Interaction of geotechnics with society through education

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Abstract: The Federal University of Goiás (UFG) and the University of Brasília (UnB), in partnership with the company Eletrobras Furnas, have developed research and, based on this, extension projects aimed at education in a broad sense, in which they seek to disseminate and popularise technical-scientific knowledge. This paper aims to present and evaluate educational actions carried out in the area of soil science and geotechnics applied to engineering, geography, and the environment. To do so, the educational experiences developed within the scope of two extension projects are shared. Beside that, the relevance of publishing books and primer, with language adapted to lay society, within the scope of research projects, is analyzed. The results collected regarding the effectiveness of the extension actions as a tool for learning point to a positive evaluation by the students. Furthermore, social networks are an important tool for scientific dissemination and have the potential to disseminate knowledge more widely than in a classroom course. By comparing the number of citations in Google Scholar of the books and booklets with the papers arising from these projects, one can observe the reach of this type of publication, although its purpose is the popularisation of science, with reach in places not considered in the technical-scientific publication metrics. Finally, for effective scientific development, it is necessary to have public policies, effective interaction between universities, research centres and schools, and the participation of professional associations, funding and evaluation agencies, Education Departments and the Ministry of Education, Science, Technology and Innovation.

Keywords: Teaching; Science popularization; Extension curriculum; Soil science; Geotechnical Engineering; Social media.

1. Introduction

Science communicates its research, scientific questions, investigative and analytical methods, as well as the results of this research and its answers, correct or not. In general, this is done in the form of a text with a formal technical language specific to each area of knowledge. In this way, this communication is presented and validated among peers, fundamentally in specialised journals and conference proceedings. This is very important for the advancement of science, since such communication enables the knowledge produced to be subject to evaluation, criticism, reproduction, and modification, but it also means that it is circumscribed within the professional environments of science. It is worth remembering that scientific practices take place within society and for society, yet this type of communication, as a rule, does not reach them in an accessible way. So how to reach the general population with scientific knowledge? The strategies used for this purpose are in the field of scientific dissemination.

According to Silva (2006), scientific dissemination is not restricted to a single type of text, but is associated with historical, cultural and technological contexts. According to this author, the circulation of the first scientific books for children dates back to 1770. Claret (2007) points out that the advent of electronic techniques may extinguish the traditional book printed on paper, whose content could be passed on by other means. Nowadays, books in digital format are very popular, and there are even specific electronic devices for this type of reading, although it is also possible to download, store and read this type of book on cell phones. Cell phones have increasingly sophisticated technologies linked to social network applications, which are a great option for the diffusion of knowledge. However, on this platform, all kinds of information circulate, not always with reliable quality and not necessarily grounded on scientific bases, which generates a dangerous condition for lay people seeking to access information.

A study on the public perception of science and technology in Brazil developed by the Centre for Strategic Management and Studies of the Ministry of Science, Technology, Innovations and Communications indicates that 73% of Brazilians think that Science and Technology (S&T) brings only benefits, or more benefits than harm to society, and consider it very important for the future (CGEE, 2019). However, they expect greater investment in this sector, including for greater access to and consumption of information about science. If the various areas of science are not concerned with disseminating and making scientific knowledge accessible, people may access poor quality information that is harmful to society and to the maintenance of the

credibility of scientific endeavours. The COVID-19 pandemic has exposed a scenario of disinformation, with the intensification of rumours, fake news and conspiracy theories, as discussed by Carvalho (2022). According to this author, this discredit to science led to political actions in Brazil, which, associated with cultural and educational aspects, culminated in the promotion of drugs without any scientific basis for the treatment of COVID-19 and even the non-recommendation of vaccination, which ultimately contributed to the occurrence of thousands of deaths.

What does scientific dissemination, the democratisation of scientific knowledge and the disastrous management of a health crisis in a pandemic context have to do with geotechnics? Geotechnical engineering, based on the science of soil mechanics, rock mechanics and the knowledge of engineering geology and geography, evaluates the mechanical behaviour of soils and rocks and, therefore, has a great responsibility for the prevention and mitigation of natural phenomena with the potential to damage society and human lives, such as landslides, erosion, silting, and flooding. As an example, we have the threats to life and to private and public property generated by erosion that are occurring in Buriticupu - MA (Globo, 2023). Every year, in all parts of the world, thousands of lives are lost in disasters that are considered natural, but which would have great potential to be predicted and avoided if we could broaden our view in time and space and invest more in the broad education of society.

According to the ONU (2021), natural disasters accounted for 45% of all deaths in the last 50 years in the world. According to Kobiyama et al. (2006), historically, disasters such as floods are the ones that caused the greatest loss of life in Brazil. However, it is not difficult to observe, by broadening our gaze, that most of them have their origins in human practices land occupation. Macedo & Sandre (2022), when analyzing the database of deaths from landslides of the Institute of Technological Research of the State of São Paulo (IPT), observed that the total number of fatal victims was 4146. The larger the cities, the greater the number of victims, since in these places there is a more complex socioeconomic dynamic associated with the occupation of slopes. Estarque (2023), through the Integrated Disaster Information System, points out that at least 7.7 million Brazilians have been forced to move in the last 18 years. Among them, 6.4 million were made homeless or displaced by natural disasters. This author reinforces the assertion of Kobiyama et al. (2006) that floods are among the disasters that most displace Brazilians (45%) and in second place flash floods (32%).

The mitigation or prevention of most natural disasters must go through stages of planning, regulatory legislation, and infrastructure works that are properly planned and executed. In this context, education stands out as a powerful tool for the prevention of natural disasters, especially those of a geotechnical nature. Managers should be concerned to be educated and updated to keep these issues in mind within the legislative and executive fields; engineers need to be educated and well trained about the most current techniques and the socio-environmental impacts of their work interventions; and society needs to be educated and enlightened to recognise risk situations, to avoid them, as far as possible, through appropriate initiatives and practices, and to pressure public management for strategic actions. Thus, in Brazil, teaching in schools as well as through non-formal education about floods, erosion, and landslides can have a great preventive function. Of course, it is necessary to consider all the social segregation issues involved in the occupation of risk areas, but knowledge of the inhabited geographic space is the first means of citizen emancipation. It was knowledge of the inhabited space, the peculiarities of the soil, the river dynamics, seasons and types of plants that first allowed human civilisation to stop being nomadic and settle in the Mesopotamian plain and fertile crescent of the Nile.

Thus, the interactions of geotechnics with society through education should occur in different ways and considering multiple social spheres, which are: the development and use of specialised and diversified teaching material; publication of articles at local, regional and national events; publication of articles in journals; publication of primers, book chapters and technical books with language accessible to those with different levels of education, also reaching lay people; publication of videos, posts, folders, and brochures, among others. The production of these materials occurs in the context of research and extension actions whose fruits can reverberate throughout society. It is noteworthy that education in the field of geotechnical engineering should not contain social or gender limits, as illustrated in the book "Conversations between girls and engineers: planting opportunities for gender equality in science" (Hora et al., 2021).

From this general context, this article aims to present and evaluate some experiences of geotechnical interaction with society through extension activities, teaching and research, in some cases using social networks, developed at undergraduate and graduate level.

2. Extension as a strategy for socialising teaching

2.1. Extension projects

Aiming to promote the interaction between undergraduates, graduates and society through accessible educational practices for the socialisation of teaching, learning, research, knowledge, science and technologies generated, and meeting the current regulations of the Ministry of Education (MEC, 2018, 2019) and the Federal University of Goiás (UFG), during the COVID-19 pandemic, two extension projects linked to the Graduate Program in Geotechnics, Structures and Civil Construction (PPGGECON) were created.

The extension project "Multiplying knowledge: a new look at education in geotechnics" (EP1) was created in October 2020 and closed in December 2022, in partnership with the extension project "Multiplying knowledge about soils" of the Institute of Socio-Environmental Studies (IESA) of UFG, which aims to use knowledge of soils as an instrument of appropriation and construction of knowledge about the geographic space that one inhabits and as an instrument of environmental education aimed at the prevention of processes of soil degradation and the environment. As a theoretical reference, we have the papers by Camapum de Carvalho et al. (2018), which mention the need to delve into the processes of education and teaching, developing reflection and a critical sense, and the papers by Gonçalves et al. (2018), Limiro et al. (2018), Oliveira et al. (2018), Mascarenha et al. (2018), Matos et al. (2019), Carvalho & Jesus (2019), Carvalho et al. (2020), and Mascarenha et al. (2021), which present experiences of university extension action focused on soil education.

EP1 was inserted in two classes of the subject Tropical Soils, taught remotely due to the context of the COVID-19 pandemic, between May and October 2020. The classes were organised in groups in order to develop didactic videos to present the concepts of the subject and the knowledge achieved in research projects related to the topic, in a dynamic and didactic way and with accessible language. Matilda et al. (2021) developed the activity called "The Itas that form our soil", referring to soil mineralogy, while Aguiar et al. (2021) adapted the tablet method for expeditious soil identification (DERSA, 2006) for home execution. Souza et al. (2023) presented concepts of expansive soils and the adapted methylene blue test (Fabbri, 1994), totalling nine videos that were posted on the Instagram account @saberessobresolos. Here is a brief addendum: the contents of unsaturated tropical soils, predominant in countries with

144 tropical climates and with remarkable particularities, as is the case of Brazil, should be inserted
145 in the teaching and learning process of society in its different stages.

146 The extension project entitled "Use of Instagram as a teaching tool, dissemination of knowledge
147 and popularisation of science applied to paving" (EP2) was initiated in August 2021, focusing
148 on the area of paving, with a duration of 5 years.

149 The content produced in the project and presented in this article was disseminated via Instagram
150 in the period from 05/08/2021 to 17/06/2022 with the professional account @labasfalto.ufg.
151 The graphic design platform Canva (https://www.canva.com/), version Canva Pro, was used to
152 produce the design of the images and videos of the posts. In the period of analysis presented
153 two series were produced, namely: Series 1 - Dissecting Asphalt Pavement: formed by 20
154 weekly posts referring to basic topics on asphalt sidewalks; Series 2 - Sustainable Pavements:
155 formed by 21 weekly posts (Table 1) referring to topics related to sustainability in paving, this
156 being a more current theme or with newer content.

157 Table 1. Titles of the contents published in each series.

Series 1 - Dissecting Asphalt Pavement		Series 2 - Sustainable Pavements	
Post	Post Title	Post	Post Title
1	Series Presentation	1	Series Presentation
2	How good is our asphalt?	2	Do you know the different types of sidewalk?
3	S-day science video	3	How to reduce the impact on wildlife caused by a highway? Ecoducts/Green bridges!
4	Is asphalt sidewalk an engineering structure?	4	What is the influence of sidewalks on heat islands?
5	How to determine the load acting on this structure?	5	Is it possible to reduce urban traffic noise?
6	What about climate? Does it interfere with sidewalk behaviour?	6	The sidewalk as an ally in the generation of sustainable electric energy.
7	Starting to understand the sidewalk from its foundation...	7	Permeable concrete sidewalk.
8	And what is on top of the subgrade?	8	Permeable asphalt: safety and renewable resource capture.
9	And what is on top of the sub-base?	9	Can asphalt be recycled? The use of milled asphalt in the composition of asphalt surfacing.
10	Can every type of soil be used in the sidewalk structure?	10	Foamed bitumen, what is it?
11	How to choose the materials for asphalt surfacing?	11	Not only can asphalt be recycled, it can also be reused. How? Incorporating milled asphalt into granular soils.

12	How to dose an asphalt mixture?	12	Can other granular waste be used in sidewalks?
13	How can the quality of an asphalt mix be guaranteed?	13	Where can vehicle tyres go at the end of their useful life? Introducing: "Asphalt-Rubber".
14	How to size an asphalt sidewalk?	14	Traffic on plastic waste.
15	What must not be missing when laying asphalt?	15	Can industrial co-products be used in the base layers of sidewalks?
16	And after the work is done?	16	Can industrial co-products be used as aggregates in paving?
17	Which defects should be noted?	17	The evolution and applicability of animal bioligands.
18	How can a sidewalk be restored?	18	The great possibilities offered by vegetable bioligands.
19	Does UFG carry out studies on this subject??	19	And finally, are there any examples of sustainable sidewalk?
20	And finally!	20	How can the use of advanced technologies and equipment contribute to sustainability?
-		21	See you soon!

In the mentioned projects, the use of Instagram was prioritised to disseminate the produced content since, with the COVID-19 pandemic, the consumption of information within social media increased significantly (Volpato, 2021). As presented in the We Are Social (2020) report, Instagram was the fourth most used social network in Brazil in 2020, with 95 million users, second only to Facebook, WhatsApp and YouTube. The use of Instagram as an auxiliary tool in educational practices and dissemination of technical-scientific content was reported by Alves et al. (2018), Ansari & Khan (2020) and Moreira et al. (2021). In engineering and related areas, some positive reports on the production and dissemination of technical-scientific content through digital platforms or social media can be observed in the works published by Lima et al. (2019), Silva et al. (2019), Gomes et al. (2021) and Cipriano et al. (2022). It is understood, therefore, that universities can interact in all spheres and areas of activity with this platform and contribute to the popularisation of science in society and to the training of qualified human resources with the professional skills and competencies currently required.

2.2. Results

2.2.1. Extension Project "Multiplying knowledge: a new look at education within Geotechnics

The videos produced under this project were published on the Instagram of the project "Multiplying knowledge about soils" @saberessobresolos. Most users who access the content of the account are from Brazil (93.1%), with a small audience in the United States (2%), Portugal (0.3%), Australia (0.3%) and Colombia (0.3%). In Brazil, the audience comes from Goiânia (26.6%), Aparecida de Goiânia (4.6%), Rio de Janeiro (< 2%), São Paulo (< 2%), and Brasilia (< 2%), i.e., the reach of the content is local and regional. Having a local niche audience demonstrates the potential of the account in making scientific dissemination that values the geographic and spatial specificities, in order to arouse greater affinity and the interest of the specific audience, because, according to Moreti (2019), the mobilisation of affective dimensions should be considered in the process of knowledge construction.

The main age group of users accessing the account is between 25 and 34 years old (44.4%), followed by those between 35 and 44 years old (24.2%) and between 18 and 24 years old (18.9%). The other age groups account for a public percentage of less than 13%. Of this audience, 60.8% are women and 39.1% are men. The fact that this Instagram account has a multidisciplinary bias with soil content interfacing between Geotechnical Engineering, Agronomy, Pedology, Geography, Geology, Ecology, Environmental Sciences, Forest Engineering, Arts and other areas of knowledge may contribute to the fact that there is a mostly female audience. An opposite scenario usually occurs on Instagram accounts with very specific engineering content, as the engineering field has proportionally more male professionals. It is noteworthy that multidisciplinarity can favour the equalisation of gender issues by bringing broader conceptual approaches, uniting several areas of knowledge, and providing the lay public with a more global and integrated assimilation of the phenomena, in this specific case associated with tropical soils.

Table 2 shows the main interactions concerning the publications produced in the context of the project "Multiplying knowledge: a new look at education within Geotechnics", in order of the dates of their posts. Observation of the data indicates a significant number of interactions.

Table 2. Metrics of the videos published on Instagram @saberessobresolos.

Post						Accounts Reached		
						Non-followers	followers	Total
Soil formation	354	78	1	1	4	62	92	154
Soil Aggregation	336	63	8	23	5	103	330	433
Soil mineral formation	210	46	2	15	13	89	295	384
Minerals 2:1	166	36	0	1	7	93	241	334
MCT expedition	301	28	2	18	5	92	298	390
Expansive soils 1	2237	139	16	77	14	1378	502	1880
Expansive soils 2	1520	83	4	40	6	917	354	1271
Methylene Blue Adsorption	1110	50	3	18	8	609	365	974
Mean	779	65	5	24	8	418	310	728
Standard deviation	764.3	35.4	5.2	24.7	3.8	500.5	116.4	596.0
Coefficient of variation (%)	98.1	54.1	116.4	102.5	48.6	119.8	37.6	81.9

: views; : likes; : comments; : sharing; : saves.

As the number of posts on the subject increased, the number of views increased significantly. It is worth mentioning the number of referrals and saves, which indicate that the user liked the content to the point of indicating it to another person and saving it for himself. The language level adopted in the videos was considered to be easy for high school and technical students to understand. However, it is believed that the didactic quality of the explanations facilitates the understanding of undergraduate students as well.

The Geotechnical Engineering graduate students who produced the videos, after finishing the course, answered a questionnaire to evaluate the teaching method. Of these students, 82% reported that, among the academic activities of the course, the production of the teaching videos was the activity that required the most preparation time. Despite this, the evaluation was positive, since, in the same percentage, the students considered that there should be more extension initiatives with graduate programs. Some other questions were answered considering a scale of 1 to 5, with 1 being absolutely no contribution and 5 a high contribution. When asked if the interaction teaching and extension contributed to the learning in the discipline, 73% gave the maximum score (5). Eighty-two percent of the students considered that extension had the potential to sensitise society about knowledge in soils, and that the production of didactic materials in the context of extension collaborated in the construction of technical and scientific

knowledge in geotechnics. It is also noteworthy that 64% of the students consider that extension activities help add knowledge that can be applied to solve problems in engineering projects and works. These positive responses from the students regarding the interaction between extension and graduate studies and research reinforce the importance of extension in the technical and scientific training of the Geotechnical Engineer.

2.2.2. Extension project "Use of Instagram as a teaching tool, dissemination of knowledge and popularisation of science applied to paving"

The audience that follows the Instagram account @labasfalto.ufg has the following profile: 27.9% from Goiânia, 3.4% from Aparecida de Goiânia, 2.3% from São Paulo and 1.9% from Belo Horizonte; 89.5% from Brazil, 1.5% from Colombia, 1.0% from Mexico and 0.9% from Peru; main age groups: 43.4% between 25 and 34 years, 22.3% between 18 and 24 years, 19.3% between 35 and 44 years and 8.5% between 45 and 54 years; 57.1% are men and 42.8% are women.

From the profile of the account @labasfalto.ufg, it appears that its reach is still local, with most of the public located in the metropolitan region of Goiânia. The audience is mostly formed by young people under 34 years old, which is the most common profile of Instagram users, and male, which is still a characteristic of the engineering area.

During the development of the project, the following aspects were observed: the interaction among all project participants, regardless of institutional ties, stimulating the integration between undergraduates and post-graduates as well as between teaching, research and extension; the experience and sharing of technical and scientific knowledge about the paving area with the search for updated information, from reliable and verifiable sources, during the writing of the texts of the captions of the posts; the encouragement of critical analysis during the planning, content development, and metrics monitoring phases, as well as ethical and integrity practices throughout the process; the development of skills related to the responsible use of new technologies, teamwork, creativity, and communication with peers and society. Table 3 presents the mean, maximum, minimum, standard deviation and coefficient of variation values obtained for the metrics evaluated in this work seven days after publication.

Table 3. Mean values obtained for the metrics on Instagram @labasfalto.ufg after seven days of content dissemination.

Post						Accounts Reached		
						Non-followers	**Followers**	**Total**
Series 1 - Dissecting Asphalt Pavement								
Mean	239	28	2	2	1	175	329	504
Maximum	511	49	8	25	4	787	490	1211
Minimum	86	14	0	0	0	3	201	272
Standard deviation	117.6	9.7	1.7	5.5	1.2	173.2	85.7	224.3
Coefficient of variation (%)	49.3	35.0	72.1	260.5	92.9	99.0	26.0	44.5
Series 2 - Sustainable Pavements								
Mean	219	35	4	13	3	350	310	664
Maximum	452	138	10	25	26	653	555	1006
Minimum	120	15	0	8	0	22	193	215
Standard deviation	89.3	25.6	2.5	5.0	5.6	160.0	97.3	207.9
Coefficient of variation (%)	40.8	74.0	69.3	38.7	166.7	45.7	31.4	31.3

 : views;  : likes;  : comments;  : sharing;  : saves.

With the monitoring of the publications of the two series linked to the project "Use of Instagram as a tool for teaching, dissemination of knowledge and popularisation of science applied to paving", the following analysis can be performed:

a) Before the existence of the extension project, the account @labasfalto.ufg had 880 followers, after the publication of Series 1 this number increased to 989 and, at the end of Series 2, it reached a total of 1066 followers. This increase in followers demonstrates the interest of society in accessing technical-scientific information published via Instagram;

b) The values of the metrics of the reach of the account increased in Series 2 compared to Series 1, which can be explained by the increase in the number of followers of the account and by the possible greater interest in the topic of Series 2 compared to that of Series 1;

c) It is also observed that the publications were also accessed by a considerable number of non-followers, which may indicate an interest in viewing more on the basis of a specific subject than in constantly following the publications of the series;

d) The two series had a frequent following of a little over 300 followers. This number may be considered small when compared to other profiles in the area, but when thinking about this

content being taught in a classroom course with 50 students, it can be seen that the team's effort had a six times greater impact on the dissemination of knowledge during a semester, and may even have reached other parts of society;

e) It is noteworthy that the content published in the Feed can be freely disseminated, accessed or retrieved at any time, which will also increase access to updated and reliable technical-scientific information.

3. Technical-scientific research as a strategy for the socialisation of education

In order to popularise science, the Graduate Program in Geotechnics, Structures and Civil Construction (EECA/UFG) and the Graduate Program in Geotechnics (FT/UnB) have worked on the publication of books and primers with language adapted to lay society in the scope of three research projects: Prevention and recovery of potential areas of degradation by surface, deep and internal erosion processes in the Midwest of Brazil (RP1), Rainwater infiltration structures as a means of flood and erosion prevention (RP2) and Monitoring and study of alternative techniques in the stabilization of erosive processes in UHEs reservoirs (RP3). These materials are freely available on the websites of the mentioned Programs (https://gecon.eec.ufg.br/p/18785-publicacoes; https://geotecnia.unb.br/index.php/pt/producao-academica/livros) and of partner institutions (https://www.abms.com.br/; https://www.furnas.com.br/). The books are aimed at professionals, and university students and teachers, and the primers, within the same theme, are aimed at teachers and students in kindergarten, elementary and high school, and apply to formal and non-formal education. The participants in these publications, authors and consultants, are linked to various areas of science, thus enabling the texts to be useful in the multidisciplinary, interdisciplinary, transdisciplinary, and disciplinary fields as far as reflection and practices related to land use and occupation are concerned. The free availability, the adaptation of the language to the target audience and the various perspectives represent the effort of the working groups to ensure that research is not confined within the walls of universities and to a restricted audience, but reaches society as a whole.

Although there is often resistance to taking more applied geotechnical content and concepts into elementary and high schools, such practice is relevant because, in addition to contributing to the reduction of environmental and engineering problems, it then facilitates teaching and learning at the university level. For example, in the booklet "Environment: Infiltration" (Lelis

& Camapum de Carvalho, 2011), aimed at first to fifth grades of elementary school, there is an activity in which the child learns, by playing, the first concepts about soils and the behaviour of unsaturated soils. Although this is just one example, others may be conceived, because children who work with this content will already arrive at the university course of Engineering and related areas knowing basic concepts about soils and unsaturated soils, thus facilitating the teaching-learning process.

Another example is contained in the primer "Environment: Erosion" (Camapum de Carvalho & Lelis, 2006), aimed at first to fifth grades of elementary school, in which children are introduced to the relevance of planting in contour lines.

The primers "Environment: Infiltration" (Lelis & Camapum de Carvalho, 2011) and "Environment: Erosion at Reservoir Borders" (Ribeiro et al., 2016) introduce the rights and duties in relation to the environment contained in the Federal Constitution, thus opening space for the introduction and discussion of other federal, state, and municipal legislation.

Moving into the discussion of social issues, the booklet "Environment: Erosion at a Reservoir Edge" (Ribeiro et al., 2016) introduces children to the relevance of accessibility while showing the need to avoid erosive processes.

Although one should, as far as possible, seek to universalise technical-scientific knowledge, it must go through adjustments of style, language, and sometimes also content. Carvalho (2008) and Silva (2007) developed rainwater infiltration systems and the techniques developed were set out, in a language appropriate to elementary school, in the booklet "Environment: Infiltration" (Lelis & Camapum de Carvalho, 2011), as illustrated in Figure 1. The same content was developed in the booklet "Infiltration" (Camapum de Carvalho & Lelis, 2010), aimed at elementary school and high school. In this case, there are more construction details regarding the materials used, and an example of an infiltration well is shown in Figure 2. The children and adolescents who receive this education will take it with them into their lives and, for sure, will contribute to avoiding problems such as flooding and erosion. It should be clear that this form of education is aimed at building awareness and not at generating technical training, which should occur in engineering courses, as it involves detailed studies of the soil and definition of project parameters.

Figure 1. Infiltration structures (modified from Lelis & Camapum de Carvalho, 2011).

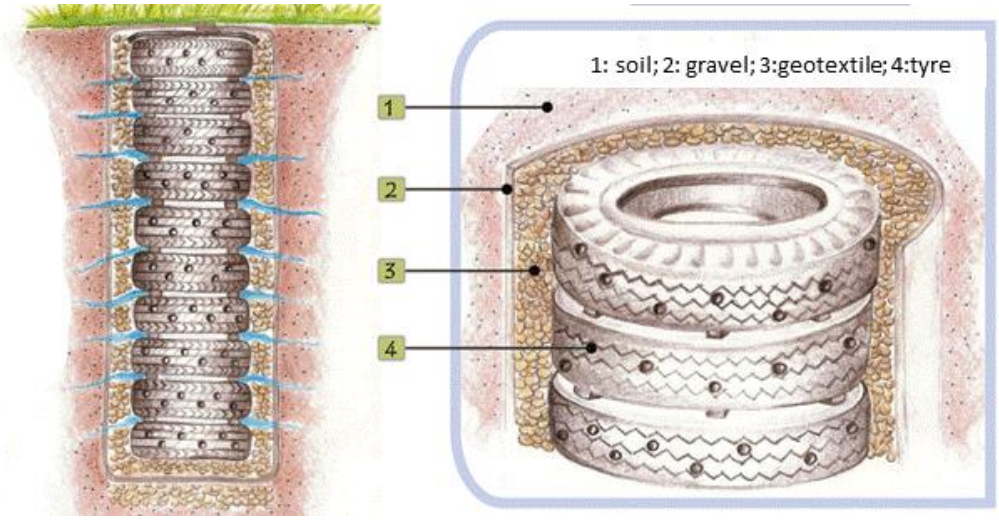
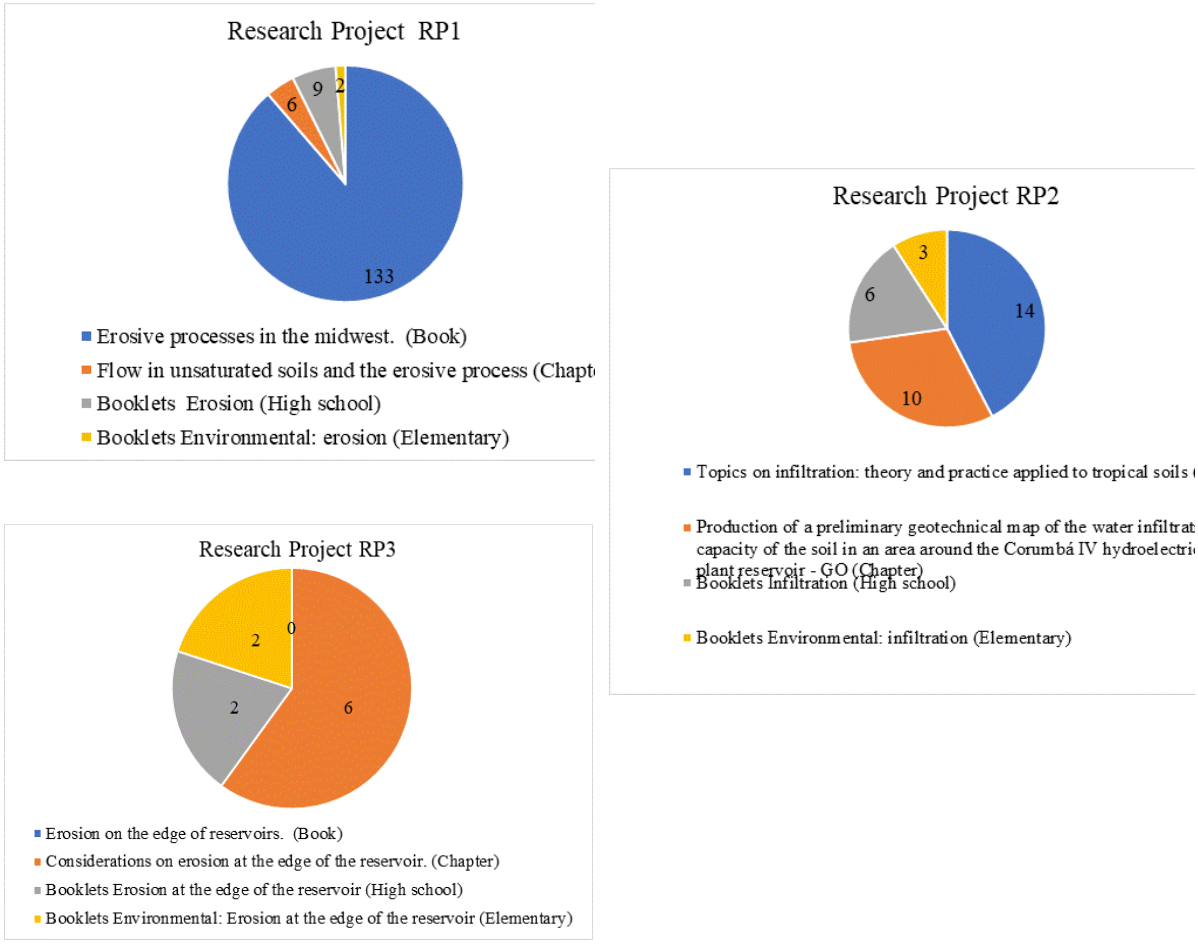


Figure 2. Infiltration well (Camapum de Carvalho & Lelis, 2010).

It is emphasised in this opportunity that the geotechnical content to be transferred to society in a broad sense should be based on knowledge consolidated through research, experience and observations, requiring adaptations of language to different levels of schooling, whether in formal or non-formal education.

Figure 3 shows the number of citations observed in Google Scholar of the various publications within the project, as well as the most cited book chapters. As expected, there are fewer citations of the primers, due to the nature of the publication, its target audience and the weak link in this field between the Universities, the Ministry of Education and the State and Municipal Departments of Education, lacking, despite being a public policy, efforts to popularise science.



346 Figure 3. Number of citations of publications collected on March 15, 2023 in Google Scholar.

347 Figure 4 shows the number of citations of journal articles related to each of the themes (erosion,
348 seepage and erosion at reservoir edges), originating from the abovementioned projects.
349 Comparing Figures 3 and 4, it can be seen that the books of RP1 have from four to nine times
350 the number of citations of the most cited paper, showing the reach of this type of publication,
351 although its purpose is the popularisation of science, with reach in places not considered in the
352 technical-scientific publication metrics. It is worth emphasising the importance of the
353 engagement of public institutions in the dissemination and use of these materials in their various
354 technical and educational activities.

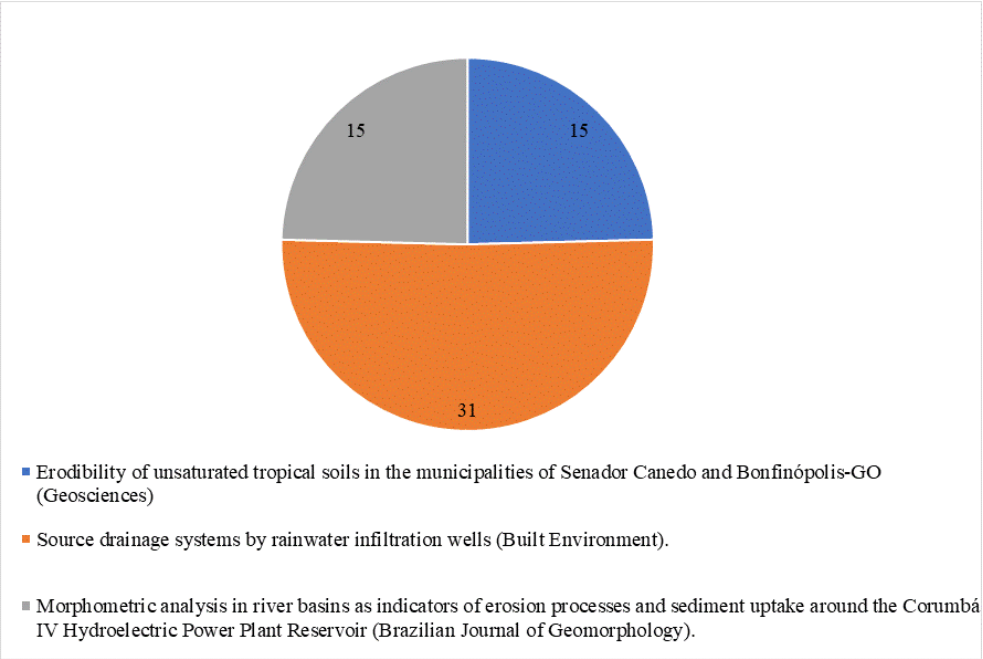


Figure 4. Number of citations of papers collected on March 15, 2023 in Google Scholar.

In engineering, most studies are of an applied nature and often require multidisciplinary action, requiring adequate dissemination and acceptance of the work developed by disciplinary axes of science.

Camapum de Carvalho (2023) has shown that countries with a higher human development index (HDI) value non-citable publications more highly than countries with lower HDI. For example, the primers presented in Figure 3, although not part of the citable publications themselves, are of fundamental importance for the development of society and reinforce the need for the dissemination of knowledge generated in scientific development to involve both citable and non-citable publications.

In addition, the purely disciplinary framing and valuation of publications hinders the work and the due valuation of multidisciplinary actions, which are indispensable to scientific development and to the solution of society's problems.

Another problem concerns the need to go beyond the specific disciplinary content. For example, Valencia (2009) presented an appropriate technique for the control of erosive processes through the use of native bacteria, and Muñetón (2013) showed that it is possible to use the same soil treatment in sidewalk structures. Both studies counted on the effective participation of a biologist and a veterinarian, but the fusion with contents generated by the different areas of knowledge starting with Geotechnics was not an easy task. It is worth mentioning that the study, given its originality, gave rise to a patent application by the University of Brasilia.

4. Discussion of education in technical scientific conferences

Professional associations can develop an important role not only for the transfer of knowledge generated in universities and research centres to engineering professionals, but also to promote discussion, establishing links with other disciplinary backgrounds and with society itself in the broad sense. The Brazilian Association of Soil Mechanics (ABMS) is the professional association of engineers working in Geotechnics and is composed of nine Technical Committees: Slopes, Risk, Dams, Field Investigation, Geosynthetics, Foundations, Unsaturated Soils, Environmental Geotechnics and Pavements.

ABMS does not have a specific committee focused on education, unlike the Brazilian Society of Soil Science (SBCS), the professional association of agronomists who work with soil science, which has a committee on soil education and the public perception of soil. It should be noted, however, that more recently ABMS promoted the XIX Brazilian Congress of Soil Mechanics and Geotechnical Engineering (COBRAMSEG 2018), in which, in an unprecedented way, it presented a specific session for education in geotechnics.

This session focused on education in geotechnics had 15 papers published in the proceedings of this event, about 1.6% of the published papers, representing a historical advance with ABMS and COBRAMSEGs, as it was the first time that a session on education was proposed in this event. The regions that collaborated most with the submission of papers were the Northeast (5 papers), the Southeast (4 papers), and the Centre-West (4 papers). The southern and northern regions contributed one paper each.

Figure 5 shows that the lines of research addressed in the articles were teaching materials (TMt), public perception (PP), Project Based Learning (PBL) pedagogical projects, bibliometrics (B) and teaching methodology (TM). It can be observed in this set of articles that most of them have a very specific focus on the formality of teaching the contents of the subjects. This pedagogical concern of professors is very relevant in the context of teaching practice, considering that most university professors in technological areas, although highly qualified scientifically, do not have pedagogical training. Even so, it is considered that there is a long way to go to transpose the pedagogical concern beyond the university boundaries through actions that are more directed to society in general. A reflection of this path can be seen in the fact that four studies focused on the dissemination and popularisation of knowledge about soils for society. However, only three papers indicated education as a keyword in their abstracts.

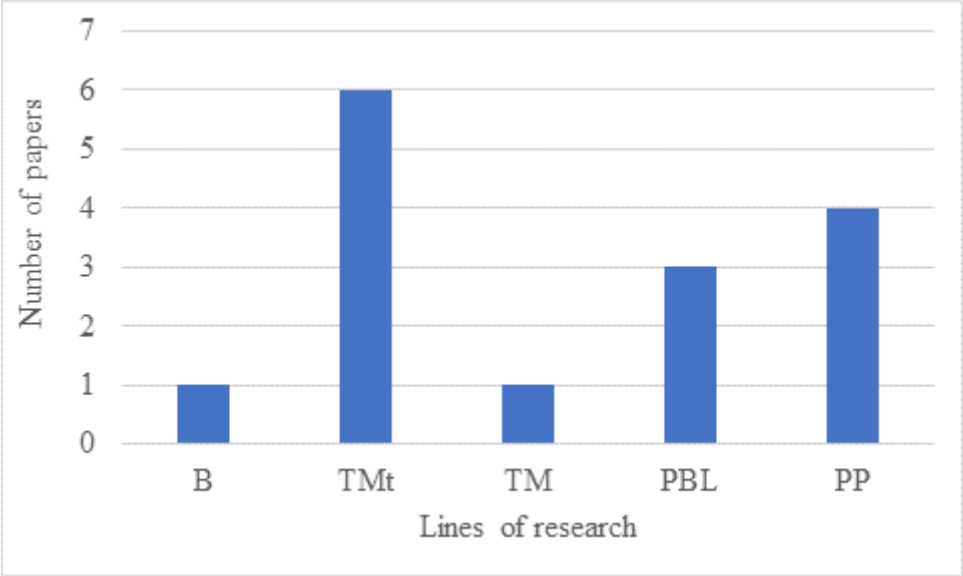


Figure 5. Research lines addressed in the Education Session of COBRAMSEG 2017.

Another action focused on education was the IV Symposium of Geotechnical Engineering Practice in the Midwest Region (GEOCENTRO 2017), which enabled the exhibition of educational content on soils produced by students of the Geotechnical League of the School of Civil and Environmental Engineering (EECA) of UFG under the extension project "Understanding soil erosion as a tool for environmental education". This project was the result of a multidisciplinary partnership between engineering professors from EECA and geography professors from IESA (Institute of Environmental Studies) and involved engineering students as well as students from Geography, Environmental Sciences and Ecology, and biology professors from both institutes. As news of the project became known, undergraduate students from several courses requested to be part of the working group, leading to the expansion of the project, which now has a more comprehensive name to accommodate the multidisciplinarity, resulting in the additional reference to "multiplying knowledge about soils".

In 2019, GEOCENTRO included a booth for the presentation of teaching materials, which was widely visited. The students participating in the project reported, at the end of the event, that they had acquired a more integrated view of the environment and the potential for its inclusion in the performance of engineering works and social aspects.

These discussions highlight the importance of multidisciplinary to establish links between different levels of education and society. With an eye on multidisciplinary, the Symposium on Tropical Soils and Erosive Processes in the Midwest was created, held in Brasília in 2003, in

Goiânia in 2005, and in Cuiabá in 2013. The idea of this regional event was to enable discussions bringing together professionals with different backgrounds and not only civil engineers, but it was incorporated into the Geocentre, returning to the disciplinary emphasis. Meanwhile, erosive processes and problems related to tropical soils are increasing in the Midwest region, as well as in the rest of the country, and these, like it or not, are beyond the strict geotechnical domain.

5. Conclusions

Nowadays, social networks are an important tool for scientific dissemination and have the potential to disseminate knowledge more widely than in a classroom course, according to the metrics presented in this article by the accounts @labasfalto.ufg and @saberessobresolos. The results, although positive, point to the relevance of drawing up new dissemination strategies to engage the followers in their publications, increasing their reach and the impact of the project and the democratisation of teaching-learning, including more direct links with society through professional and localities associations, schools and universities.

The students' evaluation of the effectiveness of the curricularisation of extension in learning the content of academic disciplines, in the construction of technical-scientific knowledge in geotechnics, and in solving problems in engineering works reinforces the importance of extension in the technical-scientific education of the geotechnical engineer. Although applied soil studies are usually restricted to university education, many topics are of great relevance to society as a whole. As soil is ever-present in people's lives, knowledge of it has great relevance, even with regard to certain topics of a more applied nature, such as erosion, slope ruptures and flooding.

Formal studies on soil should begin in childhood, when children begin to interact with it in their daily lives, from a simple walk to leisure activities and art exercise. Camapum de Carvalho (2022) showed that primers such as the ones cited in this article can and should be used in the education of society to avoid socio-environmental problems such as slope ruptures and floods. In non-formal education, as many have not had access to this knowledge in elementary and high school, the focus should turn to the socio-environmental context, which will often require adaptations to the language and form of addressing the issues, as well as the didactic suitability in order to better enable the training and awareness-raising of society about the content and its relevance.

Finally, it is noteworthy that the scientific development achieved, however applicable and practical it may be, ends up, in countries like Brazil, being disseminated and made available to an extremely restricted public and usually with a high level of knowledge, serving almost solely for the development of new research or the continuation of existing works. For further-reaching links to be successfully made, public policies are needed, as well as effective interaction between universities, research centres, and schools. The effectiveness of these interactions almost always requires a broader participation of professional associations, funding and evaluation agencies, education departments, and the Ministry of Education, Science, Technology and Innovation.

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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

Márcia Maria dos Anjos Mascarenha: Writing – original draft, Methodology, Investigation, Formal Analysis. **José Camapum de Carvalho**: Writing – original draft, Methodology, Investigation, Formal Analysis. **Andrelisa Santos de Jesus**: Writing – original draft, Methodology, Investigation, Formal Analysis. **Lilian Ribeiro de Rezende**: Writing – original draft, Methodology, Investigation, Formal Analysis. **Mauricio Martines Sales**: Formal Analysis, Writing – review & editing, **Marta Pereira da Luz**: Formal Analysis, Writing – review & editing.

Data availability

The datasets of this current study are available from the corresponding author on request.

List of symbols

ABMS	Brazilian Association of Soil Mechanics
B	Bibliometrics
COBRAMSEG	Brazilian Congress of Soil Mechanics and Geotechnical Engineering
EECA	School of Civil and Environmental Engineering
EP1	extension project 1
EP2	extension project 2
GEOCENTRO	Geotechnical Engineering Practice in the Midwest Region
HDI	higher human development index
IESA	Institute of Socio-Environmental Studies
IPT	Institute of Technological Research of the State of São Paulo
MEC	Ministry of Education
PBL	Project Based Learning
PP	public perception
PPGGECON	Graduate Program in Geotechnics, Structures and Civil Construction
RP1	Research Project 1
RP2	Research Project 2
RP3	Research Project 3
SBCS	Brazilian Society of Soil Science
S&T	Science and Technology

510 TM teaching methodology

511 TMt teaching materials

512 UFG Federal University of Goiás

513 UnB University of Brasília

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