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Mitigation of natural disasters through knowledge in geotechnics

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Article

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Abstract

In recent years, Brazil has experienced a growing frequency of natural disasters, particularly those triggered by intense rainfall and unregulated urban expansion in geotechnically vulnerable areas. This scenario highlights the urgent need for educational and participatory strategies aimed at disaster risk reduction and the promotion of resilient communities. This article presents a case study of the Geotechnical Study Group (GEGEO), an outreach initiative based at the Federal University of Paraná (UFPR), which developed a series of actions between 2020 and 2023 to raise awareness about geotechnical and environmental risks. The initiatives included a Massive Open Online Course (MOOC), in-person educational workshops, and participatory risk mapping in collaboration with public schools and local communities. The study employed a qualitative approach to analyze the effectiveness of these activities in fostering civic responsibility and disaster preparedness. Results indicate that participatory methodologies—grounded in dialogical education and contextualized technical knowledge—enhanced community engagement and contributed to the co-production of localized risk management tools. Moreover, the integration of teaching, research, and extension proved to be a powerful strategy for promoting socially engaged engineering education. The outcomes reinforce the relevance of university extension programs as instruments for risk mitigation, educational innovation, and community empowerment in areas exposed to geotechnical hazards.

1. Introduction

In recent years, the intensification of extreme weather events—such as heatwaves, droughts, and intense rainfall—has been observed across various regions worldwide, triggering natural disasters that severely impact human health, disrupt ecosystems, cause significant agricultural and economic losses, and impose substantial social burdens (Ballester et al., 2024; Toreti et al., 2022; Newman & Noy, 2023; IPCC, 2021). Among these changes, the frequency of very strong El Niño events has shown a slight increase under global warming, while the rate of very strong La Niña events has risen more sharply (Marjani et al., 2019).

In Brazil, landslides have become increasingly frequent, particularly in the states of Santa Catarina, Rio de Janeiro, Bahia, Minas Gerais, Pernambuco, São Paulo, and Rio Grande do Sul (Coutinho et al., 2025). Municipalities with higher numbers of landslide victims are typically large urban centers, where socio-economic pressures often drive informal settlements on steep hillsides (Bonini et al., 2025). Cities situated in mountainous or coastal regions near mountain ranges—such as the Serra do Mar—exhibit high natural susceptibility to mass movements. Notable examples include Nova Friburgo, Teresópolis, and Petrópolis in the State of Rio de Janeiro (Macedo & Sandre, 2022). Similarly, recurring flood events have been documented in southern Brazil (Egas et al., 2025). Between late April and early May 2024, the state of Rio Grande do Sul experienced Brazil's most severe geo-hydrological disaster to date, with 850 mm of rainfall recorded in just 13 days. The event triggered massive floods and landslides, affecting over two million people, resulting in 183 deaths, 27 individuals reported missing, and approximately 500,000 displaced or left homeless.

Although intense precipitation is often identified as the immediate trigger for gravitational mass movement events, it is crucial to recognize the significant influence of anthropogenic disturbances on slope stability. Activities such as deforestation, cut-and-fill operations on steep terrain, surface sealing, and inadequate management of solid and liquid waste exacerbate the vulnerability of urban and peri-urban areas to landslides and hillslope failures.

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Data from the Basic Municipal Information Survey (IBGE, 2017), which examined municipalities that recorded gravitational slope movements between 2013 and 2017, indicate that 61.9% of reported events occurred in areas with inherently susceptible geomorphological conditions—primarily slopes and escarpments. Additionally, 39.5% of incidents were associated with irregular land occupation, and 35.5% with inadequate drainage infrastructure. These findings underscore that both the physical characteristics of the terrain and land-use practices—such as soil degradation, poor wastewater management, and the absence of stormwater infrastructure—serve as key predisposing factors for the emergence of such geohazards.

Within this context, fostering civic and environmental education becomes essential to cultivating public awareness of local environmental vulnerabilities. Such awareness supports the adoption of preventive, mitigating, and adaptive strategies to address natural disaster risks, which are frequently intensified by human activities. Environmental Education should be addressed in a continuous, integrated, and permanent manner across all levels and modalities of education, as mandated by Brazil's National Curriculum Parameters and the National Environmental Education Policy (PNEA). School-based programs aligned with these principles have demonstrated positive impacts on learning outcomes and broader societal awareness (Mattos & Castanha, 2009).

Moreover, the Brazilian Federal Constitution establishes the inseparability of teaching, research, and extension in higher education institutions (Brasil, 1988). A high-quality higher education system must simultaneously fulfill the functions of instruction, scientific inquiry, community engagement, and knowledge production (Medina, 2019). Teaching supports the learning process, research fosters the development of context-relevant solutions, and extension enables the dissemination and application of academic knowledge to address societal needs. Extension practices include a variety of formats such as vocational training, community outreach, technical consulting, and technology transfer (Medina, 2019).

University extension initiatives provide opportunities for students to develop civic consciousness and recognize their potential to act as socially engaged professionals. These programs encourage critical thinking, the internalization of scientific knowledge, and the establishment of vital connections between academia and society through participatory processes. They foster the co-creation of solutions and help bridge the gap between classroom knowledge and real-world challenges.

Currently, nearly 2,500 schools in Brazil are located in areas vulnerable to hydrological and/or geological disasters—most of which are public institutions offering basic education (Marchezini et al., 2018). Given the unpredictability of such disasters, environmental education combined with participatory learning is a key pathway toward risk prevention and mitigation. The active involvement of communities, particularly those in high-risk areas, plays a critical role in advancing effective disaster risk governance (Ivenicki, 2021).

One of the primary challenges in this context is the fragmented and limited dialogue among stakeholders and institutions. Overcoming this gap requires integrative and inclusive strategies aimed at strengthening societal resilience and public safety (Bieder, 2018).

In response to these challenges, the Geotechnical Study Group (GEGEO), an extension initiative established in 2016 at the Federal University of Paraná (UFPR), develops a variety of projects, activities, and events centered on Geotechnical Engineering. Anchored in the foundational pillars of teaching, research, and outreach, GEGEO contributes to the technical, academic, and civic education of engineering and geology students. Through its community engagement initiatives, the group fosters the practical application of theoretical knowledge, promotes sustainability, and strengthens the connection between universities and society.

GEGEO's mission includes transforming undergraduate education and enhancing public understanding of environmental and geotechnical issues. Its core objectives involve raising awareness about natural hazards—such as floods, landslides, and soil erosion—and building competencies for disaster prevention, risk identification, and emergency preparedness. The group also seeks to mitigate negative impacts and reduce material losses from such events.

Central to its methodology is a participatory, dialogue-based approach. GEGEO employs interactive and didactic strategies—including hazard simulation models, presentations, instructional materials, educational games, and tactile learning experiences—to foster collaborative knowledge construction and community resilience.

This article examines the essential role of geotechnical and environmental literacy in disaster prevention, with a particular focus on GEGEO's contributions to community capacity building. It also analyzes the pedagogical and engagement strategies adopted by the group and highlights the outcomes of these actions in fostering a safer and more resilient society.

2. Materials and methods

The Geotechnical Study Group has undertaken efforts in developing initiatives aimed at fostering critical awareness within society regarding local environmental issues, promoting actions that mitigate the damage caused by natural disasters. To achieve this goal, activities were designed with a focus on three key areas: (1) raising awareness and mobilizing children living in at-risk areas on the importance of soil care, drainage, proper waste disposal, and constructing homes in safe locations; (2) engaging communities residing in vulnerable regions on the relevance of proper soil management, urban drainage, appropriate waste and sewage disposal, and the construction of dwellings in safe zones; and (3) training primary and secondary school teachers to incorporate natural disaster-related themes within the school curriculum.

The activities take the form of lectures, training sessions, educational programs, and geotechnical solution-based projects applied to students and educators from primary schools and vulnerable communities located in geological and geotechnical hazardous areas. Engagement strategies include: (1) visits by the group to public schools or hosting students and teachers at the Polytechnic Campus of the Federal University of Paraná, where in the latter format, children also gain exposure to the academic environment; (2) provision of a Massive Open Online Course (MOOC) aimed at training educators; and (3) offering free community services and technical guidance in Geotechnical Engineering to socially disadvantaged populations. These projects aim to reduce the impact of issues such as erosion, landslides, and differential settlements. Furthermore, the initiative contributes to the civic education of undergraduate and postgraduate students involved in its implementation.

These activities align with the United Nations Sustainable Development Goals (SDGs), which seek to promote sustainable development across three core pillars: social, economic, and environmental. The actions undertaken contribute to multiple SDGs, including: Good Health and Well-being (SDG 3), through flood and inundation mitigation efforts; Quality Education (SDG 4), by empowering and educating local communities; Clean Water and Sanitation (SDG 6), through the restoration of slopes near water bodies and riparian forests; Sustainable Cities and Communities (SDG 11), by encouraging waste separation and proper disposal practices; and Climate Action (SDG 13), by protecting and rehabilitating ecosystems and fostering community adaptation to climate-related impacts.

3. In-person courses and activities

Matsuo & Silva (2021) conducted a literature review that identified the approaches employed by extension groups in Brazil. In their comprehensive analysis of educational practices related to disaster risk reduction, over 70 distinct modalities and pedagogical resources were identified, including lectures, demonstrations, simulations, experiments, science fairs, field trips, and the development of alert systems. Among 124 groups, 81% delivered lectures which were usually conducted by professionals from partner institutions, such as Civil Defense, Fire Department, Environmental Police and other universities. Notably, the experiential approach emerged as the predominant method, employed in 96 school-based initiatives across all educational levels—from early childhood education to elementary and secondary education. This evidences the central role of hands-on learning in fostering risk awareness and preparedness among students.

Knowledge dissemination in the context of disaster risk reduction may be facilitated through diverse educational strategies, including workshops, discussion forums, experiential learning activities, and capacity-building courses. A prominent example is the project "Landslide Prevention Is Learned in School: Citizen Science in Disaster Risk Reduction", developed by the National Center for Monitoring and Early Warning of Natural Disasters – CEMADEN (Cunha et al., 2019). This initiative promotes geotechnical awareness through practical workshops on landslide monitoring, one of which involves the construction and use of low-cost rainfall sensors known as "pluvioPETs" for daily precipitation data collection.

The "Encosta Viva" Project, coordinated by the Polytechnic School of Federal University of Rio de Janeiro (UFRJ), has produced a robust body of scientific literature focused on disaster risk reduction education, especially related to landslides in vulnerable communities across Brazil. The studies developed under this initiative emphasize the importance of interdisciplinary and community-based approaches, bringing together engineering, environmental education, and public policy. By engaging with local schools, museums, and neighborhoods such as "Rocinha", researchers have aimed to translate technical knowledge into accessible and transformative learning experiences. Mendonça (2024), for instance, highlights the project's mission to "popularize the theme of landslides in society," showcasing how educational actions can promote awareness and resilience among both students and residents.

Central to these efforts is the use of pedagogical innovations like scale models, videos, and interactive games, which facilitate comprehension of geotechnical concepts and stimulate dialogue. Mendonça & Freitas (2021) explore how educational games have been employed successfully in classroom settings, while Mendonça & Becker (2024) demonstrate that combining videos with hands-on models enhances engagement and conceptual understanding. Studies such as those by Marchezini et al. (2019) document community conversations that respect and integrate local knowledge, reinforcing the idea that risk awareness is most effective when rooted in the lived experiences of those affected.

Furthermore, several articles underscore the importance of connecting formal education policies to disaster preparedness. Mendonça et al. (2019) presents a disaster risk reduction education (DRRE) methodology focused on geohydrological risks, applied in a public elementary school in Miguel Pereira, Brazil. This interdisciplinary and problem-based approach integrated various subjects and collaborated with local civil defense agencies. The results showed strong engagement from students, teachers, and authorities, leading to increased awareness and meaningful learning. Educational materials like guides, games, and models proved effective and can be adapted to other vulnerable communities to foster local resilience.

GEGEO developed some in-person and experimental courses and activities which involves fostering understanding of the causes, nature, and consequences of hazards, while promoting competencies and skills that empower society to engage actively in disaster prevention. This project is called "Geoprevenção". Within this process, consistent interaction was essential as much as an experiential approach in which participants actively engage with disaster models and various soil types.

Among these events, approximately 300 children directly benefited throughout 2023, along with 40 participating educators in 2024. Between 2022 and 2025, the GEGEO initiative implemented a series of in-person educational programs, comprising courses and training sessions, which collectively engaged 610 individuals.

Relating real-life scenarios facilitates the perception of land-use impacts on soil integrity and enriches group discussions. Accordingly, students are prompted with questions regarding topics such as landslides, floods, waste disposal, and other environmental issues. This approach encourages children to stay focused and share their own knowledge. Subsequently, students—organized into small groups—participate in a series of activities: tactile-visual assessment of soils, evaluation of soil and terrain hydraulic properties, erodibility, landslide simulation, and a waste sorting relay. These experiential activities provide children with concise yet essential environmental knowledge, contributing to their environmental education and preparing them to face future challenges. Figure 1 illustrates typical activities in schools provided by GEGEO.

4. MOOC – Massive Open Online Course

The study conducted by Lustosa et al. (2023) provides a detailed understanding of the current state of Environmental Education (EE) within Brazil's National Common Curricular Base (BNCC), underscoring the urgent need for improvements in how the subject is addressed. The observation that EE-related content is treated superficially and as supplementary raises concerns regarding the effectiveness of its inclusion in the BNCC.

The 2017 version of the BNCC outlines objectives such as understanding fundamental concepts and explanatory frameworks in the Natural Sciences, mastering scientific research processes, practices, and procedures, and developing competencies that include analyzing the influence of human activities on the composition and functionality of soils—emphasizing the importance of preserving this natural resource (Brasil, 2017). In this context, the availability of teaching materials such as courses emerges as a relevant initiative, as classroom dissemination of this knowledge can play a crucial role in mitigating the risks of natural disasters and promoting more sustainable land-use practices.

In the book "Teaching in a Digital Age: Guidelines for Designing Teaching and Learning", Bates (2015) discusses how distance education and online courses can transform teaching by enhancing access to knowledge and enabling personalized learning experiences. Bates emphasizes that these modalities reach diverse audiences and foster educational inclusion. Based on this premise, the decision was made to develop a course following the Massive Open Online Course (MOOC) format—an approach within the domain of distance education and a progression of the open education ideals proposed by Open Educational Resources (OER) (UNESCO, 2011).

The course was published through "UFPR Aberta", an online learning platform of the Federal University of Paraná, which aims to democratize access to knowledge and promote distance education for any individual without requiring formal enrollment at the institution. It was developed in partnership with the Laboratory for Innovation and Educational Technologies (LabCIPEAD) under the Secretariat of Distance Education and Innovation (SEADIP)—units dedicated to researching and producing educational and technological materials to enhance the quality of distance education.

Figure 1. School activities in schools provided by GEGEO, Curitiba, Brazil.

Entitled "Soils and Natural Disasters", the course is intended to train teachers from upper elementary and secondary education in topics related to Geotechnical knowledge for sustainable development (Universidade Federal do Paraná, 2023). It comprises 25 hours of self-paced instruction and was designed to address four central questions: (1) What is Geotechnical Engineering and how does soil factor into engineering challenges? (2) What are environmental disasters and why do they occur? (3) How do human actions influence environmental disasters? (4) How can society and individuals minimize the consequences of such disasters?

The content is organized into seven modules: Engineering and Geotechnics; Soil Formation; Soil Characteristics; Natural Disasters; Factors That Intensify Natural Disasters; Urban and Solid Waste; and Best Practices in Engineering. Each module includes the essential knowledge teachers need to apply the content in the classroom and offers both theoretical and practical activities aligned with curriculum areas such as Mathematics, Languages, Natural Sciences, and Human Sciences. These activities serve as suggestions for learners to apply the knowledge in future teaching scenarios.

Moreover, the modules include instructional guides with slide decks for classroom use, and for deeper exploration of the content, an e-book containing the full theoretical material is available. The course materials were designed with interactive tools throughout the modules to maintain learner engagement and avoid fatigue.

Course assessment consists of a multiple-choice test at the end of each module, which can be automatically graded by the platform. A minimum passing score is required to unlock subsequent modules, and a certificate is issued upon successful completion of all seven module assessments.

5. Geotechnical projects for vulnerable communities

Slope stability, as highlighted by Duncan & Wright (2005), arises from a delicate balance among geological, hydrological, and anthropogenic factors. However, this equilibrium is frequently disrupted in areas of informal urban occupation, where the absence of urban planning and housing policies forces vulnerable populations into high-risk zones, such as riverbanks and natural slopes. This dynamic not only exacerbates geotechnical and hydrological hazards but also reframes a technical issue as a socio-territorial challenge (Lefebvre, 2001). In this context, geotechnical engineering—traditionally associated with large-scale infrastructure—must be reconfigured as a tool for social transformation. Kolathayar et al. (2024) underscore the role of innovation in engineering as a means to address social demands sustainably, with particular emphasis on minimizing environmental impacts and promoting social inclusion.

The service-learning methodology combines student learning with service to society and promotes project-based learning. A very important reference in the field of service-learning in engineering is Hong Kong Polytechnic University, which since 2010 has adopted service-learning as an institutional strategy (Chan et al., 2019; Chan et al., 2021). Another work to highlight is the EPICS (Engineering Projects in Community Service) teaching program developed at Purdue University (West Lafayette, IN, USA) that began in 1995 (Coyle et al., 2005; Jamieson et al., 2001; Oakes et al., 2000). A teaching experience at the University of Burgos (Burgos, Spain) has been reported on the implementation of the service-learning methodology as part of a civil-engineering degree subject (Dorys et al., 2022). In this program, engineering students were awarded academic credits for developing long-term and long-range projects that solved problems for local community organizations. This teaching experience was part of the "Construction Methods" subject, in the third year, sixth semester of the degree in Civil Engineering.

GEGEO, through its outreach initiatives, engages in risk mapping activities within underserved communities, while simultaneously providing free technical assistance and promoting environmental education in cities of Parana State (Brazil). These actions also contribute to the critical education of students and future engineers. The Service-Learning project described here was titled "Geoprojetos Sociais", and it is a part of GEGEO Extension Program. These initiatives are carried out by undergraduate students from the first to fifth year of Civil Engineering, Environmental Engineering, and Geology programs, under faculty supervision.

The group's activities are driven by societal demands and encompass issues such as landslides, flooding, erosive processes, and accessibility. Requests are received and evaluated to determine appropriate forms of response. The selection of risk mitigation alternatives is guided not only by geotechnical aspects but also by the physical, social, and financial constraints of the community. The outcomes, presented in the form of reports, are delivered to the requesting parties and showcased through seminars and graduation projects. The proposed solutions are developed within the academic context as technical support for future interventions. These outputs may include slope stability analyses, qualitative stability analyses, risk and susceptibility maps.

From a training point of view, this project seeks to instill values of Social Responsibility, as well as values associated with environmental protection and the efficient use of resources. On the other hand, another of the priority lines of the project is the interaction between students and social agents most directly involved in the neighborhoods. For the development of the project, the students were encouraged to obtain relevant information from public bodies and institutions, neighborhood associations, NGOs and religious institutions, in addition to the local community.

The "Portelinha" community, located in Curitiba, Brazil, serves as a representative example of conditions prevalent in numerous informal settlements across the country.

Over the past decade, the GEGEO has implemented stabilization strategies in this region, contributing valuable insights into geotechnical risk mitigation. Situated on the floodplains of a local stream, the area is marked by high population density and unregulated construction practices—often lacking both technical oversight and suitable materials. The monthly rainfall average ranges from 100 to 200 mm, with historical peaks reaching up to 450 mm, underscoring precipitation as a critical factor influencing slope stability. The soil composition is notably heterogeneous, comprising construction debris, decomposing organic waste, and inert materials. Basic infrastructure is absent: residents lack access to potable water and electricity, and there is no formal system for waste collection or treatment. Figure 2 illustrates typical dwellings observed within the community.

Field investigations, carried out under the supervision of faculty experts, are central to the risk assessment process. During these visits, the research team identifies the geoenvironmental processes affecting the area, examines terrain predisposing factors, and evaluates signs of instability—attributes that collectively indicate the susceptibility of the site. These observations are complemented by analysis of land-use patterns and the local population's adaptive capacity in the face of environmental hazards. Topographic characterization is performed through aerial photogrammetry using Unmanned Aerial Vehicles (UAVs) equipped with Global Navigation Satellite System (GNSS) receivers. Where UAV surveying is not feasible, conventional topographic methods—including the use of a theodolite and leveling instrument—are employed. Soil sampling is conducted for laboratory analysis whenever possible; however, the retrieval of undisturbed samples is frequently impeded by the prevalence of rubble and waste material in the terrain. Based on the geometric and geotechnical data acquired, a representative profile model is constructed to support the interpretation of instability mechanisms.

Three technical alternatives were developed to address the identified problem, each accompanied by a brief description and relevant technical and construction-related considerations. A detailed engineering design was presented for the selected solution, chosen among the three alternatives. For instance, in the slope stabilization effort within the "Portelinha" community, the team analyzed the applicability of three retaining wall solutions: a gravity wall made of mortared stone, a reinforced concrete block wall (grouted masonry), and a soil-cement bag wall. Due to its ease of construction and material cost-effectiveness, the soil-cement bag wall was selected as the most viable option in this context.

Another area of intervention involves community training and technical guidance. In the municipality of Antonina, located on the coast of Paraná, GEGEO developed a catalog of slope stability models aimed at providing residents with practical solutions for landslide risks specific to the region.

Figure 2. Built Structures in the "Portelinha" Community, Curitiba, Brazil.

The creation of these prototypes stemmed from both the need and opportunity to design solutions informed by the historical occurrence of geotechnical accidents, as well as the lack of formal engineering projects in underserved communities. The catalog serves as an initial guide for contractors, offering preliminary design recommendations without replacing proper geotechnical investigation. The parameters employed reflect a conservative approach intended to support residents in addressing localized instability. In total, eighteen distinct geometries were proposed for gravity retaining walls.

The development of risk and susceptibility maps is also within the scope of the group's work. The community of "Vila Nova" is in "Roça Grande" neighborhood, in Colombo municipality, Metropolitan Region of Curitiba, state of Paraná, and covers 48,500 m^2 in a densely occupied valley with approximately three hundred houses. At the bottom of the valley, it permeates a body of low flow water in times of drought and high flow, causing flooding, in times of flooding. In this community, GEGEO works in the elaboration of a geological-geotechnical risk map, as well as a charter of susceptibility to shallow translational landslides (Pontes et al., 2021; Pontes, 2019).

The Municipal Risk Reduction Plan (PMRR) for the municipalities of Paranaguá and Colombo, located in the state of Paraná, Brazil, is currently under development by the Laboratory for Geoprocessing and Environmental Studies (LAGEAMB) at the Federal University of Paraná (UFPR), in partnership with the Center for Scientific Support in Disasters (CENACID), GEGEO and the Federal Institute of Paraná (IFPR) – Paranaguá Campus. At UFPR, the PMRR project is registered as a university extension project and commenced its activities in April 2024 (LAGEAMB, 2024a, b). The Municipal Risk Reduction Plan (PMRR) focuses on identifying hazardous processes, mapping risk-prone areas, and proposing measures for risk mitigation and reduction. The analysis encompasses geological, hydrological, geomorphological, and technological risks—including explosions, fires, and hazardous material leaks. For the areas identified as being at risk, both structural and non-structural measures are proposed. These include recommendations for interventions that contribute to risk reduction, with a priority placed on green and blue infrastructure and Nature-Based Solutions (NbS), as well as additional strategies related to monitoring and early warning systems, education and capacity-building, community organization, and the updating of territorial management tools.

6. Results

In the year of its founding, 2016, GEGEO had fifteen members, including undergraduate and graduate students from the Civil Engineering program at UFPR. At that time, the Group was structured into four working fronts: Organization, Didactic Materials, Laboratory, and Projects. In 2017 and 2018, these fronts were reorganized according to project demands (Ferreira & Silva, 2017), and the Group comprised approximately twenty-three members, the majority from Civil Engineering, with some participation from Geology students. Between 2016 and 2018, member involvement was strictly voluntary, with no required workload or mandatory functions. As such, the early years of the Group's activity were based on proactivity and member autonomy.

Beginning in 2019, the Group was formally recognized as an Extension Program, and its first cohort of scholarship recipients was selected. As of 2025, GEGEO includes twelve undergraduate scholarship holders and twenty additional students—both undergraduate and graduate—from Civil Engineering, Environmental Engineering, and Geology, who volunteer across various projects. With the primary aim of positively impacting undergraduate programs and the broader community, enhancing higher education and promoting awareness of geotechnical engineering, GEGEO also encompasses the projects "Geoprevenção" and "Geoprojetos Sociais", which carry out activities focused on the mitigation of natural disasters.

Between 2022 and 2025, GEGEO conducted in-person courses and training sessions that reached a total of 610 participants. This audience comprised members of the Civil Defense agencies from the States of Paraná and Santa Catarina, as well as elementary and secondary school teachers and students. In support of these initiatives, three instructional booklets were developed, focusing on the following topics: soil landslides, floods, and urban inundations. These materials serve as pedagogical tools in activities coordinated with educational institutions. Course and training evaluations were conducted through online feedback forms completed by participants. The resulting critiques and suggestions have provided valuable input for the continuous improvement of the project's instructional approaches. The evaluation instruments employed were intentionally designed to be clear and concise, focusing on participants' assessments of both the materials and methodologies used, as well as the relevance and clarity of the content presented.

In addition to thematic and didactic evaluations, participant comprehension was analyzed in relation to both subject matter and linguistic accessibility—specifically, whether the content was readily understandable or presented conceptual challenges. Feedback from school partners has proven instrumental in the evolution and refinement of the project. Post-visit insights have enabled the project team to enhance its outreach strategies, allowing for greater methodological flexibility and responsiveness to specific educational contexts.

The course "Soils and Natural Disasters" received a notably positive reception from the academic community, with approximately 330 participants enrolled over the ten-month period following its release. Participant performance resulted in an average grade exceeding 85%, highlighting both the relevance of the course content and the effectiveness of the digital platform utilized.

This relevance is rooted in the course's capacity to deliver high-quality education to a diverse audience, particularly on critical topics such as land use and occupation. The initiative contributes meaningfully to continuing education and professional development while also aligning with the guidelines established by the Brazilian Base Nacional Comum Curricular (BNCC), which emphasizes environmental education and sustainability. Moreover, the platform supporting the course represents a significant advancement in terms of digital inclusion and accessibility to knowledge. It responds effectively to contemporary educational demands for flexibility and innovation. Beyond its pedagogical value, the course fosters increased awareness regarding land occupation and the sustainable management of natural resources, thereby enriching both the technical training of participants and their civic engagement in environmental matters.

The "Geoprojetos Sociais" initiative has played a significant role in addressing critical urban challenges across the coastal cities of Paraná State, as well as in Curitiba and its metropolitan region. Through engineering projects, training programs, manual development, and risk mapping efforts, the initiative has actively contributed to the resolution of social and environmental issues. Over the past two years, containment structures were implemented in six different locations, directly benefiting more than ten families.

Risk mapping is a vital tool for identifying, analyzing, and managing areas vulnerable to natural and technological disasters, particularly in socioeconomically marginalized urban territories. It enables authorities and communities to detect zones exposed to hazards such as landslides, floods, erosion, and irregular settlement patterns, thereby facilitating informed decision-making. One such initiative involved the mapping of landslide and flood-prone areas in the Vila Nova Community, located in Colombo, where over thirty households are currently situated within high-risk zones. These studies have served as foundational data sources for ongoing environmental restoration projects in the area.

Municipal Risk Reduction Plans, developed by LAGEMAB with support from GEGEO, have identified twenty-three risk-prone sectors in Colombo and 43 in Paranaguá. These include zones affected by geological, hydrological, and technological risks, encompassing over 340 residences in Colombo and more than 450 in Paranaguá—impacting a total of approximately 2,400 individuals. For areas classified as high and very high risk, both conventional engineering solutions and nature-based approaches have been designed to mitigate adverse impacts.

Self-construction is a widespread phenomenon in underserved communities, especially within urban areas of Latin America, including Brazil (Ferreira, 2020). This practice arises when individuals or families lacking formal housing options build their own residences with limited resources and often without technical guidance or government support. As a direct response to the urgent need for shelter, self-construction showcases the resilience and organizational capacity of marginalized populations. However, it also presents considerable challenges, such as structural insecurity, unsanitary conditions, substandard building materials, and the absence of essential infrastructure. Many residents acquire construction techniques through observation, peer interaction, and hands-on experience, resulting in highly varied—and frequently unsafe—building practices.

In light of these conditions, educational materials of both theoretical and instructional nature have been developed to guide communities in constructing gravity-type retaining walls. These resources are not intended to replace geotechnical surveys or the role of professional engineers, but rather to serve as provisional guidance in areas lacking access to such services (GEGEO, 2022).

7. Conclusion

The increase in natural disasters—particularly those associated with intense rainfall and unregulated urban expansion—has highlighted the urgent need for integrative strategies in disaster risk reduction. Geotechnical and environmental education play a crucial role in this context, particularly when grounded in participatory, accessible, and community-centered approaches.

This study presented the actions of the Geotechnical Study Group (GEGEO) founded in 2016 at the Federal University of Paraná (UFPR), focusing on initiatives carried out between 2020 and 2023. These included a Massive Open Online Course, in-person workshops, and participatory risk mapping activities developed in collaboration with schools, residents of vulnerable communities, and public agencies.

The outcomes of these actions demonstrate that dialogical educational practices—combined with geotechnical knowledge—can effectively promote risk awareness, civic responsibility, and preparedness in the face of environmental hazards. The participatory methodologies employed by GEGEO proved especially effective in engaging local populations, producing context-sensitive knowledge, and contributing to the development of risk mitigation tools.

The integration of teaching, research, and extension—an institutional commitment of Brazilian public universities—was shown to be a powerful framework for fostering socially responsive engineering education. Through active student involvement, interdisciplinary collaboration, and community engagement, GEGEO has contributed to strengthening resilience and reducing vulnerability in at-risk areas.

These initiatives were designed to produce instructional resources and didactic strategies aimed at fostering environmental literacy, with particular emphasis on early childhood education. The initiative seeks to cultivate a critical comprehension of geodynamic processes linked to the recurrence of hazardous phenomena—including mass wasting events (e.g., landslides), fluvial flooding, and pluvial inundations—thereby reinforcing a culture of risk prevention and enhancing community resilience to natural disasters.

Given the central role of educators within society, it is essential to acknowledge their responsibility in disseminating knowledge that extends beyond the confines of formal classroom instruction. Within the scope of natural disaster education, the educator's role extends beyond the mere dissemination of technical information to include the cultivation of critical, reflective, and contextually grounded learning processes. By imparting practical skillsets related to disaster risk reduction and emergency response strategies, teachers serve as transformative agents in the socio-educational landscape. Their pedagogical contributions surpass conventional curricular boundaries, fostering collective consciousness and proactive preparedness within the broader community in the face of adverse environmental events.

Considering this professional function, it becomes imperative that students engage actively and critically in the educational process, thereby enhancing the development of analytical reasoning and encouraging ongoing reflection on environmental and social dynamics. From this perspective, the educational reach and transformative impact of pedagogical practice can be significantly amplified.

The course "Soils and Natural Disasters", offered in MOOC format, is freely accessible to the public. Its adoption by educators aims to provide an opportunity for expanding their knowledge and, as a result, to promote the importance of Geotechnics and the appropriate use of soil in the mitigation of natural disasters.

Several of the group's projects are dedicated to university extension, applying engineering and educational methodologies to address societal challenges. Extension activities serve as a vital link between academic knowledge and real-world social demands, fostering sustainable development through practical application. In geotechnically and hydrologically unstable, informally occupied areas, the group conducts studies and proposes viable technical solutions for structural stabilization, grounded in performance criteria, economic feasibility, and community-specific conditions. These actions not only offer academic technical support for future interventions but also promote critical reflection on the role of geotechnical engineering in socially vulnerable territories shaped by historical patterns of urban exclusion. In this context, engineering is affirmed as a tool for secure settlement and territorial improvement, guided by technical rigor, socio-contextual sensitivity, and ethical commitment to transformative practice.

Geotechnical and environmental awareness constitutes a fundamental component of disaster risk reduction strategies. Through its targeted initiatives, GEGEO has demonstrated a significant role in capacitating communities to address geohazard-related challenges. These efforts are systematically aligned with key United Nations Sustainable Development Goals, specifically SDGs 3 (Good Health and Well-being), 4 (Quality Education), 6 (Clean Water and Sanitation), 11 (Sustainable Cities and Communities), and 13 (Climate Action).

Given the increasing frequency and severity of environmental risks, sustained investment in initiatives of this nature is imperative. Such engagement contributes to the construction of a scientifically informed and socially resilient society, equipped to respond proactively to complex environmental dynamics and the multifactorial causes of disaster vulnerability.

The success of these initiatives reinforces the importance of maintaining and expanding university extension programs as part of broader public policies for disaster prevention and education. It also highlights the need for continued investment in educational strategies that promote awareness, collaboration, and local capacity-building.

Future work may include scaling these practices to other municipalities, expanding digital educational offerings, and deepening partnerships with civil defense institutions, thereby amplifying the impact of university-led geotechnical and environmental education.

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Declaration of interest

The authors have no conflicts of interest to declare. All co-authors have observed and affirmed the contents of the paper and there is no financial interest to report.

Authors' contributions

Roberta Bomfim Boszczowski: conceptualization, data curation, formal analysis, investigation, methodology, validation, visualization, writing – original draft, writing - review & editing. Liamara Paglia Sestrem: conceptualization, data curation, formal analysis, investigation, methodology, validation, visualization, writing – original draft, writing – review & editing. Karoline Guedes de Souza: conceptualization, data curation, formal analysis, investigation, methodology, validation, visualization, writing – original draft, writing – review & editing.

Data availability

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

Declaration of use of generative artificial intelligence

This work was prepared without the assistance of any generative artificial intelligence (GenAI) tools or services. All aspects of the manuscript were developed solely by the authors, who take full responsibility for the content of this publication.

List of symbols and abbreviations

BNCC	Brazil's National Common Curricular Base
CEMADEN	National Center for Monitoring and Early Warning of Natural Disasters
CENACID	Center for Scientific Support in Disasters
DRRE	Disaster Risk Reduction Education
EE	Environmental Education
EPICS	Engineering Projects in Community Service
GEGEO	Geotechnical Study Group of UFPR
GNSS	Global Navigation Satellite System
IFPR	Federal Institute of Paraná
LabCIPEAD	Laboratory for Innovation and Educational Technologies
LAGEAMB	Laboratory for Geoprocessing and Environmental Studies
MOOC	Massive Open Online Course
NbS	Nature-Based Solutions
OER	Open Educational Resources
PMRR	Municipal Risk Reduction Plan
PNEA	National Environmental Education Policy
SDG	Sustainable Development Goals
SEADIP	Secretariat of Distance Education and Innovation
UAV	Unmanned Aerial Vehicle
UFPR	Federal University of Paraná
UFRJ	Federal University of Rio de Janeiro

References

Ballester, J., van Daalen, K.R., Chen, Z.Y., Achebak, H., Antó, J.M., Basagaña, X., Robine, J.-M., Herrmann, F.R., Tonne, C., Semenza, J.C., & Lowe, R. (2024). The effect of temporal data aggregation to assess the impact of changing temperatures in Europe: an epidemiological modelling study. *The Lancet Regional Health. Europe*, *36*, 100779. https://doi.org/10.1016/j.lanepe.2023.100779.

Bates, A.W. (2015). *Teaching in a digital age: guidelines for designing teaching and learning*. Retrieved in May 20, 2024, from https://www.bates.ca/teaching-in-a-digital-age/

Bieder, C. (2018). Societal risk communication: towards smart risk governance and safety management. In M. Bourrier & C. Bieder (Eds.), *Risk communication for the future* (pp. 155-175). Cham: Springer. https://doi.org/10.1007/978-3-319-74098-0_11

Bonini, J.E., Martins, T.D., Sugiyama, M.T.O., & Vieira, B.C. (2025). Landslide inventory of the 2023 Serra do Mar disaster (Brazil). *Discover Geoscience*, *3*(1), 40. https://doi.org/10.1007/s44288-025-00153-2.

Brasil. (1988). *Constituição da República Federativa do Brasil de 1988*. Presidência da República. Retrieved in March 19, 2024, from http://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm

Brasil. Ministério da Educação – MEC. (2017). *Base Nacional Comum Curricular*. MEC. Retrieved in March 19, 2024, from http://basenacionalcomum.mec.gov.br/a-base

Brazilian Institute of Geography and Statistics – IBGE. (2017). *Profile of Brazilian municipalities. Coordination of Population and Social Indicators*. IBGE (in Portuguese).

Chan, S.C.F., Ngai, G., & Kwan, K.P. (2019). Mandatory service learning at university: do less-inclined students learn from it? *Active Learning in Higher Education*, *20*(3), 189-202. https://doi.org/10.1177/1469787417742019.

Chan, S.C.F., Ngai, G., Yau, J.H.Y., & Kwan, K.P. (2021). Impact of international service-learning on students' global citizenship and intercultural development. *The International Journal of Research on Service-Learning and Community Engagement*, *9*(1), 8. https://doi.org/10.37333/001c.31305.

Coutinho, R.Q., Ehrlich, M., Futai, M.M., Bressani, L.A., Lacerda, W.A., & Morais, B.D. (2025). Gravitational mass movements in Brazil: causes, consequences, and solutions. *Soils and Rocks*, *48*(3), e2025001625. https://doi.org/10.28927/SR.2025.001625.

Coyle, E., Jamieson, L., & Oakes, W. (2005). EPICS: engineering projects in community service. *International Journal of Engineering Education*, *21*, 1-13.

Cunha, A.P., Marengo, J.A., Alves, L.M., Alvalá, R.C.S., Brito, S., & Moraes, O.L.L. (2019). Drought monitoring and impacts assessment in Brazil: the CEMADEN experience. *Anais da Academia Brasileira de Ciências*, 90(2), 1-15. https://doi.org/10.13140/RG.2.2.27484.64641.

Dorys, C., González, J.M., Mena, A., & Vicente, M.A. (2022). Added value of service-learning in a bachelor's degree in civil engineering. *Cogent Engineering*, 9(1), 2119532. https://doi.org/10.1080/23311916.2022.2119532.

Duncan, J.M., & Wright, S.G. (2005). *Soil strength and slope stability* (309 p.). John Wiley & Sons.

Egas, H.M., Stabile, R.A., Andrade, M.R.M., Michel, G.P., Araújo, J.P.C., Michel, R.D.L., Mendes, T.S.G., Nery, T.D., de Paula, D.S., & Reckziegel, E.W. (2025). Comprehensive inventory and initial assessment of landslides triggered by autumn 2024 rainfall in Rio Grande do Sul, Brazil. *Landslides*, *22*(2), 579-589. https://doi.org/10.1007/s10346-024-02410-w.

Ferreira, K.S.M., & Silva, A.C.G. (2017). Grupo de Estudos em Geotecnia da Universidade Federal do Paraná: primeiro ano de atuação. In *XLV Congresso Brasileiro de Educação em Engenharia*, Joinville, Santa Catarina. Brasília: ABENGE (in Portuguese).

Ferreira, M.B. (2020). Self-construction and housing self-management in Brazil: A comparative study of two periods: 1975–1986 and 2004–2018. *Journal of Urban Technology and Sustainability*, *3*(1). (in Portuguese). Retrieved in March 19, 2024, from https://www.redalyc.org/journal/6481/648167353005/html/

Grupo de Estudos em Geotecnia – GEGEO. (2022). *Caderno de projetos de contenções (Rev. 00, Out/2022)*. Universidade Federal do Paraná (in Portuguese). Retrieved in March 19, 2024, from https://gegeo.ufpr.br/wp-content/uploads/2024/10/caderno-de-projetos-de-contencoes.pdf

IPCC. (2021). Climate change 2021: the physical science basis. In Intergovernmental Panel on Climate Change (Eds.), *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 2391*. Cambridge University Press.

Ivenicki, A. (2021). Higher education and the commitment to its public mission: the case of extension projects in a Brazilian University. In A. Papadimitriou & M. Boboc (Eds.), *Re-envisioning higher education's public mission*. Palgrave Macmillan. https://doi.org/10.1007/978-3-030-55716-4_9

Jamieson, L., Oakes, W., & Coyle, E. (2001). EPICS: Documenting service-learning to meet EC 2000. In *31st Annual Frontiers in Education Conference*, Reno, NV, USA. New York: IEEE.

Kolathayar, S., Chandra Menon, N.V., & Sreekeshava, K.S. (2024). *Civil engineering innovations for sustainable communities with net zero targets* (1st ed.). CRC Press. https://doi.org/10.1201/9781032686899.

LAGEAMB. (2024a). *Plano Municipal de Redução de Riscos de Colombo – PMRR: Relatório 01 – Plano de Trabalho*. (in Portuguese). Retrieved in March 19, 2024, from https://prefeitura.colombo.pr.gov.br/plano-municipal-de-reducao-de-riscos-pmrr/

LAGEAMB. (2024b). *Plano Municipal de Redução de Riscos de Paranaguá – PMRR: Relatório 01 – Plano de Trabalho*. Paranaguá: Arquivos da Prefeitura de Paranaguá (in Portuguese).

Lefebvre, H. (2001). *O direito à cidade* (149 p.). Centauro (in Portuguese).

Lustosa, T.P., Gomes, P.N., & de Souza Carvalho, C. (2023). A abordagem da Educação Ambiental na Base Nacional Comum Curricular (BNCC): o que se mostra na etapa do ensino médio. *Revista Gestão & Sustentabilidade Ambiental*, *12*(1), e18293. https://doi.org/10.59306/rgsa.v12e12023e18293.

Macedo, E.S., & Sandre, L.H. (2022). Mortes por deslizamentos no Brasil: 1988 a 2022. *Revista Brasileira de Geologia de Engenharia e Ambiental*, *12*, 110-117. (in Portuguese).

Marchezini, V., Mendonça, M.D., Sato, A.M., Rosa, T.S., & Abelheira, M. (2019). Educação para redução de riscos e desastres: experiências formais e não formais no Estado do Rio de Janeiro. *Anuário do Instituto de Geociências*, *42*(4), 102-117. https://doi.org/10.11137/2019_4_102_117.

Marchezini, V., Muñoz, V.A., & Trajber, R. (2018). Vulnerabilidade escolar frente a desastres no Brasil. *Territorium*, (25), 161-178. https://doi.org/10.14195/1647-7723_25-2_13.

Marjani, S., Alizadeh-Choobari, O., & Irannejad, P. (2019). Frequency of extreme El Niño and La Niña events under global warming. *Climate Dynamics*, *53*(9-10), 5799-5813. https://doi.org/10.1007/s00382-019-04902-1.

Matsuo, P.M., & Silva, R.L.F. (2021). Disasters in Brazil? Practices and approaches in education in risk and disaster reduction. *Educar em Revista*, *37*, e78161. https://doi.org/10.1590/0104-4060.78161.

Mattos, E.M.A., & Castanha, A.P. (2009). *A importância da pesquisa escolar para a construção do conhecimento do aluno no ensino fundamental*. (in Portuguese). Retrieved in March 19, 2024, from http://www.diaadiaeducacao.pr.gov.br/portals/pde/arquivos/2525-6.pdf

Medina, B.O. (2019). Community engagement of state universities and colleges in the Philippines: towards socially and culturally responsible research and extension initiatives. *International Journal of Advanced Research and Publications*, *3*(4), 20-25.

Mendonça, M.B. (2024). Encosta Viva: popularizando o tema dos deslizamentos de terra na sociedade. *Fórum UFRJ em Revista*, *2*(1), 16-19. https://doi.org/10.29327/2290975.2.1-4. (in Portuguese).

Mendonça, M.B., & Becker, L.B. (2024). The use of a video and a small-scale model for rain-induced landslides in geotechnical engineering education. *Soils and Rocks*, *47*(2), e202400662. https://doi.org/10.28927/SR.2024.006623.

Mendonça, M.B., & Freitas, A.C. (2021). Jogos pedagógicos para redução de riscos. *Vértices*, *23*(1), 299-314. (in Portuguese).

Mendonça, M.B., Rosa, T.S., & Bello, A.R. (2019). Transversal integration of geohydrological risks in an elementary school in Brazil: A disaster education experiment. *International Journal of Disaster Risk Reduction*, *39*, 101213. https://doi.org/10.1016/j.ijdrr.2019.101213.

Newman, R., & Noy, I. (2023). The global costs of extreme weather that attributable to climate change. *Nature Communications*, *14*(1), 6103. https://doi.org/10.1038/s41467-023-41888-1.

Oakes, W.C., Coyle, E.J., & Jamieson, L.H. (2000). EPICS: a model of service learning in the engineering curriculum. In *Proceedings ASEE Conference and Exhibition*, St. Louis, Missouri. https://doi.org/10.18260/1-2--8361.

Pontes, C.V. (2019). *Análise da susceptibilidade a movimentos gravitacionais de massa da comunidade de Vila Nova, Colombo/PR* [Final Course Project, Federal University of Paraná]. Federal University of Paraná's repository (in Portuguese). Retrieved in March 19, 2024, from https://gegeotecnia.wixsite.com/gegeoufpr/monografias-dissertacoes-e-teses

Pontes, C.V., Boszczowski, R.B., & Ercolin Filho, L. (2021). Geological-geotechnical risk mapping of gravitational mass movements in an urban area in Colombo, Brazil. *Soils and Rocks*, *44*(4), e2021070721. https://doi.org/10.28927/SR.2021.070721.

Toreti, A., Bassu, S., Asseng, S., Zampieri, M., Ceglar, A., & Royo, C. (2022). Climate service driven adaptation may alleviate the impacts of climate change in agriculture. *Communications Biology*, *5*(1), 1235. https://doi.org/10.1038/s42003-022-04189-9.

UNESCO. (2011). *Guidelines for open educational resources (OER) in higher education*. Retrieved in March 19, 2024, from https://unesdoc.unesco.org/ark:/48223/pf0000213605

Universidade Federal do Paraná (2023). *Solos e desastres naturais* [Online course]. UFPR Aberta. Retrieved July 29, 2025, from https://ufpraberta.ufpr.br/course/view.php?id=1617