which are public institutions, one federal and one state, with the other being private and confessional, applied for more than 40 years. The adopted methodological experiments of the teaching-learning process aim to improve the learning motivation and learning performance of the geotechnical engineering students.

2. Materials and methods

The creation of a geotechnical laboratory nucleus with equipment ranging from conventional and basic to the most modern, and which has adequate functional space, is essential for carrying out experiments with laboratory and field tests (Ferreira, 1987, 1993; Ferreira & Lacerda, 1993; Ferreira et al., 2020) The creation of an environment with space where different research groups can be brought together to interact, with computer programs and equipment capable of simulating field conditions, helps to stimulate teaching, research, and extension, and favors the pedagogical teaching-learning process in the educational system. Mechanical and electronic workshops contribute to the setting up of special laboratories for unsaturated soils and environmental geotechnics, as well as computer graphics that assist in the teaching-learning process. The development, construction, and acquisition of new equipment are important moments in learning, sharing, and socialization of knowledge. When working in teams, everyone grows when knowledge is shared. The development of new equipment stimulates creativity and entrepreneurship. The research lines and projects bring together undergraduate and graduate students, each with objectives and strategies to help reach the established goals.

There is a one-to-one correspondence between the elements that participate in the teaching-learning process. The teacher, the learner, the objective, the content, and the strategy must interact dynamically and cyclically to guarantee each phase of the process, whether planning, execution, or evaluation. The structure of the teaching-learning process presented in Figure 1 is used in the development of each experiment. The teacher interacts with the learner, initially indicating a proposal for an experiment or accepting another one presented by the learner. Goals and objectives are defined. A set of bibliographic references is consulted, test techniques are selected, equipment and projects are elaborated. The strategies for carrying out the experiments are defined in time and space. The initial planning is thus underway. During the execution of the experiments, the strategies, goals and objectives are evaluated, being able to be validated, adjusted or reformulated and what was initially planned can be revised. Thus the experiments are monitored.

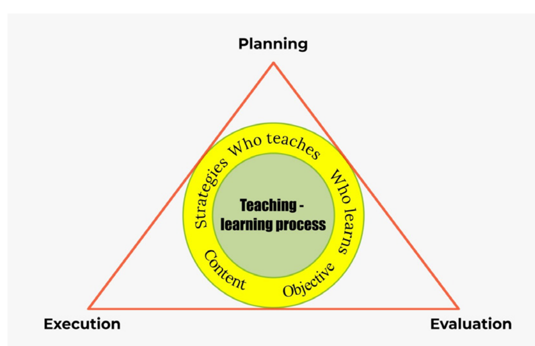

Figure 1. The structure of the teaching-learning process.

Three integrated methodological experiments from the teaching-learning process carried out in the area of geotechnics at three universities in the state of Pernambuco, Brazil, are presented. The first one was developed with undergraduate students in specific disciplines of geotechnical engineering who interact with companies that operate in the sector, performing laboratory and field tests and geotechnical instrumentation. The second experiment integrates students and professors from different areas of activity in the civil engineering programs around a multidisciplinary project and, finally, the third experiment brings together undergraduate and graduate student research activities in the same project and in an environment that extends from the development and construction of geotechnical equipment, through the development of new soil improvement techniques, to land use and occupation planning. The experiments were developed along two fields of research. One addresses hydro-geomechanical soil behavior with the topics of problem soils, soil improvement, equipment development, adaptation, and construction, and the other addresses land use and occupancy with the topics of geotechnical cartography, slope stability, foundations, and environmental geotechnics.

In the methodological experiments developed with the soil mechanics and foundations students, the theoretical and practical contents taught in the classroom were applied in the laboratory and on field trips. The students were divided into groups (maximum five people) and received samples of different types of soils to perform physical characterization, permeability, compressibility, and shear strength tests, accompanied by laboratory technicians and professors. They prepared and defended technical reports. Field visits were carried out to monitor percussion drilling, determine the penetration resistance index, and collate samples. The visits were described in a report. Each activity was part of the evaluation of the teaching-learning process.

In the slope stability course content, students visit a hillside in the city, where they perform a topographic survey, collect undisturbed samples, perform shear strength tests in the laboratory, and use software to analyze stability. The students also simulate variations in shear strength with variations in humidity and infiltration and then present and discuss the results in seminars and evaluate both the other teams and their teams (self-evaluation).

In the foundations course, students, in groups of five, create fictitious companies to design foundations. They are given data from real structures, a load plan, and a geotechnical investigation program from another site to prepare the foundation design. As the theoretical lectures are given, the design is developed by the students. The teacher plays the role of a technical consultant as the teaching-learning process develops. The project is presented, discussed, and defended, and must meet all the requirements of a real project, with elaborated alternatives, justifications, calculation log, budget, and construction details. The defense of the project is a moment of celebration, a time to observe the students' development, creativity, and team interaction, associating academic activity with the practice of calculating an actual project. This experience was lived by the author, while an undergraduate student of Professor Jaime Gusmão Filho at Federal University of Pernambuco, and was later applied in the courses he teaches as a professor.

In the methodological experiments integrated with multidisciplinary projects, final-year civil engineering students had the opportunity to participate in and follow the design and construction stages of a commercial building, in fields such as geotechnical investigation, planning, budgeting, building services, and construction.

In methodological experiments integrated with research and extension, undergraduate and graduate (masters and doctorate) civil engineering students participate in the same project developing research and extension activities. Each of the specific subprojects contributes to achieving the overall goal. All of the experiments are integrated in time and space.

3. Analysis and results

The integration of lecture classes with practical activities in the field, laboratory, technical visits, and project development, accompanied by teachers who encourage and motivate those who learn through the interaction of theory and practice, favors the teaching-learning process.

The paper presents a significant amount of new information and discusses the importance of providing significant experiences to students (undergraduate and graduate degrees) with a broad-based education for civil engineers to work with the multidisciplinary skills required for engineering industry such as: technical and computer science skills, problem-solving, research and critical thinking.

3.1 Methodological experiments integrated with multidisciplinary projects

In the Improving the Quality of Engineering Education projects at the Center for Technology and Geosciences of the Federal University of Pernambuco (UFPE) and the Final Course Project for Civil Engineering, funded by the Brazilian Financier of Studies and Research (Finep) of the Engineering Development Program/Reengineering of Engineering Education (PRODENGE/REENGE), the final-year students prepared tutorials on geotechnical soil characterization, laboratory tests, lowering of the water table, water analysis, technical bulletins on soil suction, dispersive soils, and on roads and transportation (Dourado & Ferreira, 1996; Ferreira, 1996, 1997; Ferreira et al., 1997). They accompanied the design and construction stages of a commercial building, accompanied by professors and engineers from the construction company. They had the opportunity to participate in the execution of the foundation soil improvement process with sand piles, the pouring of the foundations and execution of the structure, masonry, and cladding.

3.2 Methodological experiments integrated with university research and extension

Figure 2a shows the quantitative evolution of the students who participated in the integrated methodological research experiments from 1982 to 2022, which contributed to the academic and professional training of 158 students (undergraduate, masters, and doctoral students). Of the undergraduate (scientific initiation) research assistants (85), 32% are master's degree students, and of these, 46% are DSc. students. Master's students totaled 62, with 13% obtaining DSc. and 15% pursuing a DSc. The total number of master's and doctoral students who participated in the methodological experiments was 73, of which 40% are university professors. Figure 2b shows that 26% of the master's and DScs participated in the experiments in problematic soils, 18% in soil improvement, 7% in development and adaptation of equipment, 21% in environmental geotechnics, 13% in foundations, 9% in slope stability, and 6% in geotechnical cartography.

3.2.1 Scientific initiation

The Scientific Initiation program plays an important role in academic education and, later on, in the professional life of the undergraduate. It is relevant for the teacher in research development. One of the main objectives of scientific initiation in universities and research centers is the formation of human resources that have a scientific spirit, where the solutions to problems are pursued seriously and methodologically. Learning how to solve problems and not simply acquire "ready-made" scientific knowledge or "magic" formulas, but develop a creative, critical, analytical, and proactive mindset that, combined with the scientific spirit, makes it possible to find more adequate solutions. This is the mentors' responsibility in the work of scientific initiation in the teaching-learning process.

Knowing how to refine the evaluation criteria to distinguish and separate the principal from the secondary and the essential from the accidental, is an important critical analysis in research. The objective and goals must be well defined and delimited in time and space (Ferreira, 1992). "I think so" or "I believe so" do not satisfy the objectivity of knowledge and the rationality of the scientific spirit. Being humble and recognizing limitations, accepting the possibility of mistakes and errors, being impartial, honest, and courageous, and having initiative and perseverance are some qualities of the scientific spirit that should be developed and encouraged in the young researcher (Ferreira, 1996).

Students in the scientific initiation program should not be merely performing disorganized tasks, and they should not participate in multiple research projects simultaneously, nor be considered interns. The scientific initiation training program demands objectivity, a spirit of observation, analysis, synthesis, reflection, and creativity. It is essential to develop a scientific spirit, which seeks adequate, impartial, objective, and rational solutions when examining the problems that are presented.

The University of São Carlos, in the state of São Paulo, Brazil, has held the Scientific Initiation Congress since 1981, and some of the UFPE students mentored were encouraged to present their SI projects. However, the distance, reconciliation of the academic calendar, and the operational cost of the students' trip made it difficult for them to participate. These factors inspired the creation of the 10th Symposium of Scientific and Technological Initiation in Pernambuco, in 1989, which had 91 registered projects, and involved about 100 students, 67 professors, 20 departments, 4 universities, and the Pernambuco Research Agency. A total of 230 people participated. In subsequent years, UFPE organized scientific initiation congresses for all areas of knowledge and began to organize the event with the financial support of an organization of the Brazilain federal government named the National Council for Scientific and Technological Development (CNPq).

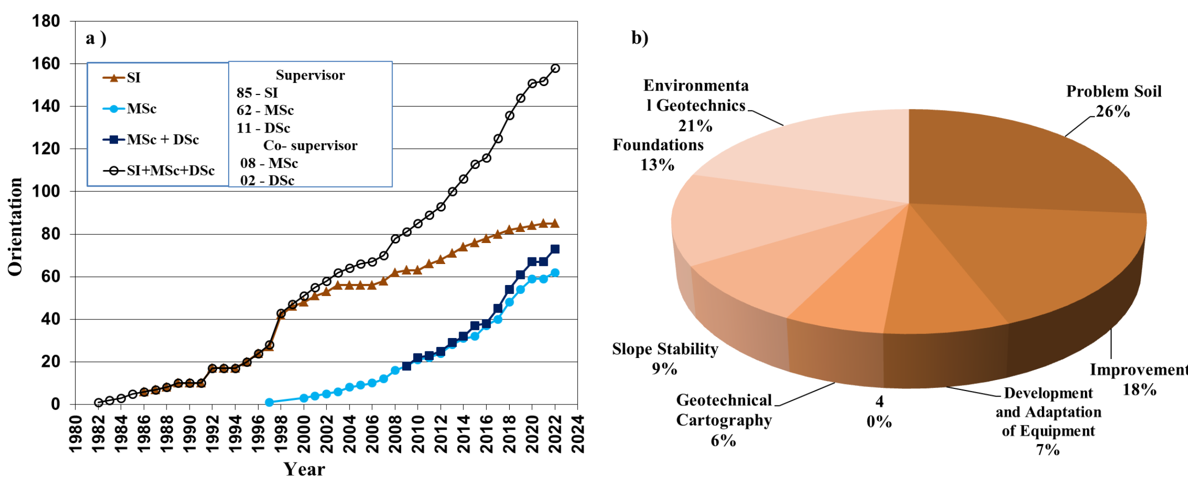

Figure 2. Evolution of experiment participants over time: a) quantitative evolution of the students participating in the experiments; and b) distribution of participants by research activity. IS - Scientific Initiation, MSc - Master of Science, DSc - Doctor of Science

Scientific initiation students accompanied the installation of the inclinometer and participated in the monitoring of displacement over time. They prepared reports and participated in scientific initiation congresses. Some of the students received master's degrees and doctorates, and many are today professors at public and private universities, designers, or federal and municipal public employees.

3.2.2 Dissemination of methodological experiments

The results of the integrated methodological experiments were published in 326 publications, of which 59% were on the Geomechanical Behavior of Soils, 39% on Soil Use and Occupancy, and 2% on Teaching, as shown in Figure 3a. Under the theme of Geomechanical Behavior of Soils, 49% were about Problematic Soils, 7% on Soil Improvement, and 7% on Equipment Development and Adaptation, as shown in Figure 3b. Under the theme of Soil Use and Occupancy, 3% were in Geotechnical Cartography, 3% in Slope Stability, 7% in Foundations, and 17% in Environmental Geotechnics, as shown in Figure 3c.

A group of experiments were carried out field and laboratory on expansive soil in the same location municipality of Paulista, Pernambuco which resulted in dissertations, theses and made it possible to: a) monitor the crack propagation process through photographic images in the field (Figure 4a), in an area without (Figure 4b) and with vegetation (Figure 4c), during dry and rainy seasons, (Araújo, 2020); b) develop and adapt equipment that allows for the removal of anchored piles (Figure 5a) with loading and unloading cycles (Figure 5b), drying and wetting cycles (Figura 5c), and monitoring of the crack propagation process (Araújo, 2020); c) develop laboratory equipment to monitor the crack propagation process through drying and wetting cycles, with variations in soil weight, temperature, relative humidity, and suction (Araújo, 2020); d) evaluate the stress-strain resistance behavior of soil and its mixtures with lime (Morais et al., 2017; Paiva et al., 2016), with tire fibers (Menezes et al., 2019; Faustino et al., 2023; Silva & Ferreira, 2023); e) analyze the interaction between soil particles with the addition of sand, lime, rice husk ash (Bezerra, 2019) using squeeze flow; f) evaluate the variation of the cone tip resistance with depth, using the Dynamic Penetrometer Light (DPL) in soil under natural moisture conditions and when flooded (Borges et al., 2016) and g) evaluate the soil microstructure before and after expansion using computerized tomography (Barbosa, 2019).

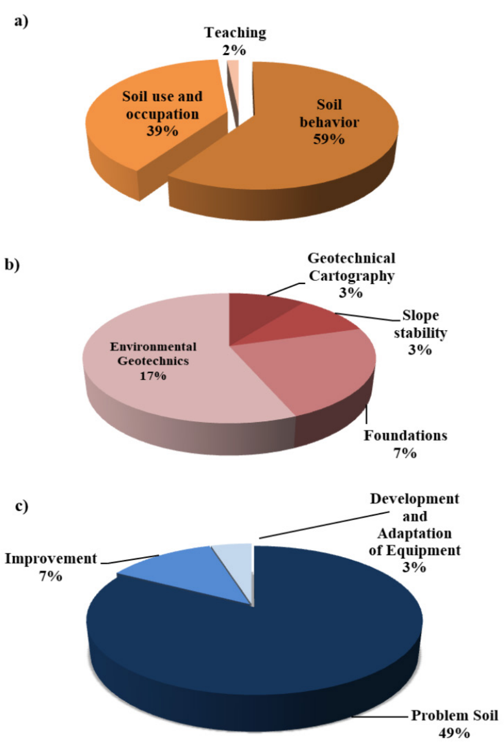

Figure 3. The number of experiments disseminated: a) Total publications; b) Land use and occupation; and c) Soil behavior.

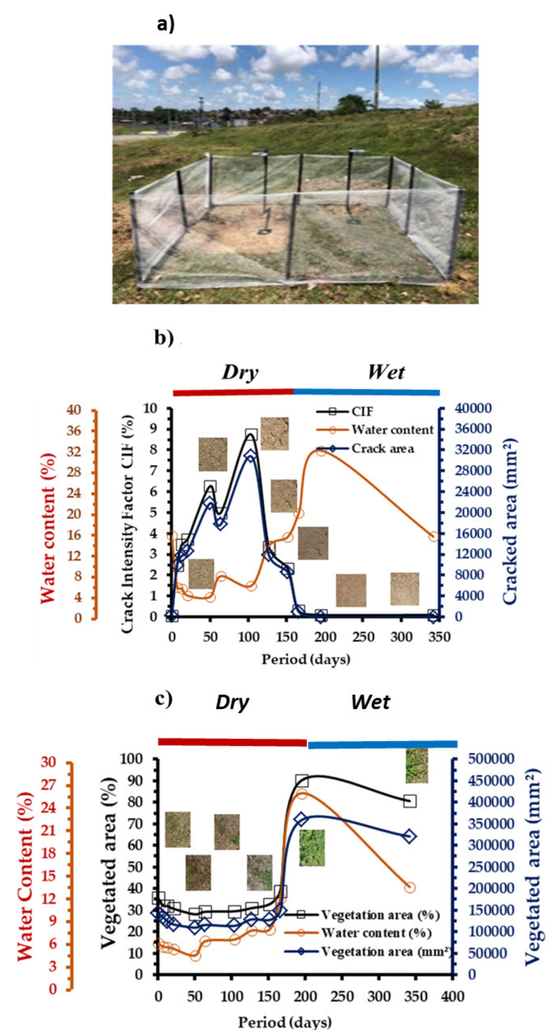

Figure 4. Methodological experiments were carried out on expansive soil in the municipality of Paulista, Pernambuco: a) Field experiment; b) Area without vegetation; and c) Area with vegetation.

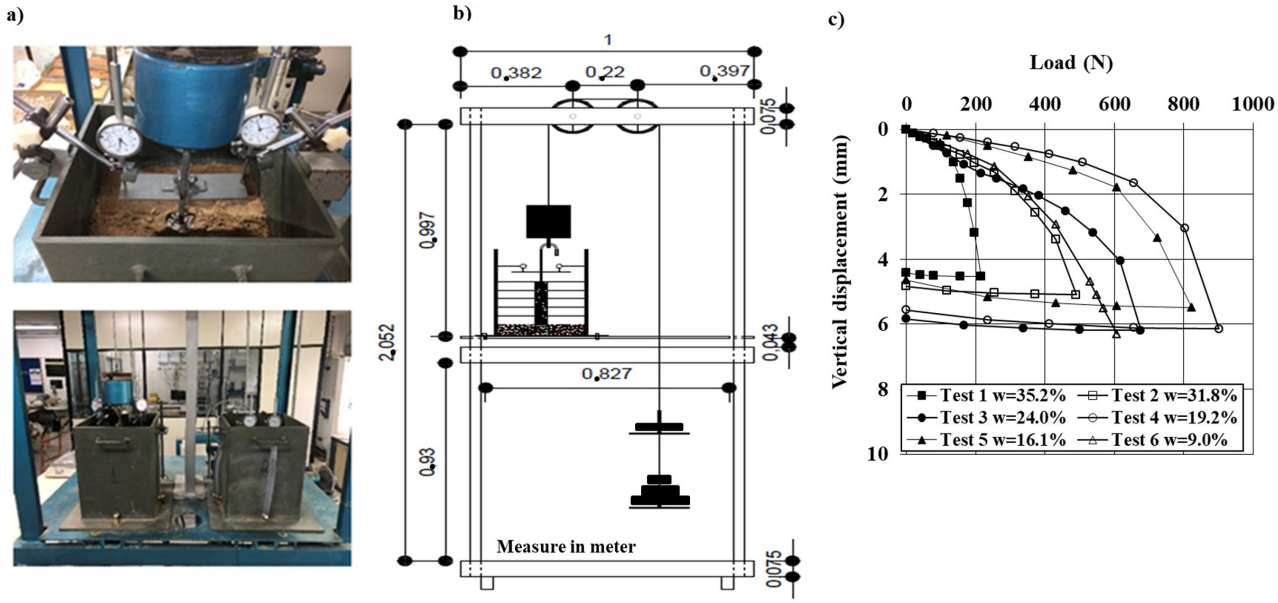

Figure 5. Methodological experiments to pullout tests on Granular Pile Anchor (GPA): a) Laboratory experiment – pullout test; b) Schematic details of the test; and c) Load displacement curve - pullout test.

In the expansive soil of the municipality of Cabrobó, PE, methodological experiments were conducted to evaluate the stress-strain behavior of soil and its mixture with hydrated lime (Paiva et al., 2016; Ferreira et al., 2017) and rice husk ash (Lacerda & Ferreira, 2020). Rice husk is a byproduct of rice processing that can cause environmental problems when performed on a large scale. To reduce the impact and the amount discarded, rice producers use the husk as fuel in the boilers of the parboiling process. Beyond being used for power generation and steam production, rice husk can be used to make bricks. The Rice husk ash (RHA) is a fine material with cementitious properties that has a high silica content and high pozzolanic activity. The experiment used RHA generated by a company in the municipality of Cabrobó, PE. The addition of RHA to soil reduced its expansiveness and showed that it was feasible to use RHA to reduce environmental liabilities. This experiment was also used with expansive soils in the municipalities of Agrestina, PE and Brejo da Madre de Deus, PE (Silva et al., 2020a).

Several methodological experiments were performed on collapsible soils. The Expansocolapsometer were carried out to evaluate the potential for collapse of collapsible soils in housing complexes and irrigation projects in Petrolândia, PE (Ferreira & Lacerda, 1993, 1995; Ferreira & Fucale, 2014), in Petrolina, PE it was used in the Nova residential complex Petrolina linked to the Minha Casa Minha Vida program and the axis of the Pontal Azul canal in Petrolina, PE and the collapsible soil of Palma, TO during the construction of the airport runway (Ferreira et al., 2002). Torres (2014) evaluated the variation in tip resistance with a Dynamic Penetrometer Light (DPL) and a static penetrometer (cone) and evaluated the collapse potential with an Expansocolapsometer in natural and flooded soil at the Nova Petrolina residential complex in Petrolina, PE, linked to the Minha Casa Minha Vida program. Borges et al. (2016) evaluated the elasticity modulus and volume variation of soil in the field, with and without previous flooding. They used a Light Weight Deflectometer (LWD), Expansocolapsometer, Dynamic Probing Light (DPL), and Static Penetrometer (PE) to perform the physical, chemical, and mineralogical characterization of the soil in the laboratory. Alves et al. (2021) obtained the characteristic curve, permeability, and soil microstructure before and after flooding using Scanning Electron Microscopy (SEM) and 3D X-ray Computed Tomography (CT), analyzed the hydro-geomechanical behavior, Sewage sludge valorization for collapsible soil improvement (Feitosa et al., 2023) and made numerical simulations with the elastoplastic constitutive model known as the Barcelona Basic Model (BBM) (Ferreira et al., 2008, 2013).

Silva & Ferreira (2003) prepared maps of the susceptibility of the occurrence of collapsible and expansive soils in the municipality of Petrolina, PE, based on pedological units. Amorim et al. (2005) used pedological, geological, and climate classification units to elaborate maps of the susceptibility of the occurrence of collapsible and expansive soils in the state of Pernambuco. Aquino & Ferreira (2022) contributed to the geotechnical cartography of the municipality of Teresina, PI, by using geoprocessing to elaborate susceptibility maps for the occurrence of problematic soils and foundation practices. Holanda (2022) elaborated susceptibility maps for collapsible and expansive soils in Brazil by applying artificial neural networks.

The geomechanical behavior of the foundation soils of the Recife II/Bongi transmission line towers was performed by Quental & Ferreira (2008). Oliveira (2013) analyzed load tests on continuous flight auger piles and their reliability for commercial buildings in the Recife Metropolitan Area. He was awarded the Icarahy da Silveira prize promoted by the Brazilian Association of Soil Mechanics and Geotechnical Engineering (ABMS) for the best dissertation in geotechnics in Brazil during the biennium 2012-2014. An evaluation of the methods for prediction and control of load capacity in H-profile steel piles was performed by Silva (2013) and experiments related to soil-structure interaction were performed by Patricio et al. (2018) and Araújo Júnior (2022).

Slope stability experiments were performed by Ferreira et al., (1999) and Ferreira et al., (2001) on hillsides in Recife and slopes in Ipojuca by Pereira (2020). Experiments on erosive and dispersive soils were performed by Quental & Ferreira (2008) and Portela et al. (2021). The evaluation of dispersivity and compressive strength of soil composites from the Barreiras Formation with RCD and lime was evaluated by Silva et al. (2019, 2020b); Portela et al. (2021). The analysis of the erosive process of a slope in the Bom Jesus neighborhood of Ilha de Itamaracá, PE was performed by Santos et al. (2021). The area was mapped using an Unmanned Aerial Vehicle (UAV) and erosion was delimited and quantified using the Universal Soil Loss Equation (USLE).

3.2.3 Methodological experiments integrated with university extension activities

In the waste and citizenship university extension experiment, the activities were oriented towards the Integrated Final Disposal Project of the municipality of Rio Formoso, PE. The undergraduate students, scientific initiation students, master's students, and technicians participated in the process of selecting the area to locate the landfill, the diagnosis of the municipality's sanitation services, the master plan, the landfill project, the composting unit, and the plastic recycling unit. During the diagnosis, the Clean Swamp action was carried out, where a large joint effort was organized to clean a 2.0 km stretch of the river near the city center. Students from five public schools, about 500 elementary school students in total, were mobilized, along with a fishing colony and other associations. In this action, 163 tons of solid wastes were removed and 6000 folders were distributed, in a great example of citizenship. An environmental education booklet entitled "Trash: From Generation to Final Destination – Environmental Education" was prepared. The illustrations in the booklet were selected by the students based on the diagnosis of sanitation services of the municipality (Ferreira et al., 2005a, b).

To implement this project, an Environmental Impact Assessment was carried out, consisting of three distinct stages: diagnosis, prognosis, and conclusions. It encompassed studies about the area where the four units of the integrated system were implemented, addressing the physical, biological, and socio-economic environments, data and information collection, and field and laboratory investigations. Students in the scientific initiation program and graduate students participated in each of the stages. For effective control of the environment, a follow-up and monitoring program of the main impacting actions was developed, according to the environmental impacts identified in the prognosis, to minimize impacts caused during the implantation phase.

Based on the cultural and solid waste characteristics of the municipality, collected during the diagnosis of the student's research, the Integrated Final Solid Waste Disposal System of Rio Formoso, PE is composed of four units: the Center for Environmental Education (CEARF), a Recycling Plant, a Composting Plant, and a Landfill, as shown in Figure 6.

The project received an Honorable Mention from the National Health Foundation of the Ministry of Health for the work entitled: An Innovative Solution: Integrated System for the Final Destination of Solid Waste from the Municipality of Rio Formoso, PE, presented at the II International Seminar of Public Health Engineering, on December 3, 2004, in Goiânia, GO (Ferreira et al., 2004).

In this project, the implementation of a green barrier to surround the construction site was envisaged, through the planting of trees that can be easily rooted from "stakes," which will speed up the creation of the barrier. This could be done with Eucalyptus citriodora Hook planted with a two-meter spacing, with the barrier formed of two equal rows, two meters apart. The project counted on the participation of federal (National Institute for Agrarian Reform – INCRA), state (Department of Science and Technology and the Environment – Sectma and the Planning Department of the State of Pernambuco SEPLAN/PE – Promata), and municipal (Rio Formoso, PE Prefecture) governments, an international non-governmental organization Avina Group, the Producers Association of the Settlements of Engenho Serra D'Água, and two universities, one federal and the other private. The project was considered by the State of Pernambuco to be a pilot project and was extended to the neighboring municipalities of Serinhaém and Tamandaré through an inter-municipal consortium. The joint actions improved the standard of living and health of the population, improved the aesthetic and environmental aspects of the cities, and transformed the waste into a product that can increase employment and income.

Oliveira et al. (2019) described an innovative experiment of the leachate treatment process with *Moringa oleifera* Lam seed extract obtaining a useful residual sludge to obtain a biosolid. The invention lies in the fields of agronomy and environmental engineering. The experiment was carried out on compost (residual sludge) from the Landfill CTR-Candeias in Muribeca, Jaboatão dos Guararapes, Pernambuco. Figure 7 shows the development of Lettuce Seeds through bioassays that allowed evaluation of the efficiency of using the waste sludge compost from sowing to germination at 25 days. The biosolid is equivalent to the use of commercial substrate, in the production of seedlings.

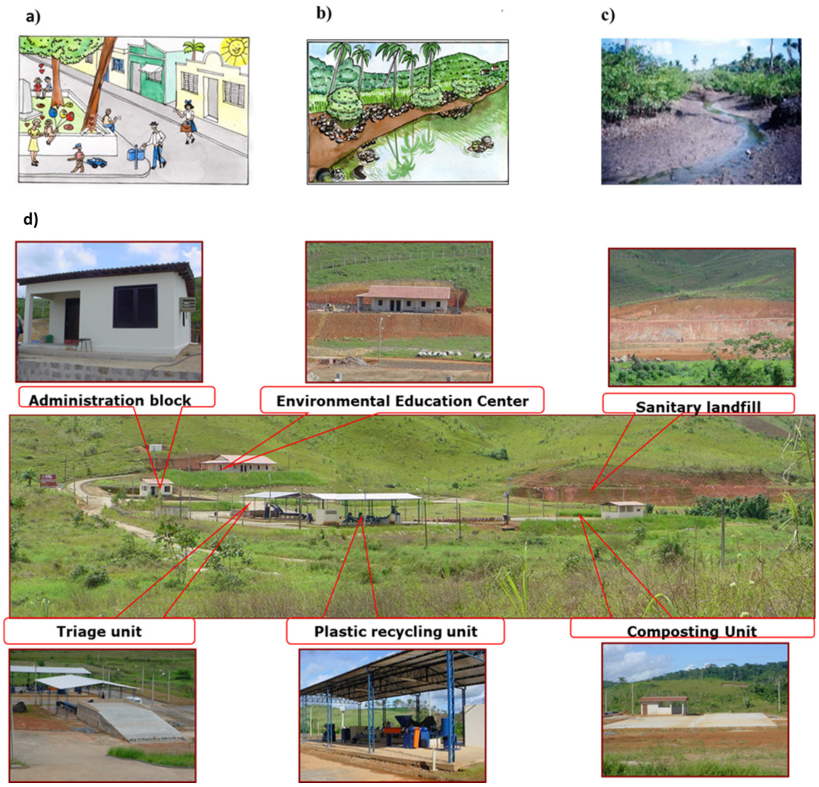

Figure 6. Methodological experiments integrated with research and extension: a) Guidebook; b) Clean slough activity; c) Cleaning slough; and d) Integrated Final Solid Waste Destination System of Rio Formoso, PE (adapted by Ferreira et al., 2005a).

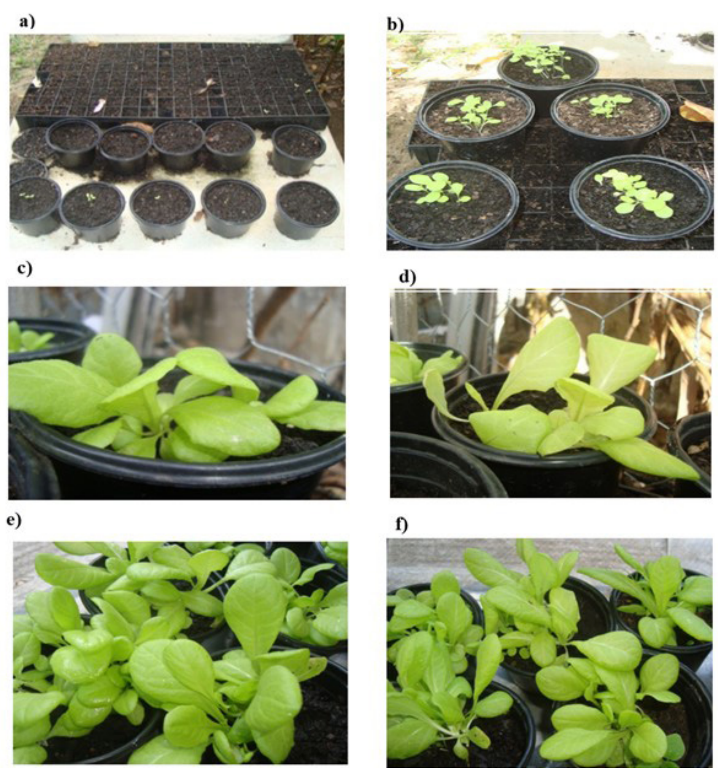

Figure 7. Lettuce seeding: a) Sowing; b) Germination with 5 days; c) Germination with 15 days – control; d) Germination with 15 days compost; e) Germination with 25 days – control; and f) Germination with 25 days – compost (adapted by Oliveira et al., 2019).

Indicating the use as an alternative to compost for reuse in the landfill nursery fertilization for the production of seedlings and reforestation of the landfill area. Reduction of the risk of contamination of the soil, groundwater and riverbeds, reduces the use of chemical fertilizers in the planting areas. The proposed methodology presents efficiency and its use can be indicated for application on a full scale, aiming at its adoption by sanitary landfills. The leachate treatment process was registered at the National Institute of Industrial Property (Oliveira et al., 2019).

4. Conclusion

The methodological experiments integrated into multidisciplinary projects provide a suitable environment for interaction between the university, designer, engineering industry and civil society, favoring the teaching-learning process.

The methodological experiments that integrate undergraduate students, from the scientific initiation program with postgraduate students (master's and doctorate) promote the advancement of knowledge, the formation of more qualified human resources, competent and qualified to respond to new scientific challenges and technological.

Methodological experiments with university extension activities bring challenges, demands from society and opportunities for the academic environment to solve problems, favoring the teaching-learning process.

This study demonstrates the use of a positive teaching-learning experience conducted in geotechnical engineering education on the development of civil engineers who possess both technical skills and professional competencies.

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Declaration of interest

The authors have no conflicts of interest to declare. The contents of the paper and there is no financial interest to report.

Authors' contributions

Silvio Romero de Melo Ferreira: conceptualization, methodology, validation, writing-review & editing, data analysis, supervision.

Data availability

The datasets generated analyzed in the course of the current study are available from the corresponding author upon request.

List of symbols

ABMS	Brazilian Association of Soil Mechanics
BBM	Barcelona Basic Model
CAPES	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
CEARF	Center for Environmental Education of Rio Formoso
CIF	Crack Intensity Factor
CNPQ	Council for Scientific and Technological Development.
CT	Computed Tomography
CTR	Waste treatment center
DPL	Dynamic Penetrometer Light
DSc	Doctor of Science
FINEP	Financier of Studies and Research
INCRA	National Institute for Agrarian Reform
IS	Scientific Initiation
MSc	Master of Science
PRODENGE	Engineering Development Program
PROMATA	Program to support the sustainable development of the Zona da Mata of Pernambuco
REENGE	Reengineering of Engineering Education
RHA	Rice husk ash
SECTMA	Secretary of Science and Technology and the Environment
SEM	Scanning Electron Microscopy
SEPLAN	Planning Secretary of the State of Pernambuco
UAV	Unmanned Aerial Vehicle
UFPE	Federal University of Pernambuco
USLE	Universal Soil Loss Equation

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